DOCTORAL TRAINING PROGRAM
OF
WITTMANN ANTAL MULTIDISCIPLINARY DOCTORAL SCHOOL OF PLANT, ANIMAL, AND FOOD SCIENCES

MOSONMAGYARÓVÁR

2024

Doctoral (PhD) training is a training, research and reporting activity in the context of individual or group preparation, adapted to the specificities of the discipline and the needs of the PhD student, and consisting of two phases: the first four active semesters are the "training and research" phase and the second four active semesters are the "research and dissertation" phase. During the eight semesters of the doctoral program, the PhD student must have acquired at least 240 credits in the study, research, dissertation, and teaching components. The detailed conditions for the training are laid down in Chapter II (§ 5-13) of the Doctoral Study and Examination Regulations (DSER).

During the training and research phase, the PhD student should obtain a total of 120 credits (30 credits per semester) *by completing the compulsory and elective courses*. In the context of the *Completion of research task 1–4* courses, credits are awarded for, among other things, carrying out experimental work, writing a review article on the subject of the thesis, giving a presentation at a scientific forum organized by the doctoral school, activities described in the section "Publication, conference participation" and teaching tasks.

At the end of the fourth active semester, PhD students must pass a complex doctoral examination, which measures and evaluates their academic and research progress. Failing this, the doctoral candidate's doctoral status shall be terminated on the last day of the examination period of the semester in question. If a PhD student applying for a complex examination in structured training does not have 120 credits by the end of the fourth active semester and the *review article* as specified in subsection 8.3 of the Doctoral School's Operational Regulations, the Doctoral School Council may decide to allow the application for the complex examination, but only if the number of credits missing is up to 20%. The missing credits and the review article may be filled in during the first two active semesters of the second stage of the training. No credits are awarded for a successful complex examination. For detailed information on the complex examination, please refer to § 42 of the DSER and to subsection 6.3 of the Doctoral School's Operational Regulations.

In the research and dissertation phase, the PhD student must acquire a total of 120 credits (30 credits per semester) in the framework of the *Completion of research task 5–8* courses. In the second phase, credits are obtained through teaching activities, continuous processing of the literature on the research topic, experimental work, evaluation of experimental results, publication activities and conference presentations, and the preparation of the dissertation, as follows:

- Dissertation activity:
  - Preparation of the literature review chapter of the PhD dissertation: 20 credits
  - Experimental work and data processing related to the topic of the dissertation: max. 30 credits per semester
  - Writing the dissertation: 20 credits
- Publication, conference participation:
  - Article in a foreign scientific journal: 15 credits*
  - Article in a national scientific journal in a foreign language: 10 credits*
  - Article in a national scientific journal in Hungarian: 8 credits*
  - Presentation at a scientific conference abroad: 6 credits
  - Presentation at a national scientific conference: 5 credits
  - Poster presented at a scientific conference: 3 credits

* If published in a journal with an impact factor, the total value is increased by 5 additional credits.

The minimum publication requirements for the PhD degree are detailed in subsection 8.3 of the Doctoral School's Operational Regulations.

During the doctoral training, PhD students also have the opportunity to apply the knowledge and skills acquired in the "Higher education pedagogy" course to their graduate teaching work by conducting practicals and seminars. This activity can be rewarded with credits under the courses "*Completion of research tasks 1–8*". For 1 contact hour of teaching per week for one semester, 3 credits are awarded. However, the number of credits earned through tutorial work shall not exceed 10 per semester.

By the end of the fourth year, the PhD student must have achieved a total of 240 credits.

The model curriculum for doctoral training, broken down by doctoral program, is as follows:

Subjects taught in Haberlandt Gottlieb Doctoral Program in Plant Science (Head of Program: Gyula Pinke DSc)				
Title of subject	Name and academic degree of the person in charge of the subject	Contact hours + individual study hours	Credits	Semester
Compulsory subjects:				
Methodology of research	Zoltán Varga PhD	14 + 136	5	1
Fundamentals and sources of scientific research work	Viktor Zsömle PhD	6 + 144	5	1
Higher education pedagogy	Viktória Gősi-Kövecses PhD	6 + 144	5	1
Technological and information background of precision agriculture	Miklós Neményi MHAS	14 + 136	5	1
Completion of research tasks 1	*László Varga DSc*	*0 + 300*	*10*	1
Traceability in post-harvest technologies	Attila József Kovács PhD	20 + 130	5	2
Plant biotechnology	Zoltán Molnár PhD	20 + 130	5	2
Completion of research tasks 2	*László Varga DSc*	*0 + 600*	*20*	2
Molecular plant pathology	László Palkovics DSc	20 + 130	5	3
Impact of abiotic and management factors on weed vegetation of arable crops	Gyula Pinke DSc	20 + 130	5	3
Completion of research tasks 3	*László Varga DSc*	*0 + 600*	*20*	*3*
Completion of research tasks 4	*László Varga DSc*	*0 + 600*	*20*	*4*
Completion of research tasks 5	*László Varga DSc*	*0 + 900*	*30*	*5*
Completion of research tasks 6	*László Varga DSc*	*0 + 900*	*30*	*6*
Completion of research tasks 7	*László Varga DSc*	*0 + 900*	*30*	*7*
Completion of research tasks 8	*László Varga DSc*	*0 + 900*	*30*	*8*
Elective subjects:				
Plant protection zoology	Rita Ábrahám-Ledó PhD	20 + 130	5	4
Robots, autonomous devices, and image analysis in precision agriculture	Bálint Ambrus PhD	20 + 130	5	4
Biology of parasitic plants	Gyula Pinke DSc (Kornél Baráth PhD)	20 + 130	5	4
Remediation, recultivation	Dóra Beke PhD	20 + 130	5	4
Design and analysis of experiments in crop production	Zoltán Varga PhD (Zoltán Berzsenyi DSc)	20 + 130	5	4
Economics of sustainable crop production	Károly Kacz, Jr. PhD	20 + 130	5	4
Biological background of horticultural production	Borbála Hanusz-Pólya PhD	20 + 130	5	4
Pesticide chemistry	Gábor Kerekes PhD	20 + 130	5	4
Herbology	Gábor Kukorelli PhD	20 + 130	5	4
Microalgae biology and biotechnology	Zoltán Molnár PhD (József Kutasi PhD)	20 + 130	5	4
Dispersal of weed seeds	László Magyar PhD	20 + 130	5	4
GIS and remote sensing	Gábor Milics PhD	20 + 130	5	4
Biotic and abiotic stress resistance of crops	Zoltán Molnár PhD	20 + 130	5	4
Crop growth models and plant physiological analysis	Miklós Neményi MHAS	20 + 130	5	4
Macro- and micronutrients in the soil–plant system	Pál Szakál CSc	20 + 130	5	4

Effects of macro- and microclimate on crop production	Zoltán Varga PhD	20 + 130	5	4
Climate change – adaptation options in crop production	Zoltán Varga PhD (Ottó Veisz CMHAS)	20 + 130	5	4

Course title:	Methodology of research		
Course code:	N_DMA02	Credits:	5
Course type:	Compulsory		
Course instructor:	Zoltán Varga PhD		
Co-instructor:	László Varga DSc		
Number of contact hours + individual study hours:	14 + 136		

Objectives of the course:
The aim of teaching research methodology is to introduce students to the theoretical, practical, and methodological issues of scientific research. Students acquire up-to-date knowledge of the major issues of scientific theory and research methodology and the forms of scientific activity and get to know the conceptual and methodological tools of their own scientific field. They recognize the methods to be used to solve problems, they are able to plan the research and carry it out. They learn the essential steps of writing scientific publications. They can distinguish between scientific and non-scientific work and recognize pseudo-scientific activity when appropriate. They are aware of the ethical rules for preparing scientific publications, as well as the important parameters of scientometrics.

Course content:

1	The importance and history of science and research methodology
2	Comparative analysis of everyday and scientific knowledge
3	Parallel examination of theoretical and empirical knowledge
4	Explanation and prediction in science
5	The practice of scientific research, the basic steps of scientific knowledge
6	Planning and conducting scientific research
7	Basic rules of scientific literature, use of internet databases; searching for technical articles and references, query techniques
8	Types of scientific and non-scientific publications, conditions of publishing
9	Strategies for choosing the right journal(s) and publishing there
10	Ethical issues of scientific research and publishing
11	Writing scientific publications (from title to references, content and form requirements)
12	Scientometrics, the measurement of scientific performance; interpretation of the most widely used performance indicators, their advantages, and disadvantages (impact factor, citations, Hirsch index, etc.)

Requirements:
Written examination, graded on a 5-point scale.

Required reading:
Harari, Y.N. (2015) Sapiens: A Brief History of Humankind. Vintage Books, London, UK.
Walliman, N. (2011) Research Methods: The Basics. Routledge, London, UK, New York, NY.

Recommended literature:
Ireland, C. (2010) Experimental Statistics for Agriculture and Horticulture, CABI, Wallingford, UK.
Popper, K. (2002): The Logic of Scientific Discovery. Routledge, London, UK, New York, NY.

Useful links:
Research integrity:
https://allea.org/wp-content/uploads/2023/06/European-Code-of-Conduct-Revised-Edition-2023.pdf
Journal lists:
https://www.scimagojr.com/journalrank.php
https://kanalregister.hkdir.no/publiseringskanaler/Forside.action?request_locale=en
https://jfp.csc.fi/en/web/haku/?restartApplication
Predatory journals:
https://www.interacademies.org/project/predatorypublishing
https://beallslist.net/wp-content/uploads/2019/12/criteria-2015.pdf
https://beallslist.net/standalone-journals/
https://media.nature.com/original/magazine-assets/d41586-019-03759-y/d41586-019-03759-y.pdf

Course title:	Fundamentals and sources of scientific research work		
Course code:	N_DOA106	Credits:	5
Course type:	Compulsory		
Course instructor:	Viktor Zsömle PhD		
Number of contact hours + individual study hours:	6 + 144		

Objectives of the course:
The aim of the course is to introduce doctoral students to the research and publishing opportunities available at Széchenyi István University and to provide them with practical knowledge to help them navigate the maze of domestic and international publishing.

Course content:

1.	Services of the University Library and Archives: • Access to printed and online literature • Hungarian Scientific Works Repository (MTMT) - registration • International scientific databases [indexing (Scopus, Web of Science), full-text (Emerald, IEEE, Springer, ScienceDirect, Wiley, etc.)] • Sustainability (using SDG keywords) • Language proofreading (proofreading) • Which journal should I publish in? (choosing the appropriate journal by entering keywords / topic / abstract) • APC-free open access (OA) publishing opportunities • Széchenyi University Publication Support Program (APC payment)
2.	Research methodology and database use based on full-text databases subscribed to: • Multidisciplinary: the journal collection of Akadémiai Kiadó, Cambridge University Press Journals, Science Direct, SpringerLink, Wiley • Electrical Engineering, Electronics, Computer Science: IEEE • Business: EMIS, Statista, Opten • Economics: Emerald • Law: HeinOnline, Yogic Code, Law Library • Humanities and social sciences: Taylor & Francis
3.	The publishing maze, the opportunities and risks of OA publishing and measuring scientific performance: • How to be visible at international scientific level (identifiers, author profiles) • Methodology for selecting scientific journals and conferences • MTMT basics, MTA journal lists • Science metrics (concept, Hungarian and international metrics) • Publication support tools (plagiarism checker for academic writing, reference management software) • Copyright basics (OA regulation, repository storage)

Requirements:
Obtaining a signature.

Required reading:
PPT files of lectures.

Course title:	Higher education pedagogy		
Course code:	N_DOA105	Credits:	5
Course type:	Compulsory		
Course instructor:	Viktória Gősi-Kövecses PhD		
	Gyöngyi Csenger PhD		
Number of contact hours + individual study hours:	6 + 144		

Objectives of the course:
The purpose of the subject is to prepare students participating in doctoral training for university education.
Knowledge: Within the framework of doctoral training, learn about the challenges of education in the 21st century. During the study of the subject, learn the steps and tasks of teaching-learning planning. Learn about modern higher education pedagogical procedures, methods, and developmental evaluation.
Skills: With the creative use of knowledge, they should be able to plan, implement, and evaluate lessons, projects, and sessions with a reflective approach. The goal is also to enable them to try out and apply the methods they have learned.
Attitudes: Develop their commitment to supporting students.
Autonomy and responsibility: Take a role with a high degree of independence in the development of courses that also apply pedagogical procedures. Take a responsible, initiating role in the development of instructor-student cooperation.

Course content:

1	Challenges in higher education – teaching and learning in the 21st century
2-3	The role of learning outcome-based planning in higher education
4	Issues of planning and organizing the teaching–learning process
5	Issues of developmental evaluation in higher education
6-7	Supporting the educational process with digital tools
8	Issues of effective application of educational methods
9-10	Project pedagogy in higher education
11-12	Cooperative teaching and learning in higher education

Requirements:
Continuous assessment – the requirement is to prepare a portfolio consisting of three tasks.

Required reading:
Curaj, Adrian; Deca, Ligia; Pricopie, Remus (2020): European Higher Education Area: Challenges for a New Decade. Springer Nature.
https://library.oapen.org/bitstream/20.500.12657/42916/1/2020_Book_EuropeanHigherEducationAreaCha.pdf
Cheng, Jiangang; Han, Wei; Zhou, Qian; Wang, Shuyan (2024): Handbook of Teaching Competency Development in Higher Education.Springer Nature
https://library.oapen.org/bitstream/20.500.12657/85104/1/978-981-99-6273-0.pdf

Recommended literature:
Stracke, Christian M.; Shanks, Michael; Tveiten, Oddgeir (2018): Smart Universities. Logos Verlag Berlin Berlin, Germany https://www.logos-verlag.de/ebooks/OA/978-3-8325-4595-6.pdf
Habbal, Fawwaz; Kolmos, Anette; Hadgraft, Roger G.; Holgaard, Jette Egelund; Reda, Kamar (2024): Reshaping Engineering Education. Springer Nature. Singapure
https://library.oapen.org/bitstream/20.500.12657/86967/1/978-981-99-5873-3.pdf Rowell, Chris (2019): Social Media in Higher Education. Open Book Publishers
https://library.oapen.org/bitstream/20.500.12657/24987/1/9781783746705_Replacement.pdf
The Future of Higher Education: Identifying Current Educational Problems and Proposed Solutions
https://www.researchgate.net/publication/366051679_The_Future_of_Higher_Education_Identifying_Current_Educational_Problems_and_Proposed_Solutions
Journal of Adult Learning Knowledge and Innovation (JAKLI) https://akjournals.com/view/journals/2059/2059-overview.xml
Hungarian Educational Research Juarnal (HERJ) https://akjournals.com/view/journals/063/063-overview.xml
Jain, Pooja (2021): Creativity. IntechOpen
https://mts.intechopen.com/storage/books/9560/authors_book/authors_book.pdf

Course title:	Technological and information background of precision agriculture		
Course code:	N_DMA65	Credits:	5
Course type:	Compulsory		
Course instructor:	Miklós Neményi MHAS		
Co-instructors:	Anikó Nyéki PhD, Gergely Teschner PhD, Bálint Ambrus PhD		
Number of contact hours + individual study hours:	14 + 136		

Objectives of the course:
The aim of the course is to familiarize students with the near and distant perspectives of agricultural sustainability, with particular emphasis on the relationship between theories and their practical application. It demonstrates the benefits of developing and applying technical and IT systems to meet sustainability requirements. The aim: a paradigm shift in thinking. The lectures will place a special emphasis on the role of artificial intelligence as a decision support tool.

Course content:

1	The first green revolution
2	Organic farming in EU after 2022; relationship between general and agricultural sustainability
3	The expectation of European green deal concerning agriculture
4	Regenerative agriculture in EU
5	Farm to fork
6	Organic farming *vs* yield
7	Management zones and VRA's
8	Decision support models in precision crop production
9	Big Data and artificial intelligence
10	The agricultural food demand and the challenges for sustainability; the 3rd green revolution; IoT with WSN – Small smart data logger tractors; the Mosonmagyaróvár IoT
11	Multispectral and hyperspectral early-stage detection of microorganisms
12	VR application: site specific seeding, spraying, mapping: soil compaction, EC, SMC

Requirements:
Oral discussion or written essay in agreement with the course instructor.

Required reading:
Brase, A.T. (2006): Precision Agriculture. Thomson.
Fluck, R.C. (1992): Energy in Farm Production. Elsevier.
Jorgensen, S.E. (2001): Thermodynamics and Ecological Modelling. CRC Press, Boca Raton, FL.
Margulis, L. (1998): The Symbiotic Planet. Weidenfeld and Nicolson, London, UK.
Mesterházi, P.Á. (2003): Development of measurement technique for GPS-aided plant production. PhD Thesis.
Mike-Hegedűs, F. (2006): Applying fuzzy logic and neural networks to database evaluation in precision agriculture. PhD Thesis.
Morowitz, H.J. (1968): Energy Flow in Biology. Academic Press.
Neményi, M. (2012): Anthropogenic impacts on nature with special regard to agricultural technologies. The impact of urbanization, industrial, agricultural and forest technologies on the natural environment, edited by Neményi, M., Mesterházi, P.Á., Milics, G. (2006a): An Application of Tillage force Mapping as a Cropping Management Tool. Biosystems Engineering 94 (3), 351-357.
Neményi, M. et al. (2022): Challenges of sustainable agricultural development with special regard to Internet of Things: Survey. Progress in Agricultural Engineering Sciences.
Neményi, M. et al. (2023): Challenges of ecocentric sustainable development in agriculture with special regard to the internet of things (IoT), an ICT perspective. Progress in Agricultural Engineering Sciences.
Neményi, M., Mesterházi, P.Á., Pecze, Zs., Stépán, Zs. (2003): The role of GIS and GPS in precision farming. Computers and Electronics in Agriculture 40 (1-3), 45-55.
Neményi, M., Milics, G. (2009): Thermodynamic modeling of agro-ecological systems especially regarding the cost and efficiency of the technological energy input. 10th IAEE European Conference. Energy, Policies and Technologies for Sustainable Economies, Vienna, 2009. 09. 07.-10., pp. 37-38.
Neményi, M., Milics, G. (2010): Optimalization of biomass production by thermodynamic approach. In: Conference AgEng2010. International Conference on Agricultural Engineering. Clermont-Ferrand, France.
Nyéki, A., Kerepesi, C., Daróczy, B., Benczúr, A., Milics, G., Nagy, J., Harsányi, E., Kovács, A.J., Neményi, M. (2021): Application of spatio-temporal data in site-specific maize yield prediction with machine learning methods. Precision Agriculture 22, 1397-1415.

Nyéki, A., Teschner, G., Ambrus, B., Neményi, M., Kovács, A.J. (2020): Architecting farmer-centric internet of things for precision crop production. Hungarian Agricultural Engineering 71-78.
Stafford, J. (2023): Precision Agriculture ’23. Wageningen Academic Publishers, Wageningen.

Recommended literature:

Farooq, M., Pisante, M. (eds) (2019): Innovations in Sustainable Agriculture. Springer.
Nordhaus, W. (2013): The Climate Casino. Yale University.
Srinivasan, A. (2006): Handbook of Precision Agriculture. Food Products Press.
+ Relevant publications of the course instructors.

Course title:	Traceability in post-harvest technologies		
Course code:	N_DMA66	Credits:	5
Course type:	Compulsory		
Course instructor:	Attila József Kovács PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
Post-harvest technologies refer to the processes and activities that take place after the harvesting of agricultural crops. This includes the processing, storage, transport, and marketing of harvested crops. Post-harvest activities aim to preserve the quality and food safety of the crops and maximize the value of the crops. This phase is critical to the successful marketing and long-term storage of agricultural products. The digitization of post-harvest technologies can represent a significant step forward in the storage, processing, and transport of agricultural produce. During the course, students will learn about these processes in close connection with traceability and related blockchain technologies.

Course content:

1	Introduction, description of requirements, definition of individual tasks
2	Concept and importance of post-harvest
3	The process of post-harvest technologies, their relationship with crop production and the food industry and trade
4	Post-harvest technologies 1: transport and material handling
5	Post-harvest technologies 2: processing (cleaning, drying, etc.)
6	Post-harvest technologies 3: storage
7	Losses in post-harvest processes
8	Digitization of post-harvest technologies
9	Digital data collection, transmission, and storage during post-harvest
10	Examples of post-harvest processes (in cereal, fruit, and vegetable production and processing)
11	Application of blockchain technology during post-harvest
12	Summary, description of individual tasks, presentation

Requirements:
Student's presentation, oral discussion, graded on a 5-point scale.

Required reading:
Chakraverty, A. (2014) Postharvest Technology and Food Process Engineering, CRC Press. ISBN 9781466553200
Chakraverty, A., Mujumdar, A.S., Ramaswamy, H.S. (Eds) (2003) Handbook of Postharvest Technology Cereals, Fruits, Vegetables, Tea, and Spices.
Chavan, U.D. (2012) Postharvest Management and Processing Technology: Cereals, Pulses, Oilseeds, Fruits and Vegetables. Daya Publishing House. ISBN 9788170357872
Florkowski, W.J., Banks, N.H., Shewfelt, R.L. (Eds) (2021) Postharvest Handling: A Systems Approach, 4th Edition. Academic Press. ISBN 9780128228456
Krishnaprabu, S. (2020) Postharvest Technology: A Textbook. Satish Serial Publishing House. ISBN 978-9388020985

Recommended literature:
McEntire J., Kennedy, A.W. (Eds) (2019) Food Traceability: From Binders to Blockchain (Food Microbiology and Food Safety). Springer.
Namasudra, S., Akkaya, K. (2023) Blockchain and its Applications in Industry 4.0. Sprenger. DOI: https://doi.org/10.1007/978-981-19-8730-4.

Course title:	Plant biotechnology		
Course code:	N_DMA05	Credits:	5
Course type:	Compulsory		
Course instructor:	Zoltán Molnár PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The concept, areas, subject, purpose, methods, and history of plant biotechnology. Plant somatic cell cultures, callus culture. Plant regeneration (morphogenesis): physiological basis, organogenesis, somatic embryogenesis. Cultivation of plant protoplasts: isolation and cultivation of protoplasts. Somatic hybridization: protoplast fusion, identification of hybrid cells, plants. Isolation of mutants from cell and tissue cultures. Somaclonal and gametoclonal variability. The importance of plant genetic engineering. Molecular structure of plant genes. Identification of plant genes, gene maps. Recombinant DNA technique. *In vitro* recombination. Identification of plant genes. Gene cloning, clone library, clone selection. Gene transfer systems. Steps of transgenic plant production. Gene transfer methods in plants. Plant biotechnology and plant breeding: biotechnology for sexual reproduction (haploid cultures: ovary, ovulum, anthers, microspore, *in vitro* pollination and fertilization, triploid cultures), embryo cultures (embryo development in vivo, embryo development *in vitro*: pregerminal and postgerminal cultures), vegetative organ cultures (root cultures, leaf cultures, meristem cultures). Plant biotechnology and propagation material production: *in vitro* vegetative micropropagation, artificial (synthetic) seed, virus removal and plant biotechnology, *in vitro* gene bank. Plant biotechnology and plant protection: pathogen-resistant transgenic plants, pest-resistant transgenic plants, herbicide-tolerant transgenic plants. GM crops in agriculture: advantages and disadvantages. Risk factors for plant genetic engineering. Legal regulation of plant genetic engineering. The economic importance of GM crops.

Course content:

1	Introduction; the concept, subject, purpose, and classification of plant biotechnology
2	Plant somatic cell cultures, callus culture; plant regeneration, organogenesis, somatic embryogenesis
3	Plant protoplast culture, somatic hybridization: protoplast fusion, hybrid cells, plant identification
4	Isolation of mutants from cell and tissue cultures; somaclonal and gametoclonal variability
5	The importance of plant genetic modification; molecular structure of plant genes; dentification of plant genes, gene maps
6	Recombinant DNA techniques; *in vitro* recombination; gene transfer systems
7	Transgenic (GM) plant production; gene transfer methods in plants
8	Plant biotechnology and plant breeding 1: biotechnology of asexual reproduction (haploid breeding)
9	Plant biotechnology and plant breeding 2: embryo cultures, vegetative organ cultures
10	Plant biotechnology and propagation material production 1: *in vitro* vegetative micropropagation
11	Plant biotechnology and propagation material production 2: artificial (synthetic) seeds, virus removal and plant biotechnology, *in vitro* gene bank
12	Plant biotechnology and plant protection; GM crops in agriculture: advantages and disadvantages

Requirements:
Written examination, graded on a 5-point scale.

Required reading:
Prasad, B.D., Sahni, S., Kumar, P., Siddiqui, M.W. (2018): Plant Biotechnology, Volume 1: Principles, Techniques, and Applications. Apple Academic Press, Oakville–Waretown, Canada, and USA.
Sahni, S., Prasad, B.D., Kumar, P. (2018): Plant Biotechnology, Volume 2: Transgenics, Stress Management, and Biosafety Issues. Apple Academic Press, Oakville–Waretown, Canada, and USA.
Stewart, C.N., Jr. (Ed.) (2016): Plant Biotechnology and Genetics: Principles, Techniques, and Applications, 2nd Edition. Wiley-Blackwell, Oxford–Hoboken, UK, and USA.

Recommended literature:
Christou, P., Klee H. (Eds.) (2004): Handbook of Plant Biotechnology. Wiley-Blackwell, Oxford–Hoboken, UK, and USA.
Davey, R.M., Anthony P. (Eds.) (2010): Plant Cell Cultures. Essential Methods. Wiley-Blackwell, Oxford–Hoboken, UK, and USA.
George, E.F., Hall, M.A., De Klerk, G.J. (2008): Plant Propagation by Tissue Culture, 3rd Edition. Springer, Berlin Heidelberg.

Neumann, K.H., Kumar, A., Imani, J. (2009): Plant Cell and Tissue Culture – A Tool in Biotechnology. Springer, Berlin Heidelberg.

Course title:	Molecular plant pathology		
Course code:	N_DMA67	Credit value:	5
Course type:	Compulsory		
Course instructor:	László Palkovics DSc		
Number of contact + individual study hours:	20 + 130		

Objectives of the course:
This course is based on the bachelor's and master's courses and presents the molecular aspects of diseases of horticultural plants and cereals, and possible ways of plant protection. It covers the concepts, areas, methods, and history of plant pathology. Detailed description of the functions of various pathogens (*e.g.*, viroids, viruses, bacteria and fungi). Different protein- and nucleic acid-based diagnostic methods. The aim of the course is to enable doctoral students to recognise plant diseases and to become familiar with control options, including biological and biotechnological methods. Pathogen-derived resistance, development of resistance in transgenic GM plants and development of resistance in genetically engineered plants, advantages and disadvantages.

Course content:

1	Introduction to plant pathology; history of plant pathology; the concept of plant diseases; pathogens: viruses, viroids, phytoplasmas, bacteria, oomycota; the importance of plant diseases; control of plant diseases
2	Plant viruses: structure, replication, and movement
3	Plant viruses: translation strategy
4	Plant viruses: spread and transmission
5	Satellite viruses, satellite RNAs, viroids : structure, function, replication, diseases
6	Phytoplasmas and bacteria: structure, function, and the diseases they cause
7	Bacterial–plant communication, infection
8	The *Agrobacterium* strategy
9	Diseases caused by fungi and Oomycota
10	Molecular diagnostics of plant pathogens 1
11	Molecular diagnostics of plant pathogens 2
12	Biological plant protection; gene silencing, transgenic approaches for crop protection; pathogen-derived resistance; gene editing

Requirements:
Written examination, graded on a 5-point scale.

Required reading:
Agrios, G.N. (2023): Plant Pathology (6th ed.). Academic Press, New York, NY, USA.
Hull, R. (2001): Matthews' Plant Virology (4th ed.). Academic Press, New York, NY, USA.
Kado, C.I. (2016): Plant Bacteriology. American Phytopathological Society (APS), St. Paul, MN, USA.

Recommended literature:
Brunt, A., Crabtree, K., Dallwitz, M. (1996): Viruses of Plants. CABI Publishing, Wallingford, UK.
Docherty, B. (2018): Plant Microbiology. Callisto Reference, New York, NY, USA.
Parker, E. (2022): Plant Pathology and Diseases. States Academic Press, New York, NY, USA.

Course title:	Impact of abiotic and management factors on weed vegetation of arable crops		
Course code:	N_DMA68	Credits:	5
Course type:	Compulsory		
Course instructor:	Gyula Pinke DSc		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to present, through the discussion of different case studies, the most important abiotic and management factors determining the species composition and the abundance of important weed species of cultivated crops. The course is particularly recommended for PhD students who are doing research in the field of herbology, but doctoral students working in other plant sciences can also gain useful knowledge, which they can use to shape their research methodology.

Course content:

1	Effects of environmental and management factors on species composition in arable weed communities
2	Weed vegetation in three management systems of winter cereals
3	Factors influencing the weed species composition of sunflower fields
4	Factors influencing the weed species composition of poppy fields
5	Factors influencing the weed species composition of rice fields
6	Factors influencing the weed species composition of soybean fields
7	Factors influencing the weed species composition of oil pumpkin fields
8	Environmental and land-use variables determining the abundance of common ragweed in arable fields
9	Factors influencing the weed species composition of phacelia fields
10	Factors influencing the weed species composition of crimson clover fields
11	Drivers of species composition in arable-weed communities of the Austrian–Hungarian borderland region: what is the role of the country?
12	Refining rare weed trait syndromes along arable intensification gradients

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Pinke, G., Giczi, Z., Vona, V., Dunai, É., Vámos, O., Kulmány, I., Koltai, G., Varga, Z., Kalocsai, R., Botta-Dukát, Z., Czúcz, B., Bede-Fazekas, Á. 2022. Weed composition in Hungarian phacelia (*Phacelia tanacetifolia* Benth.) seed production: Could tine harrow take over chemical management? Agronomy 12, 891.
Pinke, G., Karácsony, P., Czúcz, B., Botta-Dukát, Z. 2018. When herbicides don't really matter: weed species composition of oil pumpkin (*Cucurbita pepo* L.) fields in Hungary. Crop Protection 110, 236-244.
Pinke, G., Vér, A., Réder, K., Koltai, G., Schlögl, G., Bede-Fazekas, Á., Czúcz, B., Botta-Dukát, Z. 2024. Drivers of species composition in arable-weed communities of the Austrian–Hungarian borderland region: What is the role of the country? Applied Vegetation Science 27, e12764.

Recommended literature:
Pinke, G., Gunton, R.M. 2014. Refining rare weed trait syndromes along arable intensification gradients. Journal of Vegetation Science 25, 978-989.
Pinke, G., Blazsek, K., Magyar, L., Nagy, K., Karácsony, P., Czúcz, B., Botta-Dukát, Z. 2016. Weed species composition of conventional soyabean crops in Hungary is determined by environmental, cultural, weed management and site variables. Weed Research 56, 470-481.
Pinke, G., Csiky, J., Mesterházy, A., Tari, L., Pál, R., Botta-Dukát, Z., Czúcz, B. 2014. The impact of management on weeds and aquatic plant communities in Hungarian rice crops. Weed Research 54, 388-397.
Pinke, G., Pál, R.W., Tóth, K., Karácsony, P., Czúcz, B., Botta-Dukát, Z. 2011. Weed vegetation of poppy (*Papaver somniferum*) fields in Hungary: effects of management and environmental factors on species composition. Weed Research 51, 621-630.

Course title:	Plant protection zoology		
Course code:	N_DMA90	Credits:	5
Course type:	Elective		
Course instructor:	Rita Ábrahám-Ledó PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to learn about the results of different treatments used in plant protection, how they affect population trends and how they can be used in integrated pest management. Soil, seed and plant treatments for crop protection play a role in the conditions of economic production and quality production. The various treatments provide a wide range of opportunities for designing experiments, the results of which can be used to improve practical procedures. The fundamental objective of integrated pest management is to reduce the use of pesticides that are harmful to the environment and health. Therefore, we attach particular importance to agrotechnical, mechanical, physical, biological, biotechnological, resistance breeding techniques, as well as monitoring of forecasts, remote sensing, aerial photography, etc. It is essential to study the biotic and abiotic factors that influence the fate of agrobiotic communities that build up on agrobiotopes.

Course content:

1	Classification of damaging animal species, based on morphology and molecular biology
2	Dominance, abundance and population dynamics of harmful species, based on auto- and synecological knowledge
3	Insect nutrition physiology, chemical communication (sex pheromones and attractants)
4	Relationship between plant quality, plant microclimate and pest population
5	Forecasting methods to determine the optimal timing of protection
6	Pests of cereals and maize
7	Pests of potatoes and sugar beets and their role as a virus vector
8	Pests of leguminous plants
9	Pests of oil and fiber crops
10	Pests of field-grown vegetable crops
11	Pests of fruit orchards (apple, pome, and grape)
12	Application of of precision technologies and their benefits

Requirements:
Writing an essay on a predetermined topic.

Required reading:
Gillott, C. (2005). Entomology (3rd Ed.) University of Saskatchewan, Saskatoon, Canada.

Recommended literature:
Kerruish, R.M., Unger, P.W (2010): Plant Protection 1: Pests, Diseases and Weeds (4th ed.). RootRot Press, Hughes, ACT, Australia.
Minks, A.K., Harrewijn P. (1988-1989): Aphids: Their Biology, Natural Enemies and Control. Elsevier, Amsterdam.

Course title:	Robots, autonomous devices, and image analysis in precision agriculture		
Course code:	N_DMA81	Credits:	5
Course type:	Elective		
Course instructor:	Bálint Ambrus PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to familiarize students with the automation, robotics elements and systems, as well as image analysis methods, both theoretical and practical, that are necessary to operate precision tools in precision agriculture through digitalization.

Course content:

1	Introduction: historical overview, definition, and classification of robots
2	Mobile robots: relative positioning (dead reckoning) and odometry
3	Mobile robots: navigation and path planning, trajectory planning
4	Robot manipulators: kinematics, dynamics
5	Robotics in crop production
6	Robotics in animal livestock
7	Internet of Things (IoT) and the concept and significance of big data
8	Fundamentals of image processing: characteristics of light, human vision, structure of the human eye, properties of our vision
9	Color systems: The RGB color system, CMY and CMYK color systems, YUV color system, HSV color system
10	Image processing operations: point-to-point operations, histogram transformations, arithmetic and logical operations, local operations, convolution-based operations, convolution properties, sequential filters, operations in the spatial frequency domai
11	Relationship between filtering in the spatial frequency domain and convolution; morphological operations: correction of segmentation errors, erosion, dilation, opening, closing, skeleton, thinning
12	Shape recognition: thresholding, contour detection, segmentation, Hough transform

Requirements:
Writing an essay on a predetermined topic.

Required reading:
Karkee, M., Zhang, Q. (2021). Fundamentals of Agricultural and Field Robotics. https://www.researchgate.net/publication/353507008_Fundamentals_of_Agricultural_and_Field_Robotics
Learning OpenCV 3: Computer Vision in C++ with the OpenCV Library, Kaehler, Adrian, Bradski, Gary, eBook.

Recommended literature:
Zhang, Q., Karkee, M. (2021). Agricultural and Field Robotics: An Introduction. https://www.researchgate.net/publication/353505090_Agricultural_and_Field_Robotics_An_Introduction**.**

Course title:	Biology of parasitic plants		
Course code:	N_DMA82	Credits:	5
Course type:	Elective		
Course instructor:	Gyula Pinke DSc (Kornél Baráth PhD)		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
There are currently nearly 4,750 species of parasitic plants worldwide, which have evolved along twelve completely independent lineages during the evolution of angiosperms. As a result of the parasitic lifestyle, their bodies are specialized, in many cases reduced, and with the help of their special organ called haustorium, they obtain vital nutrients from other plants. Many parasitic plants are dangerous agricultural pests, as they can also parasitize cultivated plants, significantly reducing their size, crop, and seed yield. The most dangerous parasites are capable of causing up to 100% yield loss in certain crops. Effective control is based on understanding their body structure, development and biology. Recognition and differentiation of parasitic plants at species level are also important. Although species that are phylogenetically distant from each other due to convergent evolution are often extremely similar, different species tend to prefer different host plants, and effective protection against them also requires different methods.

Course content:

1	Basic concepts of parasitic plants
2	Overview of the phylogenetic diversity of parasitic plants
3	Taxonomy of mycoheterotrophic plants, characterization of their body structure and biology
4	Facultative hemiparasitic species; characterization of their body structure and biology
5	Obligate hemiparasitic species; characterization of their body structure and biology
6	Holoparasitic root-parasite species; characterization of their body structure and biology
7	Holoparasitic stem-parasite species; characterization of their body structure and biology
8	Overview of agricultural damage caused by parasitic plants in different crops
9	Methods of protection against parasitic plants 1: herbicides and resistance testing
10	Methods of protection against parasitic plants 2: complex control, crop rotation, mechanical removal, biological control, hyperparasitism
11	The regulatory role of parasitic plants in natural plant communities
12	The use of parasitic plants in medicine

Requirements:
Written examination, graded on a 5-point scale.

Required reading:
Baráth, K., Csiky, J. (2012): Host range and host choice of *Cuscuta* species in Hungary. Acta Botanica Croatica 71 (2), 215-227.
Nickrent, D.L. (2020): Parasitic angiosperms: how often and how many? Taxon 69, 5-27.
Nickrent, D.L., Musselman, L.J. (2004): Introduction to Parasitic Flowering Plants. The Plant Health Instructor. DOI:10.1094/PHI-I-2004-0330-01.

Recommended literature:
Baráth, K. (2012): A new method for evaluating host preference of *Cuscuta* species. Acta Botanica Hungarica 54 (3–4), 219-234.
Joel, D.M., Gressel, J., Musselman L.J. (2013): Parasitic Orobanchaceae: Parasitic Mechanisms and Control Strategies. Springer, Berlin. https://doi.org/10.1007/978-3-642-38146-1_16.

Course title:	Remediation, recultivation		
Course code:	N_DMA83	Credits:	5
Course type:	Elective		
Course instructor:	Dóra Beke PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
As a result of economic and industrial development, the natural environment, including soil, is increasingly degraded, threatening food supplies and the maintenance of a healthy human environment. One of the greatest dangers of pollution is that it remains hidden and takes effect over long periods of time through soil and groundwater. The main pollutants and their sources and potential soil remediation options will be reviewed. The nature of the damage, its impact on soil fertility and potential remediation options will be examined. The specificities of farming and forestry in restored areas will be discussed.

Course content:

1	Principles of soil conservation
2	Classification of soil contaminants
3	Oil pollution
4	PAH, PCB
5	Remediation technologies 1
6	Remediation technologies 2
7	Remediation technologies 3
8	Basis for recultivation
9	Hazard effects, affected areas
10	Techniques of recultivation
11	Biological techniques for recultivation
12	Utilization of rehabilitated areas

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Duarte, A., Cachada, A., Rocha-Santos, T. (2017): Soil Pollution from Monitoring to Remediation. ISBN: 9780128498736, Academic Press.

Recommended literature:
Meuser, H. (2013): Soil Remediation and Rehabilitation: Treatment of Contaminated and Disturbed Land. Springer, Dordrecht, The Netherlands
Morgan, R.P.C. (2005): Soil Erosion and Conservation (3rd ed.). Blackwell Publishing, Oxford, UK.
Miller, M.E., Bowker, M.A., Reynolds, L.R., Goldstein, H.L. (2012): Post-fire land treatments and wind erosion: lessons from the Milford Flat Fire, UT, USA. Aeolian Research 7, 29-44.

Course title:	Design and analysis of experiments in crop production		
Course code:	N_DMA84	Credits:	5
Course type:	Elective		
Course instructor:	Zoltán Varga PhD (Zoltán Berzsenyi DSc)		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The course gives information about the nature of research and different types of experimental approach, the fundamental rules of experimental design and the purpose of statistical analysis of experimental data. The objective of this course is to teach PhD students about the theoretical, practical, and methodological questions of designing, setting up, and evaluating field experiments in crop production (and in other disciplines). The students get up-to-date knowledge of the traditional and computer-based new methods of biometrical analysis of field experiments. The following issues are also important parts of the course: the different types of crop production experiments (single-factor-, bi- and multi-factorial experiments, series of experiments, long-term experiments, technology adaptation experiments); the principles and models of analysis of variance (ANOVA), correlation and regression analyses (linear and non-linear, multiple); and use of special computer programs (Genstat for Windows, SPSS) in designing and evaluating field experiments. Students of the course will understand the use of multivariate biometric methods (principal component analysis, cluster analysis, discriminant analysis) and they will be able to decide on which analytical and synthesizing methods to use. Demonstrations of several experimental data series, computer-based data processing and exercises equally contribute to the acquirement of experimental methods. The final objective of this course is that the PhD students should be able to use the methods of statistical data analysis in their own research programs.

Course content:

1	Introduction to research by experimentation. The nature of research and different types of experimental approach. The fundamental rules of experimental design. The purpose of statistical analysis of experimental data.
2	Descriptive statistics. Measurements of central tendency, dispersion, and sample reliability. Basic concepts of geostatistics (autocorrelation, crosscorrelation, semivariogram, kriging).
3	Single-sample and two-sample parametric tests (Student's t-tests).
4	Experimental designs and structures of experiments.
5	Principles of analysis of variance (ANOVA). Single-factor experiments (completely randomized, randomized complete block, latin square, lattice design). Testing for statistical significance. Multiple comparison tests.
6	Two-factor experiments (completely randomized, complete block, split-plot, strip-plot design). Modelling genotype by environment interaction.
7	Three or more factor experiments, analysis of data from series of experiments.
8	Fixed and random effects. Introduction to linear mixed models. Using computer packages (Genstat for Windows, SPSS, Excel) for the analysis of different types of experiments.
9	Correlation analysis. Linear and non-linear regression analysis. Multiple linear regression analysis.
10	Non-parametric sample comparison tests.
11	Multivariate methods in agricultural research. Principal component analysis (PCA), discriminant analysis, cluster analysis.

Requirements:
The assessment consists of a written and an oral exam. The written exam consists of two homework problems (one ANOVA and one analysis of regression) and an oral presentation. The problems can be solved without the use of computer programs. In the oral examination, PhD students will be asked questions on a comprehensive set of topics drawn from the course material (which has been familiarized to the students). The emphasis is on general knowledge of the subject matter.

Required and recommended reading:
Baird, D., Murray, D., Payne, R., Soutar, D. 2023. Introduction to Genstat for Windows (23rd ed.). VSN International, Hertfordshire, UK.
Davis, C. 2013. SPSS for applied sciences. Basic statistical testing. CSIRO Publishing, Collingwood, Australia.
Ireland, C.R. 2010. Experimental statistics for agriculture and horticulture. CAB International, Wallingford, UK.
Kiernan, D. 2018. Natural resources biometrics. Sunny College of Environmental Science and Forestry. https:// stats.libretexts.org.

Mead, R. Curnow, R.N., Hasted, A.M. 2003. Statistical methods in agriculture and experimental biology. Chapman & Hall / CRC, Boca Raton, Florida.
Nielsen, D.R., Wendroth, D. 2003. Spatial and temporal statistics. Catena Verlag GmbH, Reiskirchen, Germany.

Course title:	Economics of sustainable crop production		
Course code:	N_DMA85	Credits:	5
Course type:	Elective		
Course instructor:	Károly Kacz, Jr. PhD		
Co-instructor:	Nóra Gombkötő PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to enhance the economic knowledge of students pursuing PhD studies in the Doctoral Program in Plant Science with different backgrounds in sustainable crop production, and to present good practices. The focus of the teaching is on the economics of crop production as a system and on the planning, organization, analysis, and processes of sustainable crop production. In addition to the basic concepts of these main topics, we want to give students the opportunity to gain an insight into the role and importance of plant production in the national and global economy, in addition to the operational and company aspects.

Course content:

1	The economic characteristics, economic and social sustainability of crop production
2	The macroeconomic/market environment (domestic and international) of crop production
3	The regulatory system of crop production and its application in practice
4	Structure of crop production, size of enterprises and sectors
5	Centralization and concentration in crop production
6	The product structure of the crop production sectors, the structure and functioning of the product pathways in crop production
7	Basics and components of production management
8	Use of resources, efficiency analysis, cost and revenue calculation
9	Analysis and decision preparation
10	Planning, organizing, and controlling
11	Innovation, product and technology development issues in livestock farming
12	Market information system and its functioning

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Kay, R.D, Edwards, W.M., Duffy, P.A. (2016): Farm Management (8th ed.). McGraw Hill Education, New York, NY.

Recommended literature:
Dijkman, J.T., Lecq, F. (2021): The economic sustainability of animal production: balancing prosperity and responsibility. Sustainability, 13 (19), 10962.
Swinnen, J. (2020). Economics of sustainable intensification in agriculture. Annual Review of Resource Economics, 12, 63-79.

Course title:	Biological background of horticultural production		
Course code:	N_DMA86	Credits:	5
Course type:	Elective		
Course instructor:	Borbála Hanusz-Pólya PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
This course familiarizes students with important aspects of horticultural production, covering various sectors of horticulture, and specifically examines their biological backgrounds. It aims to convey scientific and encyclopedic knowledge. The course is divided as follows: 40% vegetable production, 30% fruit and nursery cultivation, and 30% vine growing and winery. The biological background of horticulture is emphasized through the everyday use of both new and older varieties. The cultivation, circulation, and collection of these varieties are maintained in research institutes and gene banks. Educational topics are closely aligned with the activities of research institutes, addressing issues such as the health problems of major plants, isolation and control measures, and key aspects of disinfection programs.

Course content:

1	General issues of horticultural production
2	Morphology of vegetables in temperate zones
3	Flowering and fertilization of vegetables
4	Growing important vegetables (iteration)
5	Morphology of fruits in temperate zones
6	Floral biology of important fruits
7	Propagation of fruit species
8	Nursery, rootstocks of fruit varieties
9	Issues of breeding maintenance
10	Morphology and propagation of vine varieties
11	Maintenance of vine varieties
12	Plant health problems, disinfection in horticulture

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Nyéki, J., Soltész, M. (1996): Floral Biology of Temperate Zone Fruit Trees and Small Fruits. Akadémiai Kiadó, Budapest.
Taiz, L., Møller, I.M., Murphy, A., Zeiger, E. (Eds) (2022): Plant Physiology and Development (7th ed.). Oxford University Press, Oxford, UK.
Westwood, M.N. (2009): Temperate-Zone Pomology: Physiology and Culture (3rd ed.). Timber Press, Portland, OR, USA.
Wien, H.C., Stutzel, H. (2020): The Physiology of Vegetable Crops (2nd ed.). CABI, Wallingford, UK.

Recommended literature:
Racskó, J., Nyéki, J., Soltész, M., Szabó, Z. (2007): Floral biology, pollination and fertilisation of temperate zone fruit trees. International Journal of Horticultural Science 13 (3), 7-12.

Course title:	Pesticide chemistry		
Course code:	N_DMA88	Credits:	5
Course type:	Elective		
Course instructor:	Gábor Kerekes PhD		
Co-instructor:	Pál Szakál CSc		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to explore the chemical systems used to control pests, including weeds, animals, and pathogens, in cultivated crops. The course will evaluate the main achievements in this field and examine future prospects for research and development. Major topics include pesticide formulations, insecticides, weed control agents, fungicides, antibacterial agents, and alternative methods. The lectures will cover essential characteristics of active ingredients in various plant protection chemicals, focusing on common and primary traits of pesticide groups. Discussions will also address biological modes and mechanisms of action, resistance development, environmental stability, and toxicology. Special emphasis will be placed on the limitations of using these products in integrated pest management.

Course content:

1	Basics of plant protection chemistry
2	Different forms and different goals of pesticide formulations
3	Insecticides
4	Weed control agents
5	Antifungal agents
6	Antibacterial agents
7	Side effects of pesticides
8	Pesticide residues and degradation products in food and the environment
9	Human and environmental toxicology of pesticides
10	Applicability of pesticides in integrated crop production
11	Alternatives to the use of pesticides
12	Rules for the authorization of pesticides

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Jeschke, P., Witschel, M., Krämer, W., Schirmer, U. (2019): Modern Crop Protection Compounds. Wiley-VCH.
Wang, C.J., Liu, Z.Q. (2007): Foliar uptake of pesticides—Present status and future challenge. Pesticide Biochemistry and Physiology 87 (1), 1-8.

Recommended literature:
Jones, R.L. et al. (2000): Processes affecting the movement of pesticides to drainage in cracking soil. Pesticide Outlook 11 (5), 174-179.
Ntalli, N.G., Spiroudi, U. (2011): Pesticides of Botanical Origin. pp. 3-24. InChem.
Ohkawa, H., Miyagawa, H., Lee, P.W. (2007): Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety. Wiley-VCH.
Stoycheva, M. (Ed.) (2011): Pesticides, Formulations, Effects, Fate. InTech.

Course title:	Herbology		
Course code:	N_DMA89	Credit value:	5
Course type:	Elective		
Course instructor:	Gábor Kukorelli PhD		
Co-instructor:	Gyula Pinke DSc		
Number of contact + individual study hours:	20 + 130		

Objectives of the course:
The aim of this course is to present the latest scientific principles, methods, and findings related to weed regulation. We will address both the damage caused by weeds and their beneficial properties. To understand these aspects, we will explain the economic conditions and biological characteristics of weeds. The course provides a comprehensive overview of various weed control methods, with a particular emphasis on nonchemical weed management strategies. We will delve into precision weed control and discuss the latest national and international developments in this field.

Course content:

1	The concept of weed, the significance of weeds, tendencies of changes in weed flora
2	Competition and indirect damage
3	The ecology and lifestyle of weeds
4	Reproduction biology of weeds
5	Current state of weed management in organic and conventional cropping systems
6	Prevention strategies in weed management
7	Nonchemical weed management strategies
8	Cultural weed management
9	Mechanical weed management
10	Role of allelopathy in weed management
11	Herbicide resistance in weeds and crops: challenges and opportunities
12	Field applications of automated weed control

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Chauhan, B.S., Mahajan, G. (2014): Recent Advances in Weed Management. Springer, New York, NY, USA.
Naylor, R.E.L. (Ed.) (2002): Weed Management Handbook (9th ed.). Blackwell Publishing, Oxford, UK.
Upadhyaya, M.K., Blackshaw, R.E. (2007): Non-chemical Weed Management: Principles, Concepts and Technology. CABI, Wallingford, UK.
Young, S.L., Pierce, F.J. (2014): Automation: The Future of Weed Control in Cropping Systems. Springer, Dordrecht, The Netherlands.

Recommended literature:
Cobb, A.H., Reade, J.P.H. (2010) Herbicides and Plant Physiology. Wiley, Chichester, UK.
Hurford, C., Wilson, P., Storkey, J. (2020): The Changing Status of Arable Habitats in Europe: A Nature Conservation Review. Springer Nature Switzerland, Cham, Switzerland.
Krähmer, H. (2016): Atlas of Weed Mapping. Wiley, Chichester, UK.

Course title:	Microalgae biology and biotechnology		
Course code:	N_DMA03	Credit value:	5
Course type:	Elective		
Course instructor:	Zoltán Molnár PhD (József Kutasi PhD)		
Co-instructors:	Boglárka Somogyi PhD, Kálmán Tapolczai PhD		
Number of contact + individual study hours:	20 + 130		

Objectives of the course:
The course gives an introduction into macro- and microalgae taxonomy based on traditional and molecular biological methods. The description of the prokaryotic (cyanobacteria) and eukaryotic divisions includes the main physiological characteristics, which significantly influence laboratory cultivation of microalgae, such as: photosynthetic pigments, photosynthesis, heterotrophic growth, regulation of buoyancy, nitrogen and phosphorus metabolism, and nitrogen fixation. The biotechnology component focuses on valuable compounds of microalgae and their possible use in agriculture and renewable energy production. Microalgae compounds, which are useful in plant production and protection, like: (1) plant hormones, (2) antimicrobial compounds, (3) volatile organic compounds, and (4) toxins are highlighted. Evidence is presented showing that microalgae composition depends on environmental factors, which is the basis of biofuel production with microalgae.

Course content:

1	Concept of algae. Characterization of prokaryotic algae (cyanobacteria).
2	Occurrence, reproduction, nitrogen fixation, and photosynthesis of cyanobacteria.
3	Eukaryotic algae divisions: rhodophyta and heterokontophyta.
4	Eukaryotic algae divisions: cryptophyta, dinophyte, and euglenophyta. Eukaryotic algae division: chlorophyta and its main classes.
5	Occurrence, reproduction, photosynthesis, as well as nitrogen and phosphorus metabolism of green algae.
6	Establishing and maintaining algae collections. Isolation and description of new algal species.
7	Plant hormone production by microalgae and plant biostimulant effects. Introduction of the bioassay. Effects of microalgae on plant yield, crop yield, and flowering.
8	Effects of microalgae on soil, biostimulant effects. Antimicrobial effects of microalgae.
9	Microalgae and bacteria cooperation, algal attractants and communication compounds, microfluidics research. Human nutritional significance and occurrence of specific organic compounds of microalgae.
10	Antioxidant pigments and antioxidant measurement. Influence of environmental factors on lipid content, lipid production, and fatty acid composition.
11	Photosynthetic activity and optimization measurements in microalgae.
12	Algal mass culture techniques.

Requirements:
Written examination, graded on a 5-point scale.

Required reading:
Alam, M.A., Xu, J.L., Wang, Z.M. (2020): Microalgae Biotechnology for Food, Health and High Value Products. Springer Nature Singapore, Singapore.
Barsanti L., Gualtieri, P. (2022): Algae: Anatomy, Biochemistry, and Biotechnology. Taylor & Francis.
Richmond, A. (Ed.) (2004): Handbook of Microalgal Culture: Biotechnology and Applied Phycology. Blackwell Science, Oxford.

Recommended literature:
Andersen, R.A. (Ed.) (2005): Algal Culturing Techniques. Elsevier, Burlington, MA, USA.
Borowitzka, M.A., Borowitzka, L.J. (Eds.) (1989): Micro-algal Biotechnology. Cambridge University Press, Cambridge, UK.
Sangeetha, J., Codreanu, S., Thangadurai, D. (2023): Microalgal Biotechnology: Bioprospecting Microalgae for Functional Metabolites towards Commercial and Sustainable Applications. CRC Press, Boca Raton, FL, USA.

Course title:	Dispersal of weed seeds		
Course code:	N_DMA91	Credits:	5
Course type:	Elective		
Course instructor:	László Magyar PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of this course is to introduce PhD students to the key aspects of dispersal biology, seed ecology, and the physiology of weed seeds from a plant protection perspective, along with their practical implications. The course will begin with an overview of basic seed morphology and anatomy necessary for understanding the dispersal biology and processes of weed seeds. We will briefly cover seed formation, structure, and the roles of the embryo, endosperm, and seed coat in seed dispersal. Additionally, we will examine both the external and internal properties of seeds and the main types of seeds and fruits. Following this, we will explore the genetically determined and ecologically mediated characteristics of weed persistence, focusing on seed production and seed set. Detailed descriptions and practical examples will illustrate abiotic and biotic strategies of spatial weed seed dispersal, and we will address key issues related to anthropogenic weed dispersal in agricultural production. The main theme of the course is the temporal dispersal of weeds, recognized as a significant constraint to successful weed control. Therefore, the lectures will emphasize critical scientific information on seed dormancy and the formation of the soil seed bank. Finally, we will present new alternatives and practical guidance for designing more effective weed control technologies, highlighting the latest research findings in the field. Overall, the course will synthesize the latest knowledge in seed physiology and ecology, providing insights to understand and adapt to the practical processes involved in weed seed dispersal biology.

Course content:

1	The biological basis of seed dispersal
2	Seed production of weeds
3	Definition, purpose, and importance of seed dispersal
4	Mechanisms of spatial dispersal in weed seeds (abiotic and biotic seed dispersal)
5	Definition and significance of seed dormancy
6	Types and classification of seed dormancy
7	Regulation of seed dormancy
8	Natural mechanisms and artificial methods that terminate seed dormancy
9	Characteristics of the soil seed bank (density, longevity, and distribution in soil)
10	Dynamics of the soil seed bank and methods of analysis
11	Regulation of soil seed bank
12	New alternatives for reducing the soil weed seed bank

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Baskin, C.C., Baskin, J.M. (2014): Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination (2nd ed.). Academic Press, London, UK.
Bewley, J.D., Bradford, K., Hilhorst, H., Nonogaki, H. (2013): Seeds: Physiology of Development, Germination and Dormancy (3rd ed.). Springer, London, UK.
Fenner, M. (2000): Seeds: The Ecology of Regeneration in Plant Communities (2nd ed.). CABI, Wallingford, UK.
Gallagher, R.S. (2014): Seeds: The Ecology of Regeneration in Plant Communities (3rd ed.). CABI, Wallingford, UK.
Taiz, L., Møller, I.M., Murphy, A., Zeiger, E. (Eds) (2022): Plant Physiology and Development (7th ed.). Oxford University Press, Oxford, UK.
Upadhyaya, M.K., Clements, D.R., Shrestha, A. (2022): Persistence Strategies of Weeds. John Wiley & Sons, Ltd. 400 pp.

Recommended literature:
Benech-Arnold, R.L., Sánchez, R.A., Forcella, F., Kruk, B.C., Ghersa, C.M. (2000): Environmental control of dormancy in weed seed banks in soil. Field Crops Research 67, 105-122.
Benvenuti, S. (2007): Weed seed movement and dispersal strategies in the agricultural environment. Weed Biology and Management 7, 141-157.

Dekker, J. (1999): Soil weed seed banks and weed management. Journal of Crop Production 2, 139-166.
Juroszek, P., Gerhards, R. (2004): Photocontrol of weeds. Journal of Agronomy and Crop Science 190, 402-415.
Yan, A., Chen, Z. (2020): The control of seed dormancy and germination by temperature, light and nitrate. Botanical Review 86, 39-75.

Course title:	GIS and remote sensing		
Course code:	N_DMA06	Credits:	5
Course type:	Elective		
Course instructor:	Gábor Milics PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The course aims to introduce students to Geographical Information Science (GIS) and Remote Sensing (RS). During contact hours, students will learn to view data and information within a spatial context. General GIS and specific Agro-GIS software will be introduced, along with practical exercises in data collection, storage, and analysis throughout the semester. As part of the program, students will gain the ability to produce digital maps and analyze data with spatial relations in agriculture. The curriculum also covers remote sensing platforms and sensor technology, including satellite and airborne technologies. Leading RS platforms such as UAV technology and compatible sensors will be introduced. The course is designed to equip students with skills to participate in the decision-making cycle, interpret spatial data, and understand the decision-making process.

Course content:

1	Development of GIS, raster and vector based systems, hybrid GIS systems
2	Basics of digital mapping, requirements for digital maps, thematic map creation
3	Creation and development of digital databases, online GIS
4	ArcGIS/QGIS system
5	Coordinate transformations, georeferencing
6	Creating AgGIS databases
7	Geostatistics, outlier detection and filtering, interpolation methods
8	Interpretation of digital maps
9	Basics of remote sensing
10	RS systems, satellite, airborne and UAVs
11	Sensors in RS
12	Application of RS based data in agriculture

Requirements:
Students can meet the subject requirements by completing work prepared during personal consultations or by solving an independent GIS or remote sensing task at the end of the course. Alternatively, they may also meet the subject requirements by publishing an original research paper on GIS or remote sensing in a scientific journal.

Required reading:
Aronoff, S. (2005): Remote Sensing for GIS managers. ISBN: 978-1589480810. Esri Press. 524 pp.
Green, K., Congalton, R.G., Tukman, M. (2018): Imagery and GIS: Best Practices for Extracting Information from Imagery. ISBN: 978-1589484542. ESRI Press. 418 pp.
Longley, P.A., Goodchild, M.F., Maguire, D.J., Rhind, D.W. (2005): Geographic Information Systems and Science, 2nd Edition. ISBN: 9780470870013. Wiley, Chichester, UK, 517 pp.

Recommended literature:
http://www.itc.nl/library/papers_2009/general/PrinciplesGIS.pdf
http://fac.ksu.edu.sa/sites/default/files/gis_cartography.pdf

Course title:	Biotic and abiotic stress resistance of crops		
Course code:	N_DMA92	Credits:	5
Course type:	Elective		
Course instructor:	Zoltán Molnár PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
Plant growth and development are influenced by various biotic and abiotic environmental factors, often manifesting as intense and frequent stressors. Within certain limits, plants can adapt to different living conditions in various ways, thanks to the resilience and adaptability of their genetic programs. The course begins by examining stress phenomena and then explores both specific and nonspecific plant responses. Traditional plant breeding does not always result in genetic alterations that confer stress tolerance or resistance in crop production. Consequently, there is a need to enhance abiotic and biotic stress resistance using gene technology methods. Thus, the curriculum also includes a detailed description of plant gene technology and its outcomes.

Course content:

1	Basic phenomena of plant stress (concepts; definition of stress; stages; stress response)
2	Signal transduction processes [sensing of the environmental signal; reactive oxygen species (ROS) and their role in signal transduction; calcium ion as a secondary messenger]
3	Temperature stresses and how to avoid them (low and high temperature stresses, temperature sensing)
4	Stress caused by visible light (photoinhibition)
5	Heavy metals stress (physiological effects of heavy metals, signal transduction of heavy metal effects).
6	Oxidative stresses and their prevention (activation of oxygen; sites of formation of activated oxygen species; protective mechanisms against oxidative stress)
7	Protective mechanisms against insect pests and plant pathogens (pathogen-linked proteins, systemic acquired resistance)
8	Genetically modified (GM) crops (plant genetic engineering, transgenic crop production, genetic engineering strategies)
9	Biotic stress resistant GM crops (resistance to pathogens)
10	Biotic stress resistant GM crops (pest resistance)
11	Abiotic stress tolerant/resistant GM crops (herbicide tolerant plants).
12	Abiotic stress tolerant/resistant GM plants (plants tolerant to extreme environmental stresses)

Requirements:
Written examination, graded on a 5-point scale.

Required reading:
Gaur, R.K., Sharma, P. (Eds.) (2014): Approaches to Plant Stress and their Management. Springer, Berlin–Heidelberg, Germany.
Ricroch, A., Chopra, S., Fleischer, S.J. (Eds.) (2014): Plant Biotechnology: Experience and Future Prospects. Springer, Berlin–Heidelberg, Germany.
Stewart, C.N., Jr. (Ed.) (2016): Plant Biotechnology and Genetics: Principles, Techniques, and Applications (2nd ed.). Wiley-Blackwell, Oxford, UK and Hoboken, NJ, USA.

Recommended literature:
Hopkins, W.G., Hüner, N.P.A. (2009): Introduction to Plant Physiology. Wiley, Hoboken, NJ, USA.
Pessarakli, M. (Ed.) (2010): Handbook of Plant and Crop Stress, 3rd Edition. CRC Press, Boca Raton, FL, USA.

Course title:	Crop growth models and plant physiological analysis		
Course code:	N_DMA93	Credits:	5
Course type:	Elective		
Course instructor:	Miklós Neményi MHAS		
Co-instructor:	Anikó Nyéki PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The course will cover the basic principles and applications of crop growth simulation models. Crop growth simulation modelling is a systematic approach and powerful tool for gaining quantitative and mechanistic understanding of crop–weather–soil–management relationships and interactions, as well as for helping improve and optimize crop management based on growing season characteristics and management options. Simulation models are traditionally carried out by using conventional experience-based agronomic research in which soil–plant–atmosphere system functions are derived from statistical analysis. The structure of crop models and simulation techniques will be illustrated (*e.g.*, data request, models structure and application of models). In the course, principles of theoretical crop production ecology will be explained. Applications of crop simulation models will also be demonstrated using practical examples. This course will introduce the basic concepts, issues, opportunities, and difficulties involved with using some of the model tools with management information. Students will have the opportunity to gain first-hand experience of running simulations on a wide range of scenarios for corn and wheat yields. In the most satisfactory crop growth models, the validation of the models is used to predict crop response to different climate change models or agricultural management (*e.g.*, hybrids or dates of seeding) and offers great potential to make good decisions.

Course content:

1	Overview of physical and biological systems in the soil–plant–atmosphere system
2	Simulation of solar radiation (accumulation of dry matter in soil), photosynthesis, evaporation, and water demand on cultivars
3	Overview of crop systems models (historic background and general); importance of decision support models in agriculture
4	Structure of crop growth models (structure, data request, etc.)
5	Fields experiments and data requirements for adapting and using crop models and validation of models
6	Climate change and plant growth: adaption and use of different climate models
7	Decision support models in precision agriculture
8	Case study 1: simulation of maize hybrid growth and development with various input data
9	Case study 2: simulation of wheat hybrid growth and development with various input data
10	Genetic factors of winter and summer cereals, ecological and nutrient demand, physiological responses
11	Maize production for different utilization; phenological development and environmental demand under various management practices (in particular for sustainable crop production)
12	Oil seed phenology and development in Hungarian environmental conditions
13	Analysis of effects on soil cultivation, seeding, harvesting and the physiological growth and development of cultivars

Requirements:
Written or oral examination, graded on a 5-point scale.

Required reading:
Cao, W.X., White, J.W, Wang, E.L. (2009): Crop modelling and decision support. ISBN 978-7-302-19333-3. Tsinghua University Press, Beijing and Springer Verlag, Berlin, Heidelberg.
Fischer, G., Shah, M., Velthuizen, H., Nachtergaele, F. (2006): Agro-ecological zones assessment. EOLSS Publishers, Oxford, UK.
Hoogenboom, G., Jones, J.W., Porter, C.H., Wilkens, P.W., Boote, K.J., Hunt, L.A., Tsuji, G.Y. (2010): Decision support system for agrotechnology tranfer (DSSAT), version 4.5 (CD-ROM), volume 1. Overview. University of Hawaii, Honolulu.

Recommended literature:
Flichman, G. (2011): Bio-economic models applied to agricultural systems. ISBN: 978-94-007-1901-9. Springer.
Nagy, J. (2008): Maize production. Akadémiai Kiadó, Budapest.
Vohnout, K.D (2003): Mathematical modeling for system analysis in agricultural research. ISBN: 0-444-51268-3. Elsevier.

Course title:	Macro- and micronutrients in the soil–plant system		
Course code:	N_DMA94	Credits:	5
Course type:	Elective		
Course instructor:	Pál Szakál CSc		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to provide PhD students with an understanding of the essential macro-elements and microelements of soil and plants by building on general, organic, biochemical, and agrochemical knowledge and their interrelationships. Toxic elements affecting plant development are also highlighted. An important part of the training will be to learn about soil composition, nutrient supply capacity and factors influencing nutrient uptake necessary for plant development. The macro- and micro-nutrient content of plants will be presented, based on their involvement in biochemical processes and their impact on the quality of crop yields.

Course content:

1	Macronutrients and their role in soil: N, P, K, S, Mg
2	Essential microelements and their role in soil, toxic elements: Cu, Zn, Mn, Fe, Mo, etc.
3	Nutrient supplying capacity of soils, compound forms and their uptake
4	Plant nutrient uptake from soil, inhibitors
5	Macronutrient supply of soils and forms of compounds used for micronutrient supplementation, salts and complex compounds
6	The role of macronutrients in plants; their role in biochemical processes; nitrogen
7	Role of macronutrients in plants; their role in biochemical processes: K, S, P, Mg
8	Essential trace elements and their role in plant biochemical processes
9	Amino acids, proteins, nucleic acids, enzymes, coenzymes
10	The role of macro- and microelements in plant conditioning, plant protection context
11	Nutrient calculation exercises
12	Effect of toxic elements on plant development, enzyme inhibitors

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Barker, A.V., Pilbeam, D.J. (Eds) (2007): Handbook of Plant Nutrition. CRC Press, Boca Raton, FL, USA.
Maathuis, F.J.M. (2016): Plant Mineral Nutriens: Methods and Protocols. Humana Press, Totowa, NJ, USA.

Recommended literature:
Clayden, J., Greeves, N., Warren, S. (2012): Organic Chemistry (2nd ed.). Oxford, University Press, Oxford, UK.
Ebbing, D.D. (1984): General Chemistry. Houghton Mifflin Company, Boston, MA, USA.

Course title:	Effects of macro- and microclimate on crop production		
Course code:	N_DMA95	Credits:	5
Course type:	Elective		
Course instructor:	Zoltán Varga PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to introduce PhD students to the influence of meteorological factors on plant stands, the methods to understand these effects, and the practical application of this knowledge. The course will cover the theoretical basis for investigating the effects of meteorological factors on plants and how these effects manifest. Sensitivity analyses will identify the periods and meteorological elements to which plants are most responsive. In addition to general knowledge, we will specifically address the agrometeorological impacts throughout the entire vegetation period for four key economic crops: winter wheat, winter barley, corn, and potato. Finally, the course will explore the practical applications of agrometeorological information derived from domestic data.

Course content:

1	Basics of studying the climate–plant relationship
2	Modeling the climate–plant relationship
3	Soil climate (soil temperature, soil water balance)
4	Climate of plant stands: solar radiation and plants
5	Climate of plant stands: temperature and plants
6	Climate of plant stands: water balance and plants
7	Climate of plant stands: wind and plants
8	The role of topography in influencing microclimate
9	Phenoclimatological characteristics of plants
10	The relationship between climate and plant productivity
11	The relationship between climate and some major economic crops
12	Agrometeorological information and its use

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Geiger, R., Aron, R.H., Todhunter, P. (2003): The Climate Near the Ground, 6th Edition. Rowman and Littlefield Publisher, Lanham, MD, USA.
Larcher, W. (2003): Physiological Plant Ecology. Springer Verlag, Berlin, Germany.

Recommended literature:
Mavi, H.S., Tupper, G.J. (2004): Agrometeorology: Priciples and Applications of Climate Studies in Agriculture. Food Product Press, New York, NY, USA.
Steduto, P., Hsiao, T.C., Fereres, E., Raes, D. (2012): Crop Yield Response to Water. FAO, Rome, Italy.
Supit, L., van der Groot, N. (2013): Description of WOFOST Crop Growth Simulation Model. Supit.net. Wageningen, The Netherlands.

Course title:	Climate change – adaptation options in crop production		
Course code:	N_DMA96	Credits:	5
Course type:	Elective		
Course instructor:	Zoltán Varga PhD (Ottó Veisz CMHAS)		
Co-instructors:	Nándor Fodor PhD, Tamás Árendás PhD, Balázs Varga PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to provide up-to-date knowledge to enhance the production stability of the plant-growing sector most vulnerable to climate change. Given the strategic importance of making food production more efficient in response to population growth, the available crop area cannot be expanded further. Therefore, the solution lies in using adaptable plant varieties with high yield potential that can be grown safely, alongside cultivation technologies that increase efficiency.

Course content:

1	Climate change: facts and predictions
2	Causes and components of climate change
3	Expected changes at the global, regional, and local levels
4	Research on the expected effects of climate change
5	Phytotron as a way to study the effects of climate change
6	Demonstration of the climate manipulation outdoor experimental system and the use of the results in the cultivation and extension system (FACE, weight lysimeter station, rain shelter)
7	The role of plant water utilization in the context of climate change
8	Effect of heat stress and increasing atmospheric CO_2 concentrations on field crops
9	The impact of expected changes on cultivated plants
10	Theory and practice of breeding for resistance to abiotic stresses
11	Special breeding and selection techniques
12	Exploiting breeding results under changing weather and growing conditions

Requirements:
Preparation of an essay related to the student's PhD topic, analyzing the effects of climate change. The essay should be at least 10 pages long, aiming to assist in the preparation of PhD dissertations and provide practice in writing the dissertation and articles. I will correct the essay, and we will discuss the topic with the student. Evaluation will be based on the written essay and the oral discussion, using a 5-point scale.

Required reading:
IPCC (2023): Climate Change. Synthesis Report.
Tuteja, N., Gill, S.S. (Eds) (2014): Climate Change and Plant Abiotic Stress Tolerance, Vol. 1–2. Wiley Blackwell, 342 pp.
+ Publications and other professional resources distributed during the course.

Recommended literature:
Jackson, M., Ford-Lloyd, B., Parry, M. (Eds) (2014): Plant Genetic Resources and Climate Change. CABI Climate Change Series, 291 pp.

Subjects taught in Ujhelyi Imre Doctoral Program in Animal Science (Head of Program: Ferenc Szabó DSc)				
Title of subject	Name and academic degree of the person in charge of the subject	Contact hours + individual study hours	Credits	Semester
Compulsory subjects:				
Methodology of research	Zoltán Varga PhD	14 + 136	5	1
Fundamentals and sources of scientific research work	Viktor Zsömle PhD	6 + 144	5	1
Higher education pedagogy	Viktória Gősi-Kövecses PhD	6 + 144	5	1
Genetic basics of animal husbandry	Károly Tempfli PhD	14 + 136	5	1
Completion of research tasks 1	*László Varga DSc*	*0 + 300*	*10*	1
Animal production in terms of physiology and epidemiology	Borisz Egri MRANH	20 + 130	5	2
Breeding and selection of farm animals	Ferenc Szabó DSc	20 + 130	5	2
Completion of research tasks 2	*László Varga DSc*	*0 + 600*	*20*	2
Nutrition of high-performance farm animals	János Tossenberger PhD	20 + 130	5	3
Special research methodology in animal breeding	János Tőzsér DSc	20 + 130	5	3
Completion of research tasks 3	*László Varga DSc*	*0 + 600*	*20*	*3*
Completion of research tasks 4	*László Varga DSc*	*0 + 600*	*20*	*4*
Completion of research tasks 5	*László Varga DSc*	*0 + 900*	*30*	*5*
Completion of research tasks 6	*László Varga DSc*	*0 + 900*	*30*	*6*
Completion of research tasks 7	*László Varga DSc*	*0 + 900*	*30*	*7*
Completion of research tasks 8	*László Varga DSc*	*0 + 900*	*30*	*8*
Elective subjects:				
Biotechnology in animal husbandry	Erika Varga-Lencsés PhD	20 + 130	5	4
Molecular genetics	Károly Tempfli PhD	20 + 130	5	4
Wildlife diseases	Borisz Egri MRANH	20 + 130	5	4
New aspects of animal species-specific nutrition	János Tossenberger PhD	20 + 130	5	4
Precision livestock farming	Balázs Húth PhD	20 + 130	5	4
New theories and modern methods in horse breeding	László Pongrácz PhD	20 + 130	5	4
Sustainable cattle production	Ferenc Szabó DSc	20 + 130	5	4
Rabbit breeding	Zsolt Matics PhD	20 + 130	5	4
Modern sheep and goat production	Károly Tempfli PhD	20 + 130	5	4
Novel methods in pig breeding	Tamás Tóth PhD	20 + 130	5	4
Novel methods in poultry breeding	Katalin Gaál-Kovács CSc	20 + 130	5	4
Economics of sustainable livestock farming	Károly Kacz, Jr. PhD	20 + 130	5	4

Course title:	Methodology of research		
Course code:	N_DMA02	Credits:	5
Course type:	Compulsory		
Course instructor:	Zoltán Varga PhD		
Co-instructor:	László Varga DSc		
Number of contact hours + individual study hours:	14 + 136		

Objectives of the course:
The aim of teaching research methodology is to introduce students to the theoretical, practical, and methodological issues of scientific research. Students acquire up-to-date knowledge of the major issues of scientific theory and research methodology and the forms of scientific activity and get to know the conceptual and methodological tools of their own scientific field. They recognize the methods to be used to solve problems, they are able to plan the research and carry it out. They learn the essential steps of writing scientific publications. They can distinguish between scientific and non-scientific work and recognize pseudo-scientific activity when appropriate. They are aware of the ethical rules for preparing scientific publications, as well as the important parameters of scientometrics.

Course content:

1	The importance and history of science and research methodology
2	Comparative analysis of everyday and scientific knowledge
3	Parallel examination of theoretical and empirical knowledge
4	Explanation and prediction in science
5	The practice of scientific research, the basic steps of scientific knowledge
6	Planning and conducting scientific research
7	Basic rules of scientific literature, use of internet databases; searching for technical articles and references, query techniques
8	Types of scientific and non-scientific publications, conditions of publishing
9	Strategies for choosing the right journal(s) and publishing there
10	Ethical issues of scientific research and publishing
11	Writing scientific publications (from title to references, content and form requirements)
12	Scientometrics, the measurement of scientific performance; interpretation of the most widely used performance indicators, their advantages, and disadvantages (impact factor, citations, Hirsch index, etc.)

Requirements:
Written examination, graded on a 5-point scale.

Required reading:
Harari, Y.N. (2015) Sapiens: A Brief History of Humankind. Vintage Books, London, UK.
Walliman, N. (2011) Research Methods: The Basics. Routledge, London, UK, New York, NY.

Recommended literature:
Ireland, C. (2010) Experimental Statistics for Agriculture and Horticulture, CABI, Wallingford, UK.
Popper, K. (2002): The Logic of Scientific Discovery. Routledge, London, UK, New York, NY.

Useful links:
Research integrity:
https://allea.org/wp-content/uploads/2023/06/European-Code-of-Conduct-Revised-Edition-2023.pdf
Journal lists:
https://www.scimagojr.com/journalrank.php
https://kanalregister.hkdir.no/publiseringskanaler/Forside.action?request_locale=en
https://jfp.csc.fi/en/web/haku/?restartApplication
Predatory journals:
https://www.interacademies.org/project/predatorypublishing
https://beallslist.net/wp-content/uploads/2019/12/criteria-2015.pdf
https://beallslist.net/standalone-journals/
https://media.nature.com/original/magazine-assets/d41586-019-03759-y/d41586-019-03759-y.pdf

Course title:	Fundamentals and sources of scientific research work		
Course code:	N_DOA106	Credits:	5
Course type:	Compulsory		
Course instructor:	Viktor Zsömle PhD		
Number of contact hours + individual study hours:	6 + 144		

Objectives of the course:
The aim of the course is to introduce doctoral students to the research and publishing opportunities available at Széchenyi István University and to provide them with practical knowledge to help them navigate the maze of domestic and international publishing.

Course content:

1.	Services of the University Library and Archives: • Access to printed and online literature • Hungarian Scientific Works Repository (MTMT) - registration • International scientific databases [indexing (Scopus, Web of Science), full-text (Emerald, IEEE, Springer, ScienceDirect, Wiley, etc.)] • Sustainability (using SDG keywords) • Language proofreading (proofreading) • Which journal should I publish in? (choosing the appropriate journal by entering keywords / topic / abstract) • APC-free open access (OA) publishing opportunities • Széchenyi University Publication Support Program (APC payment)
2.	Research methodology and database use based on full-text databases subscribed to: • Multidisciplinary: the journal collection of Akadémiai Kiadó, Cambridge University Press Journals, Science Direct, SpringerLink, Wiley • Electrical Engineering, Electronics, Computer Science: IEEE • Business: EMIS, Statista, Opten • Economics: Emerald • Law: HeinOnline, Yogic Code, Law Library • Humanities and social sciences: Taylor & Francis
3.	The publishing maze, the opportunities and risks of OA publishing and measuring scientific performance: • How to be visible at international scientific level (identifiers, author profiles) • Methodology for selecting scientific journals and conferences • MTMT basics, MTA journal lists • Science metrics (concept, Hungarian and international metrics) • Publication support tools (plagiarism checker for academic writing, reference management software) • Copyright basics (OA regulation, repository storage)

Requirements:
Obtaining a signature.

Required reading:
PPT files of lectures.

Course title:	Higher education pedagogy		
Course code:	N_DOA105	Credits:	5
Course type:	Compulsory		
Course instructor:	Viktória Gősi-Kövecses PhD		
	Gyöngyi Csenger PhD		
Number of contact hours + individual study hours:	6 + 144		

Objectives of the course:
The purpose of the subject is to prepare students participating in doctoral training for university education.
Knowledge: Within the framework of doctoral training, learn about the challenges of education in the 21st century. During the study of the subject, learn the steps and tasks of teaching-learning planning. Learn about modern higher education pedagogical procedures, methods, and developmental evaluation.
Skills: With the creative use of knowledge, they should be able to plan, implement, and evaluate lessons, projects, and sessions with a reflective approach. The goal is also to enable them to try out and apply the methods they have learned.
Attitudes: Develop their commitment to supporting students.
Autonomy and responsibility: Take a role with a high degree of independence in the development of courses that also apply pedagogical procedures. Take a responsible, initiating role in the development of instructor-student cooperation.

Course content:

1	Challenges in higher education – teaching and learning in the 21st century
2-3	The role of learning outcome-based planning in higher education
4	Issues of planning and organizing the teaching–learning process
5	Issues of developmental evaluation in higher education
6-7	Supporting the educational process with digital tools
8	Issues of effective application of educational methods
9-10	Project pedagogy in higher education
11-12	Cooperative teaching and learning in higher education

Requirements:
Continuous assessment – the requirement is to prepare a portfolio consisting of three tasks.

Required reading:
Curaj, Adrian; Deca, Ligia; Pricopie, Remus (2020): European Higher Education Area: Challenges for a New Decade. Springer Nature.
https://library.oapen.org/bitstream/20.500.12657/42916/1/2020_Book_EuropeanHigherEducationAreaCha.pdf
Cheng, Jiangang; Han, Wei; Zhou, Qian; Wang, Shuyan (2024): Handbook of Teaching Competency Development in Higher Education.Springer Nature
https://library.oapen.org/bitstream/20.500.12657/85104/1/978-981-99-6273-0.pdf

Recommended literature:
Stracke, Christian M.; Shanks, Michael; Tveiten, Oddgeir (2018): Smart Universities. Logos Verlag Berlin Berlin, Germany https://www.logos-verlag.de/ebooks/OA/978-3-8325-4595-6.pdf
Habbal, Fawwaz; Kolmos, Anette; Hadgraft, Roger G.; Holgaard, Jette Egelund; Reda, Kamar (2024): Reshaping Engineering Education. Springer Nature. Singapure
https://library.oapen.org/bitstream/20.500.12657/86967/1/978-981-99-5873-3.pdf Rowell, Chris (2019): Social Media in Higher Education. Open Book Publishers
https://library.oapen.org/bitstream/20.500.12657/24987/1/9781783746705_Replacement.pdf
The Future of Higher Education: Identifying Current Educational Problems and Proposed Solutions
https://www.researchgate.net/publication/366051679_The_Future_of_Higher_Education_Identifying_Current_Educational_Problems_and_Proposed_Solutions
Journal of Adult Learning Knowledge and Innovation (JAKLI) https://akjournals.com/view/journals/2059/2059-overview.xml
Hungarian Educational Research Juarnal (HERJ) https://akjournals.com/view/journals/063/063-overview.xml
Jain, Pooja (2021): Creativity. IntechOpen
https://mts.intechopen.com/storage/books/9560/authors_book/authors_book.pdf

Course title:	Genetic basics of animal husbandry		
Course code:	N_DMA62	Credits:	5
Course type:	Compulsory		
Course instructor:	Károly Tempfli PhD		
Co-instructor:	Klaudia Szalai PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
Genetic basics are presented with a focus on domestic animal breeding, both generally and specifically for farm animal species. Our aim is to highlight genetic discoveries that can be efficiently utilized in students' future research. The course emphasizes the applicability of genetic methods and statistical analysis. It builds on genetic knowledge acquired in previous undergraduate studies and is closely connected to molecular genetics and animal breeding.

Course content:

1	The structure of nucleic acids; DNA replication and transcription; central dogma
2	The process of translation; the genetic code
3	Contemporary gene definition and the structure of genes
4	Gene and genome of prokaryotes and eukaryotes
5	The ideal population; the Hardy–Weinberg equilibrium
6	Mutation as a source of variability and its influence on genotype frequency
7	Genetic drift; bottleneck effect; effective population size; genetic distribution of populations
8	Definition of fitness; absolute and relative fitness
9	The significance of the h^2 value and its application in animal breeding; correlation and regression
10	Selection: levels and types of selection; selection models; connection between selection and drift
11	Genetic polymorphism of natural populations
12	Quantitative genetics; calculation of genetic variance, artificial selection

Requirements:
Oral examination or writing a review paper, graded on a 5-point scale.

Required reading:
Simm, G., Pollott, G., Mrode, R., Houston, R., Marshall, K. (2020): Genetic Improvement of Farmed Animals. CABI Publishing, Wallingford, UK, 484 pp.
Spangler, M.L. (2022): Animal Breeding and Genetics. Springer, New York, NY, USA, 418 pp.

Recommended literature:
Watson, J.D., Barry, A. (2003): DNA: The Secret of Life. Knopf, New York, NY, USA, 464 pp.

Course title:	Animal production in terms of physiology and epidemiology		
Course code:	N_DMA63	Credits:	5
Course type:	Compulsory		
Course instructor:	Borisz Egri MRANH		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
This course introduces PhD students to key immuno-physiological phenomena related to the quantitative and qualitative aspects of animal products. We will analyze diagnostic methods and their bacteriological and virological evaluations. The section on epidemiology provides detailed insights into zoonoses and parasitic zoonoses. Finally, the information will be integrated into practical disease control strategies.

Course content:

1	Basic phenomena of immunology and animal production
2	Vaccines and vaccination technologies (immunophysiological changes due to vaccines)
3	General epidemiology 1: methods in bacteriological diagnostics
4	General epidemiology 2: methods in virological diagnostics
5	Particular epidemiology 1: notifiable zoonoses
6	Particular epidemiology 2: notifiable parasito-zoonoses
7	Particular epidemiology 3: zoonoses andfFoods
8	Diseases control and practice

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Bauerfeind, R., Von Graevenitz, A., Kimmig, P., Schiefer, H.G., Schwarz, T.F., Slenczka, W., Zahner, H. (2016): Zoonoses: Infectious Diseases Transmissible Between Animals and Humans (4th ed.). ASM Press, Washington, DC, USA.
Bueno-Marí, R., Almeida, A.P.G., Navarro, J.C. (Eds) (2015): Emerging Zoonoses: Eco-epidemiology, Involved Mechanisms, and Public Health Implications. Frontiers Media, Lausanne. DOI: 10.3389/978-2-88919-618-0. pp. 1-30, 56-64, 108-113, 130-137, 153-180, 188-193.
Gyles, C.L., Prescott, J.F., Songer, J.G., Thoen, C.O. (2010): Pathogenesis of Bacterial Infections in Animals (4th ed.). Wiley-Blackwell, Ames, IA, USA.

Recommended literature:
Shapiro, L.S. (2010): Pathology & Parasitology for Veterinary Technicians (2nd ed.). Cengage Learning, Boston, MA, USA.

Course title:	Breeding and selection of farm animals		
Course code:	N_DMA25	Credits:	5
Course type:	Compulsory		
Course instructor:	Ferenc Szabó DSc		
Co-instructor:	Károly Tempfli PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
This course builds on the foundational knowledge and approaches of basic and animal genetics. The aim is to explore the possibilities and methods for the genetic improvement of farm animals, focusing on their production, adaptation, and competitiveness. The course will provide new and up-to-date information on traits, breeding goals, breeding value estimation, and selection methods.

Course content:

1	Qualitative and quantitative traits of farm animals and their inheritance
2	Methods of measuring and evaluation of different traits
3	Utilization of homozygosity, heterozygosity, inbreeding, heterosis
4	Phenotypic, genetic, and environmental variance and their use in breeding
5	Genotype and environment interactions
6	Heritability, repeatability, correlation of traits
7	The breeding value and its estimation methods
8	Ways of selection
9	Factors influencing genetic merit
10	Mating systems for improving homozygosity or heterozygosity
11	Using genomic information in breeding value estimation and selection
12	The role of breeding organizations

Requirements:
Oral examination or writing a review paper, graded on a 5-point scale.

Required reading:
Szabó, F., Bokor, Á., Bene, Sz., Polgár, P. (2012): Animal Breeding, TÁMOP Course Material, Kaposvár, Keszthely.
Szabó, F., Komlósi, I., Posta J. (2011): Population Genetics. TÁMOP Course Material, Debrecen, Keszthely, Mosonmagyaróvár.

Recommended literature:
Bourdon, R.M. (2000): Understanding Animal Breeding (2nd ed.). Pearson Education, Prentice Hall, Upper Saddle River, NJ.
Cunningham, M., Latour, M.A., Acker, D. (2005): Animal Science and Industry (7th ed.). Pearson Education, Prentice Hall, Upper Saddle River, NJ.
Sing, C.V. (2015): Animal Breeding and Genetics. New India Publishing Agency.

Course title:	Nutrition of high-performance farm animals		
Course code:	N_DMA64	Credit value:	5
Course type:	Compulsory		
Course instructor:	János Tossenberger PhD		
Co-instructor:	Eszter Zsédely PhD		
Number of contact + individual study hours:	20 + 130		

Objectives of the course:
The main goal of the course is to expand students' knowledge of animal physiology and nutrition, building on the foundation acquired during their five-year or MSc agricultural education. Students will gain new scientific knowledge essential for optimizing nutrient supply to intensively producing farm animals with high genetic potential. The course will also cover the theoretical and practical aspects required for the environmentally friendly production of high-quality animal-derived food ingredients. By the end of the course, students will possess professional knowledge that supports advanced scientific research and practice in this field.

Course content:

1.	Energy evaluation of feeds for farm animals: new aspects
2.	Protein (amino acid) evaluation systems
3.	Macro- and microelement supply of farm animals and its environmental aspects
4.	Evaluation of the complex effects of carbohydrate fractions and fatty acids on the feeding of ruminants
5.	Characteristics and new aspects of carbohydrate supply of monogastric animals
6.	Correlations between nutrient supply and product quality (meat, eggs, milk)
7.	Immunological aspects of nutrient supply in nutrition of farm animals
8.	Feeding aspects of robotic housing technologies in pig farming
9.	Housing-specific aspects of poultry nutrition
10.	New trends in dairy cow nutrition
11.	Genetic profile-based pig nutrition
12.	Effects of climate change on animal nutrition

Requirements:
Submission of an essay until the end of the semester and oral examination, graded on a 5-point scale.

Required reading:
González-Ortiz, G., Bedford, M.R., Knudsen, K.E.B., Courtin, C.M., Classen, H.L. (2019): The Value of Fibre. Engaging the Second Brain for Animal Nutrition. Wageningen Academic Publishers, Wageningen, The Netherlands.
Hendriks, W.H., Verstegen, M.W.A., Babinszky, L. (2019): Poultry and Pig Nutrition: Challenges of the 21st Century. Wageningen Academic Publishers, Wageningen, The Netherlands.
Van Erp-Van der Kooij, E. (2021): Precision Technology and Sensor Applications for Livestock Farming and Companion Animals. Wageningen Academic Publishers, Wageningen, The Netherlands.

Recommended literature:
The latest papers from relevant international journals related to the course content.

Course title:	Special research methodology in animal breeding		
Course code:	N_DMA27	Credits:	5
Course type:	Compulsory		
Course instructor:	János Tőzsér DSc		
Co-instructor:	Károly Tempfli PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to provide an overview of the main research methods used in animal husbandry. It will evaluate the methodologies for feeding and digestion physiology experiments with farm animal species. The course will cover the key aspects of experimental design, data collection, and data systematization methods. Recent data evaluation techniques will be presented using actual experimental data. Finally, the course will address the guidelines for publishing results in international and national scientific literature.

Course content:

1	General guidelines for designing and setting up experiments; description of experimental setups (randomized block, Latin square, crossover, etc.)
2	Determination of nutrition digestibility using animal experiments and *in vivo* methods; determination of the protein value of the feed for livestock
3	Demonstration of *in sacco* (*in situ*), mobile bag, and *in vivo* experiments used in ruminant feeding
4	Cannulation (T-shaped cannula, PVTC-cannula, re-entrant methods) and other techniques (post-mortem inspections) in the feeding of monogastric animals
5	Presentation of animal test sites in Mosonmagyaróvár (practical training)
6	Collection and evaluation of experimental data, preparation of descriptive statistics (practical training)
7	Evaluation of statistical significance (practical training)
8	Analysis of variance (practical training)
9	Correlation and regression analysis (practical training)
10	Multivariate biometric methods 1 (principal component analysis, cluster analysis, discriminant analysis)
11	Multivariate biometric methods 2 (principal component analysis, cluster analysis, discriminant analysis)
12	Publication guidelines: practical excamples

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Jadhav, V., Dolas, D. (2023): Multivariate Analysis for Data Science. Lambert Academic Publishing, London, UK.
Kaptein, M., van den Heuvel, E. (2022): Statistics for Data Scientists: An Introduction to Probability, Statistics, and Data Analysis. Springer Nature Switzerland, Cham, Switzerland.
Ørskov, E.R. (2001): Trails and Trials in Livestock Research. Macaulay Land Use Research Institute, Aberdeen, UK.
Petrie, A., Watson, P. (2013): Statistics for Veterinary and Animal Science (3rd ed.). Wiley-Blackwell, Chichester, UK.
Zagumny, M.J. (2001): The SPSS Book. iUniverse, Bloomington, IN, USA.

Recommended literature:
Timely articles from relevant national and international journals related to the course content.

Course title:	Biotechnology in animal husbandry		
Course code:	N_DMA74	Credits:	5
Course type:	Elective		
Course instructor:	Erika Varga-Lencsés PhD		
Co-instructor:	Károly Tempfli PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
In animal biotechnology, molecular biology techniques are employed to genetically engineer animals, modifying their genomes to enhance their suitability for agricultural, industrial, or pharmaceutical applications. This course aims to familiarize students with the current advancements, status, and significance of biotechnology in animal husbandry. Alongside traditional animal biotechnology methods such as artificial insemination, embryo transfer, embryo cryopreservation, and hormonal control of reproductive processes, the course also covers modern techniques in embryo manipulation and the potential applications of stem cells.

Course content:

1	History, scope, and development of biotechnology
2	Red biotechnology, pharmacogenomics knowledge, recombinant DNA technologies, assisted reproduction procedures
3	Biotechnology of reproductive procedures*: in vitro* manipulation techniques, production of embryos, embryo transfer, sex determination, eugenics, experiments with embryos
4	Gamete and embryo cryopreservation
5	Basics of genetic engineering, molecular cloning, gene mapping, DNA fingerprinting
6	Production of transgenic animals, xenotransplantation, ethical problems of tissue and organ transplantation, organ donation, legal regulation
7	Legal and moral background of the production and use of stem cell lines
8	Microbiome research
9	Bioinformatics
10	Agricultural biotechnology: genetically modified organisms, microorganisms in biological plant protection, livestock biotechnology, marker assisted selection, yield and production increase with biotechnological methods, animal health biotechnology, production of monoclonal antibodies, molecular level diagnostics
11	Food industry and nutritional biotechnology
12	Present and future of biotechnology

Requirements:
Presentation on a chosen topic related to biotechnology and oral examination, graded on a 5-point scale.

Required reading:
Thieman, W.J., Palladino, M.A. (2019): Introduction to Biotechnology. Pearson Education, London, UK.
Wilson, N. (2021): Biotechnology in Animal Husbandry. Ed - Tech Press, London, UK.

Recommended literature:
Ramadass, P. (2023): Animal Biotechnology: Recent Concepts and Developments, MJP Publishers, Chennai, India.
Venkataraman, S., Hefferon, K. (2023): Agricultural Biotechnology: Genetic Engineering for a Food Cause. Academic Press, London, UK.

Course title:	Molecular genetics		
Course code:	N_DMA78	Credits:	5
Course type:	Elective		
Course instructor:	Károly Tempfli PhD		
Co-instructor:	Klaudia Szalai PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of this course is to elucidate the current position and role of molecular genetics in animal husbandry. The course explores the impact of molecular biology and molecular genetics on animal breeding. Topics covered include proteomics, structural genomics, and functional genomics; molecular genetics methods; the effects of mutations on gene frequency; the role of major genes and Marker-Assisted Selection (MAS) in animal husbandry; and the application of molecular genetics methods in various vertebrates such as hens, horses, cattle, and pigs. Additionally, the course provides a foundational understanding of molecular genetics, encompassing biochemistry, genetics, animal husbandry, and the genetic basis of animal husbandry.

Course content:

1	Structure of genes and transcriptome in mammals; proteomics
2	Access to the whole genome in DNA level-structural genomics
3	Genetically modified animals
4	Gene expression studies in farm animals
5	Different methods to identify mutations; single nucleotide polymorphism (SNP) detection
6	Quantitative trait loci (QTL) analysis; molecular genetic methods for farm animal imoprovement
7	PCR technique; PCR reaction: denaturation, annealing, and elongation; components of a PCR reaction
8	RT-PCR: use of reverse transcriptase for cDNA synthesis; primer design
9	Detection using fluorimetric methods: real-time PCR; qualitative and quantitative analysis of PCR products
10	Application of the CRSIPR method and the possibilities of genome manipulation
11	Up-to-date results of genetic mapping
12	Functional genomics

Requirements:
Writing a review article and oral examination, graded on a 5-point scale.

Required reading:
Glick, B.R., Patten, C.L. (2022): Molecular Biotechnology: Principles and Applications of Recombinant DNA. American Society for Microbiology, Washington, DC, USA.
Michels, C.A. (2002): Genetic Techniques for Biological Research: A Case Study Approach. Wiley, Hoboken, NJ, USA.

Recommended literature:
Bustin, S.A. (Ed.) (2004): A-Z of Quantitative PCR. International University Line, La Jolla, CA.
Mullis, K.B., Ferré, F., Gibbs, R.A. (Eds) (1994): The Polymerase Chain Reaction. Birkhäuser Verlag, Basel.

Course title:	Wildlife diseases		
Course code:	N_DMA69	Credits:	5
Course type:	Elective		
Course instructor:	Borisz Egri MRANH		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
This course covers the most common diseases affecting game animals in Hungary. It describes the pathogens, clinical signs, and characteristic pathological lesions associated with these diseases. Additionally, the course addresses the suitability of game meat for human consumption. For intensively reared species such as pheasant, quail, and wild duck, the specific aspects of husbandry and feeding techniques are also analyzed.

Course content:

1	Common infectious diseases of wild birds (pheasant, partridge, quail, wild duck)
2	Common parasitic diseases of wild birds (pheasant, partridge, quail, wild duck)
3	Common infectious diseases of brown hare and rabbit
4	Common parasitic diseases of brown hare and rabbit
5	Common infectious diseases of wild boar
6	Common parasitic diseases of wild boar
7	Common infectious diseases of viral and prion origin in antlers
8	Common infectious diseases of bacterial origin in antlers
9	Common endoparasitic diseases of antlers
10	Common ectoparasitic diseases of antlers
11	Implementing the “One World–One Health” principle in practice
12	Tutorial for exam

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Atkinson, C.T., Thomas, N.J., Hunter, D.B. (2008): Parasitic Diseases of Wild Birds. Wiley-Blackwell, Ames, IA, USA.
Jessup, D.A., Radcliffe, R.W. (2023): Wildlife Disease and Health in Conservation. Johns Hopkins University Press, Baltimore, MD, USA.

Recommended literature:
Samuel, W.M., Pybus, M.J., Kocan, A.A. (2001): Parasitic Diseases of Wild Mammals. Iowa University Press, Ames, IA, USA.

Course title:	New aspects of animal species-specific nutrition		
Course code:	N_DMA79	Credits:	5
Course type:	Elective		
Course instructor:	János Tossenberger PhD		
Co-instructor:	Tamás Tóth PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The main objective of this course is to equip PhD students with specialized knowledge in feed science, essential for the efficient feeding of major livestock species (poultry, pigs, cattle). Building on the foundation provided by other PhD courses, students will learn about the latest scientific, technological, and biotechnological advancements that are crucial for the effective feeding of high-production animal breeds. These advancements aim to enhance animal immunity and health, contributing to the environmentally sustainable production of healthy animal products (milk, meat, eggs). The course will also focus on the feed aspects of precision and automated farming systems. By the end of the course, students will possess professional knowledge that supports a high level of scientific excellence in this sub-discipline.

Course content:

1	Consolidated and new trends in the energy evaluation of pig feeds
2	Protein and amino acid requirements of high-performance pigs, genotype-dependent amino acid supply
3	Species- and age-specific energy evaluation in poultry nutrition, amino acid evaluation systems
4	Energy and amino acid requirements of high and low performance broilers
5	Precision pig nutrition, automated housing and feeding systems
6	Precision broiler nutrition, automated housing and feeding systems
7	Nutrient requirements and nutrition of “long life” layers
8	Automated and ecologically integrated keeping and feeding systems of layers
9	Energy and protein/amino acid supply of high-performance dairy cows
10	Precision and automated feeding systems in the feeding of dairy cows
11	The role of feed additives in ruminant nutrition
12	Environmental effects of the production of foods (raw materials) of animal origin

Requirements:
Submission and defense of a written thesis (topic processing) at the end of the course. Oral exam from the subjects of the subject and the lectures/consultations. The evaluation takes place in a five-grade system.

Required reading:
Hendriks, W.H., Verstegen, M.W.A., Babinszky, L. (2019): Poultry and Pig Nutrition: Challenges of the 21st century. Wageningen Academic Publishers, Wageningen, The Netherlands.
Khaliduzzaman A. (Ed.) (2022): Informatics in Poultry Production: A Technical Guidebook for Egg and Poultry Education, Research and Industry. Springer Nature, Singapore.
Lyons, T.P., Jacques K.A. (2005): Nutritional Biotechnology in the Feed and Food Industries. Notthingam University Press, Nottingham, UK.
Van Erp-Van der Kooij, E. (2021): Precision Technology and Sensor Applications for Livestock Farming and Companion Animals. Wageningen Academic Publishers, Wageningen, The Netherlands.

Recommended literature:
The latest papers from relevant international journals related to the course content.

Course title:	Precision livestock farmin		
Course code:	N_DMA72	Credits:	5
Course type:	Elective		
Course instructor:	Balázs Húth PhD, János Tőzsér DSc		
Co-instructors:	Tamás Tóth PhD, Károly Tempfli PhD, Klaudia Szalai PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
In this course, PhD students will gain expertise in precision livestock production and animal nutrition for all major farm animal species. They will acquire cutting-edge interdisciplinary knowledge to address the challenges of modern animal product production effectively. The course will cover the operation of precision-based farming systems for individual farm animal species and the coordination of technological elements for optimal performance.

Course content:

1	Market conditions of the domestic poultry sector, the conditions for its efficiency, the different ways of keeping in the poultry sector, the factors determining successful production
2	Definition and goals of precision poultry farming, management systems, sensors, display of measurement results
3	Data collection and processing, enterprise management softwares, robots, cameras
4	Market conditions of the domestic pig sector, the conditions for its efficiency, various husbandry methods in the pig sector, the factors determining successful production
5	Definition and goals of precision pig farming, management systems, sensors, display of measurement results
6	Operation of animal health and animal welfare monitoring systems, interpretation of data in pig farming
7	Market conditions and efficiency conditions of the domestic cattle sector
8	Breeding implications of technological development, data collection and management systems in precision dairy cattle breeding
9	Description of automatic milking systems; new selection criteria for dairy cows suitable for robotic milking
10	Novel options to reduce the generation interval in dairy cattle
11	Description of feeding factors influencing the effectiveness of robotic milking; automation and monitoring of feed production, distribution, and intake
12	Rapid test methods for the evaluation of feed quality parameters; herd management systems, sensors, display of measurement results

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Berckmans, D. (Ed.) (2022): Advances in Precision Livestock Farming. Burleigh Dodds Science Publishing, Sawston, UK.
Noack, P.O., Breunig, P., Gerth, S., Haas, R., Hoffmann, C., Lorenzini, I., Poteko, J., Rothmund, M., Salamon, M., Schlenz, F., Uhlmann, M., Walther, S. (2023): Precision Farming – Smart Farming – Digital Farming: Grundlagen und Anwendungsfelder. Wichmann Verlag, Berlin.
Van Erp-Van der Kooij, E. (2021): Precision Technology and Sensor Applications for Livestock Farming and Companion Animals. Wageningen Academic Publishers, Wageningen, The Netherlands.

Recommended literature:
Banhazi, T., Halas, V., Maroto-Molina, F. (2022): Practical Precision Livestock Farming: Hands-on Experiences with PLF Technologies in Commercial and R&D Settings. Wageningen Academic Publishers, Wageningen, The Netherlands.
Halachmi, I. (Ed.) (2015): Precision Livestock Farming Applications: Making Sense of Sensors to Support Farm Management. Wageningen Academic Publishers, Wageningen, The Netherlands.
Hernandez, M.J. (2014): Database Design for Mere Mortals: A Hands-on Guide to Relational Database Design (3rd ed.). Addison-Wesley Professional, Boston, MA.

Course title:	New theories and modern methods in horse breeding		
Course code:	N_DMA76	Credits:	5
Course type:	Elective		
Course instructor:	László Pongrácz PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
Due to significant changes in the use of horses over the past decades, there is a need to understand how modern methods can meet new requirements. This course will build on the general and specific knowledge of physiology, genetics, reproduction, feeding, and economics to focus on the complexity of constitutional and performance traits in high-performance horses. National and international trends in sport, breeding, and research will also be discussed.

Course content:

1	Historical role of horses
2	Turf
3	Equestrian sports 1
4	Equestrian sports 2
5	New trends in horse breeding
6	Exterior and interior value of the modern horse
7	Up-to-date performance testing of horses
8	Reproduction
9	Husbandry technologies
10	Nutrition of high-performance horses
11	Economics of the horse industry
12	Equestrian research topics

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Baiely, E., Brooks, S.A. (2013): Horse Genetics. CABI, Wallingford, UK.
Field, G.T., Taylor E.R. (2012): 33. Horse breeds and breeding; 34. Feeding and managing horses. In: Scientific Farm Animal Production – An Introduction to Animal Science. Pearson Education, Upper Saddle River, NJ.

Recommended literature:
Evans, J.W., Borton, A., Hintz, H., van Vleck, E.D. (Eds) (1990): The Horse. W.H. Freeman & Company, New York, NY.
+ The latest papers from international scientific journals related to the course content.

Course title:	Sustainable cattle production		
Course code:	N_DMA77	Credits:	5
Course type:	Elective		
Course instructor:	Ferenc Szabó DSc		
Co-instructor:	László Pongrácz PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to provide advanced, post-MSc level knowledge on the principles and practical methods of cattle production. Incorporating the latest research findings, the course will cover breeding and selection methods and management strategies for sustainable milk and beef production. Additionally, the role of cattle in relation to humans and its environmental impact will be highlighted.

Course content:

1	Cattle breeding and production worldwide
2	Relationship between cattle production and the environment
3	Factors influencing sustainability of cattle production
4	Evolution of cattle and the development of breeds and types
5	Breeding goals and breeding directions in cattle production
6	Native and international breeds, gene preservation, and the genetic improvement in cattle
7	The role of dual purpose and specialized dairy and beef cattle breeds
8	Scoring and other evaluation methods of different cattle breeds
9	Methods to estimate the breeding value of cattle
10	Selection and mating methods of cattle
11	Methods of sustainable milk and beef production
12	Breeding organization, animal welfare, and environment protection during cattle production

Requirements:
Writing a review paper and/or oral examination, graded on a 5-point scale.

Required reading:
Bognár, L., Szabó, F. (2023): Management of “modern” Holstein cows focusing on sustainability and resilience – review of recent achievements. Chemical Engineering Transactions 107, 169-174.
Márton, J., Szabó, F. (2023): Some actualities and challenges in sustainable beef cattle breeding and husbandry. Chemical Engineering Transactions 107, 241-246.
Rouquette, M., Jr., Aiken, G. (2020): Management Strategies for Sustainable Catttle Production in Southern Pastures. Academic Press, London, UK.

Recommended literature:
Cunningham, M., Latour, M.A., Acker, D. (2005): Animal Science and Industry (7th ed.). Pearson Education, Prentice Hall, Upper Saddle River, NJ, USA.
Fries R., Ruvinsky A. (1999): The Gentics of Cattle. CAB International, New York, NY, USA.
Phillips, C.J.C. (2001): Principles of Cattle Production (3rd ed.). CAB International, New York, USA.
Rout, P.K., Behera, B.K. (2021) Sustainability in Ruminant Livestock: Management and Marketing. Springer Nature, Singapore.
Taylor, R.E., Field, T.G. (2002): Beef Production and Management Decisions. Pearson Education, Prentice Hall, Upper Saddle River, NJ, USA.

Course title:	Rabbit breeding		
Course code:	N_DMA75	Credits:	5
Course type:	Elective		
Course instructor:	Zsolt Matics PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to provide comprehensive knowledge about modern housing systems, breeds, and hybrids in industrial rabbit farming, as well as the applied selection goals and methods. The course will cover smart farming opportunities and solutions, address animal welfare issues, and explore organic farming practices. Additionally, modern rabbit nutrition and common digestive problems in rabbits will be examined.

Course content:

1	The importance of rabbit breeding, Hungarian and international aspects
2	Modern housing systems
3	Breeds and hybrids
4	Reproduction traits, selection methods
5	Production traits, selection methods
6	Modern rabbit nutrition
7	Health problems, illnesses of rabbits
8	Modern reproduction procedures
9	Genetic evaluation, selection
10	Animal welfare
11	Organic rabbit farming
12	Economic analyses

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Maertens, L., Coudert, P. (2006): Recent Advances in Rabbit Sciences. ILVO, Melle, Belgium.
+ Presentations of lectures.

Recommended literature:
De Blas, C., Wiseman, J. (2010): Nutrition of the Rabbit (2nd ed.). CAB International, Wallingford, UK.
+ Relevant papers of World Rabbit Congresses and scientific journals.

Course title:	Modern sheep and goat production		
Course code:	N_DMA70	Credits:	5
Course type:	Elective		
Course instructor:	Károly Tempfli PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The main goal of the course is to introduce students to modern methods and techniques used in Hungarian sheep and goat breeding. The course will review the current state and developmental potential of the sector, describe various breeds and breeding groups, and present methods to enhance sheep and goat milk production and meat quality. Additionally, the course will cover biotechnological procedures in reproduction, breeding value estimation, selection indices, and organic animal production.

Course content:

1	Significance of sheep and goat breeding
2	Determination of breeding goals
3	Sheep and goat breeds
4	Alternatives for the improvement of mutton production
5	Alternatives for the improvement of sheep milk production
6	Alternatives for the improvement of goat milk production
7	Technology in different housing systems
8	Methods of lamb fattening
9	Up-to-date procedures in reproductive biology
10	Methods to estimate breeding value
11	Methods of selection; profitability and selection indices
12	Organic sheep and goat breeding

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Field, T.G., Taylor, R.E. (2019): Scientific Farm Animal Production: An Introduction to Animal Science (12th ed.). Pearson Education, Prentice Hall, Upper Saddle River, NJ, USA.

Recommended literature:
Simm, G., Pollott, G., Mrode, R., Houston, R., Marshall, K. (2020): Chapter 10: Sheep and goat breeding. In: Genetic Improvement of Farmed Animals. CABI, Wallingford, UK.
+ Recent papers published in relevant international and national scientific journals.

Course title:	Novel methods in pig breeding		
Course code:	N_DMA80	Credits:	5
Course type:	Elective		
Course instructor:	Tamás Tóth PhD		
Co-instructor:	Károly Tempfli PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The course aims to provide comprehensive knowledge about novel breeding methods in pig production, advancements in housing technology, and the anticipated challenges in pig breeding. Students will gain an overview of the global distribution and composition of pig stocks, along with current changes and forecasts. By examining the state of domestic pig breeding, students will have the opportunity to learn about the sector's current challenges and potential solutions. The course will also cover breeding regulations and methods to enhance pig performance sustainably, including new feeding strategies, breeding techniques, breeding value estimation, and performance evaluation methods.

Course content:

1	A current overview of pig breeding in the world and in Europe
2	The expected impacts of the changing environment on pig breeding
3	Sustainability in pig breeding
4	Modern pig breeds and hybrids in Hungary and in the world
5	Presentation of modern feeding principles
6	The potential of indigenous (native) pig breeds in domestic and international environments
7	Importance of genomic selection and breeding based on genetic markers
8	The latest methods of breeding value estimation and performance testing
9	Qualification of livestock and meat testing, pork grading systems
10	Description of applied methods to evaluate reproductive biology
11	Biotechnology in pig breeding and possibilities of genetic modification
12	Animal welfare changes and improvements in farming technology

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Blair, R. (2007): Nutrition and Feeding of Organic Pigs. CAB International, Wallingford, UK.
Swain, D.L., Charmley, E., Steel, J.W., Coffey, S.G. (2007): Redesigning Animal Agriculture. CAB International, Wallingford, UK.

Recommended literature:
Rothschild, M.F., Ruvinsky, A. (2011): The Genetics of the Pig. CAB International, Wallingford, UK. Wallingford, UK, 520 pp.

Course title:	Novel methods in poultry breeding		
Course code:	N_DMA73	Credits:	5
Course type:	Elective		
Course instructor:	Katalin Gaál-Kovács CSc		
Co-instructor:	Eszter Zsédely PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to familiarize doctoral students with modern breeding and husbandry processes for commercial poultry species, along with the fundamentals of poultry breeding. The Hungarian poultry sector has historically played a significant role in both the Hungarian and European markets. The course will cover the physiological characteristics of various poultry species, hatching techniques, and technological methods for the production of eggs, meat, liver, and feathers.

Course content:

1	Egg as the basis for producing good quality chicks
2	Breeding techniques in hen breeding
3	Raising and farming breeding hens
4	Growing and fattening broiler chickens
5	Methods and regulations of producing commercial eggs
6	Methods of turkey farming
7	Methods of goose farming
8	Regulations regarding methods and future perspectives of force-feeding for liver production
9	Perspectives of raising and farming duks and Moulard in Hungary
10	Feather production and its regulation
11	Hatching
12	Genetic conservation in poultry production

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Field, G.T., Taylor E.R. (2012) Poultry and egg products, poultry breeding, feeding and management. In: Scientific Farm Animal Production – An Introduction to Animal Science. Pearson Education, Upper Saddle River, NJ.
Lesson, S., Summers, J.D. (2000): Broiler Breeder Production. Nottingham University Press, Nottingham, UK.

Recommended literature:
Crawford, R.D. (1990): Poutry Breeding and Genetics. Elsevier, Amsterdam.

Course title:	Economics of sustainable livestock farming		
Course code:	N_DMA71	Credits:	5
Course type:	Elective		
Course instructor:	Károly Kacz, Jr. PhD		
Co-instructor:	Nóra Gombkötő PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to explore the economic aspects of sustainable animal product production, understand market factors and their interrelationships, and develop the ability to apply these concepts for effective management in production and marketing. Given the unfavorable cost–income ratio in livestock farming, the course prioritizes understanding both macro- and micro-economic factors that influence income generation and competitiveness. Students will learn about various tools and methods to enhance economic efficiency and sustainability in animal product production.

Course content:

1	Economic characteristics, economic and social sustainability of livestock farming
2	Macroeconomic/market environment (domestic and international) of animal product production
3	Regulatory system of animal husbandry (breeding and fattening, etc.) and its application in practice
4	Structure of livestock farming, size of enterprises and sectors
5	Centralization and concentration in livestock farming
6	Product structure of the livestock sectors, the structure and functioning of product pathways in animal product production
7	The basics and components of production management
8	Resource use, efficiency analysis, cost and revenue calculations
9	Analysis and decision preparation
10	Planning, organizing, and controlling
11	Innovation, product and technology development issues in livestock farming
12	Market information system and its functioning

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Dijkman, J.T., Lecq, F. (2021): The economic sustainability of animal production: balancing prosperity and responsibility. Sustainability, 13 (19), 10962.
Kay, R.D, Edwards, W.M., Duffy, P.A. (2016): Farm Management (8th ed.). McGraw Hill Education, New York, NY.
van't Hooft, Wollen, T.S., Bhandari, D.P. (2012). Sustainable Livestock Management for Poverty Alleviation and Food Security. CAB International, Wallingford, UK.

Recommended literature:
Kebreab, E. (2013). Sustainable Animal Agriculture. CAB International, Wallingford, UK.
Key, N., Sneeringer, S., Maruyama, A. (2019): Industrialization and the sustainability of agriculture and food. Global Food Security 23, 188-195.
Swinnen, J. (2020): Economics of sustainable intensification in agriculture. Annual Review of Resource Economics 12, 63-79.

Subjects taught in Pulay Gábor Doctoral Program in Food Science (Head of Program: László Varga DSc)				
Title of subject	Name and academic degree of the person in charge of the subject	Contact hours + individual study hours	Credits	Semester
Compulsory subjects:				
Methodology of research	Zoltán Varga PhD	14 + 136	5	1
Fundamentals and sources of scientific research work	Viktor Zsömle PhD	6 + 144	5	1
Higher education pedagogy	Viktória Gősi-Kövecses PhD	6 + 144	5	1
Technologies and machinery in plant-based food production	Attila József Kovács PhD	14 + 136	5	1
Completion of research tasks 1	*László Varga DSc*	*0 + 300*	*10*	1
Processing and preservation of animal-based products	Viktória Kapcsándi PhD	20 + 130	5	2
Special aspects of quality assurance in food production	Balázs Ásványi PhD	20 + 130	5	2
Completion of research tasks 2	*László Varga DSc*	*0 + 600*	*20*	2
Completion of research tasks 3	*László Varga DSc*	*0 + 600*	*20*	*3*
Completion of research tasks 4	*László Varga DSc*	*0 + 600*	*20*	*4*
Completion of research tasks 5	*László Varga DSc*	*0 + 900*	*30*	*5*
Completion of research tasks 6	*László Varga DSc*	*0 + 900*	*30*	*6*
Completion of research tasks 7	*László Varga DSc*	*0 + 900*	*30*	*7*
Completion of research tasks 8	*László Varga DSc*	*0 + 900*	*30*	*8*
Elective subjects:				
Phytochemistry	Zsolt Ajtony PhD	20 + 130	5	3
Traceability in the food chain	Erika Lakatos-Hancz PhD	20 + 130	5	3
Machinery, operations, and technologies in the dairy and meat industries	Erika Lakatos-Hancz PhD	20 + 130	5	3
Food microbiology	László Varga DSc	20 + 130	5	3
Food biotechnology	Balázs Ásványi PhD	20 + 130	5	4
Food physics	Ottó Dóka CSc	20 + 130	5	4
Applied microbiology	Babett Greff PhD	20 + 130	5	4
Economics of sustainable food production	Nóra Gombkötő PhD	20 + 130	5	4

Course title:	Methodology of research		
Course code:	N_DMA02	Credits:	5
Course type:	Compulsory		
Course instructor:	Zoltán Varga PhD		
Co-instructor:	László Varga DSc		
Number of contact hours + individual study hours:	14 + 136		

Objectives of the course:
The aim of teaching research methodology is to introduce students to the theoretical, practical, and methodological issues of scientific research. Students acquire up-to-date knowledge of the major issues of scientific theory and research methodology and the forms of scientific activity and get to know the conceptual and methodological tools of their own scientific field. They recognize the methods to be used to solve problems, they are able to plan the research and carry it out. They learn the essential steps of writing scientific publications. They can distinguish between scientific and non-scientific work and recognize pseudo-scientific activity when appropriate. They are aware of the ethical rules for preparing scientific publications, as well as the important parameters of scientometrics.

Course content:

1	The importance and history of science and research methodology
2	Comparative analysis of everyday and scientific knowledge
3	Parallel examination of theoretical and empirical knowledge
4	Explanation and prediction in science
5	The practice of scientific research, the basic steps of scientific knowledge
6	Planning and conducting scientific research
7	Basic rules of scientific literature, use of internet databases; searching for technical articles and references, query techniques
8	Types of scientific and non-scientific publications, conditions of publishing
9	Strategies for choosing the right journal(s) and publishing there
10	Ethical issues of scientific research and publishing
11	Writing scientific publications (from title to references, content and form requirements)
12	Scientometrics, the measurement of scientific performance; interpretation of the most widely used performance indicators, their advantages, and disadvantages (impact factor, citations, Hirsch index, etc.)

Requirements:
Written examination, graded on a 5-point scale.

Required reading:
Harari, Y.N. (2015) Sapiens: A Brief History of Humankind. Vintage Books, London, UK.
Walliman, N. (2011) Research Methods: The Basics. Routledge, London, UK, New York, NY.

Recommended literature:
Ireland, C. (2010) Experimental Statistics for Agriculture and Horticulture, CABI, Wallingford, UK.
Popper, K. (2002): The Logic of Scientific Discovery. Routledge, London, UK, New York, NY.

Useful links:
Research integrity:
https://allea.org/wp-content/uploads/2023/06/European-Code-of-Conduct-Revised-Edition-2023.pdf
Journal lists:
https://www.scimagojr.com/journalrank.php
https://kanalregister.hkdir.no/publiseringskanaler/Forside.action?request_locale=en
https://jfp.csc.fi/en/web/haku/?restartApplication
Predatory journals:
https://www.interacademies.org/project/predatorypublishing
https://beallslist.net/wp-content/uploads/2019/12/criteria-2015.pdf
https://beallslist.net/standalone-journals/
https://media.nature.com/original/magazine-assets/d41586-019-03759-y/d41586-019-03759-y.pdf

Course title:	Fundamentals and sources of scientific research work		
Course code:	N_DOA106	Credits:	5
Course type:	Compulsory		
Course instructor:	Viktor Zsömle PhD		
Number of contact hours + individual study hours:	6 + 144		

Objectives of the course:
The aim of the course is to introduce doctoral students to the research and publishing opportunities available at Széchenyi István University and to provide them with practical knowledge to help them navigate the maze of domestic and international publishing.

Course content:

1.	Services of the University Library and Archives: • Access to printed and online literature • Hungarian Scientific Works Repository (MTMT) - registration • International scientific databases [indexing (Scopus, Web of Science), full-text (Emerald, IEEE, Springer, ScienceDirect, Wiley, etc.)] • Sustainability (using SDG keywords) • Language proofreading (proofreading) • Which journal should I publish in? (choosing the appropriate journal by entering keywords / topic / abstract) • APC-free open access (OA) publishing opportunities • Széchenyi University Publication Support Program (APC payment)
2.	Research methodology and database use based on full-text databases subscribed to: • Multidisciplinary: the journal collection of Akadémiai Kiadó, Cambridge University Press Journals, Science Direct, SpringerLink, Wiley • Electrical Engineering, Electronics, Computer Science: IEEE • Business: EMIS, Statista, Opten • Economics: Emerald • Law: HeinOnline, Yogic Code, Law Library • Humanities and social sciences: Taylor & Francis
3.	The publishing maze, the opportunities and risks of OA publishing and measuring scientific performance: • How to be visible at international scientific level (identifiers, author profiles) • Methodology for selecting scientific journals and conferences • MTMT basics, MTA journal lists • Science metrics (concept, Hungarian and international metrics) • Publication support tools (plagiarism checker for academic writing, reference management software) • Copyright basics (OA regulation, repository storage)

Requirements:
Obtaining a signature.

Required reading:
PPT files of lectures.

Course title:	Higher education pedagogy		
Course code:	N_DOA105	Credits:	5
Course type:	Compulsory		
Course instructor:	Viktória Gősi-Kövecses PhD		
	Gyöngyi Csenger PhD		
Number of contact hours + individual study hours:	6 + 144		

Objectives of the course:
The purpose of the subject is to prepare students participating in doctoral training for university education.
Knowledge: Within the framework of doctoral training, learn about the challenges of education in the 21st century. During the study of the subject, learn the steps and tasks of teaching-learning planning. Learn about modern higher education pedagogical procedures, methods, and developmental evaluation.
Skills: With the creative use of knowledge, they should be able to plan, implement, and evaluate lessons, projects, and sessions with a reflective approach. The goal is also to enable them to try out and apply the methods they have learned.
Attitudes: Develop their commitment to supporting students.
Autonomy and responsibility: Take a role with a high degree of independence in the development of courses that also apply pedagogical procedures. Take a responsible, initiating role in the development of instructor-student cooperation.

Course content:

1	Challenges in higher education – teaching and learning in the 21st century
2-3	The role of learning outcome-based planning in higher education
4	Issues of planning and organizing the teaching–learning process
5	Issues of developmental evaluation in higher education
6-7	Supporting the educational process with digital tools
8	Issues of effective application of educational methods
9-10	Project pedagogy in higher education
11-12	Cooperative teaching and learning in higher education

Requirements:
Continuous assessment – the requirement is to prepare a portfolio consisting of three tasks.

Required reading:
Curaj, Adrian; Deca, Ligia; Pricopie, Remus (2020): European Higher Education Area: Challenges for a New Decade. Springer Nature.
https://library.oapen.org/bitstream/20.500.12657/42916/1/2020_Book_EuropeanHigherEducationAreaCha.pdf
Cheng, Jiangang; Han, Wei; Zhou, Qian; Wang, Shuyan (2024): Handbook of Teaching Competency Development in Higher Education.Springer Nature
https://library.oapen.org/bitstream/20.500.12657/85104/1/978-981-99-6273-0.pdf

Recommended literature:
Stracke, Christian M.; Shanks, Michael; Tveiten, Oddgeir (2018): Smart Universities. Logos Verlag Berlin Berlin, Germany https://www.logos-verlag.de/ebooks/OA/978-3-8325-4595-6.pdf
Habbal, Fawwaz; Kolmos, Anette; Hadgraft, Roger G.; Holgaard, Jette Egelund; Reda, Kamar (2024): Reshaping Engineering Education. Springer Nature. Singapure
https://library.oapen.org/bitstream/20.500.12657/86967/1/978-981-99-5873-3.pdf Rowell, Chris (2019): Social Media in Higher Education. Open Book Publishers
https://library.oapen.org/bitstream/20.500.12657/24987/1/9781783746705_Replacement.pdf
The Future of Higher Education: Identifying Current Educational Problems and Proposed Solutions
https://www.researchgate.net/publication/366051679_The_Future_of_Higher_Education_Identifying_Current_Educational_Problems_and_Proposed_Solutions
Journal of Adult Learning Knowledge and Innovation (JAKLI) https://akjournals.com/view/journals/2059/2059-overview.xml
Hungarian Educational Research Juarnal (HERJ) https://akjournals.com/view/journals/063/063-overview.xml
Jain, Pooja (2021): Creativity. IntechOpen
https://mts.intechopen.com/storage/books/9560/authors_book/authors_book.pdf

Course title:	Technologies and machinery in plant-based food production		
Course code:	N_DMA41	Credits:	5
Course type:	Compulsory		
Course instructor:	Attila József Kovács PhD		
Number of contact hours + individual study hours:	14 + 136		

Objectives of the course:
The purpose of teaching the subject is to process the complex production technology of plant-based foods, focusing primarily on learning about new development directions and trends. PhD students choose a technology that is close to their dissertation topic and, with guided consultations, develop the entire technological production line of a product. They do this primarily by presenting some food industry operations and the machines that implement them and are related to production. Listening to the subject enables the students to follow and adapt the development directions of the plant-based product manufacturing technology they have chosen and creates the basis for their development. During independent work and organized plant visits, students can also gain practical experience.

Course content:

1	Machines and technologies in the milling industry
2	Machines and technologies in the baking industry
3	Machines and technologies in the confectionary industry
4	Machines and technologies in the canning industry
5	Machines and technologies in the refrigeration industry
6	Machines and technologies in the winemaking industry
7	Machines and technologies in the brewing industry
8	Machines and technologies in the distilling industry
9	Machines and technologies in the vegetable oil industry
10	Machines and technologies in the sugar industry
11	Machines and technologies in the beverage industry
12	Machines and technologies for storage

Requirements:
Preparation and submission of a 10-15 pages long assignment.

Required and recommended reading:
Fellows, P.J. (2017): Food Processing Technology: Principles and Practice (4th ed.). Woodhead Publishing, Duxfor, UK, Cambridge, MA, Kidlington, UK.
Ibarz, A., Barbosa-Cánovas, G.V. (2003): Unit Operations in Food Engineering. CRC Press, Boca Raton, FL.
Saravacos, G.D., Maroulis, Z.B. (2011): Food Process Engineering Operations. CRC Press, Boca Raton, FL.

Course title:	Processing and preservation of animal-based products		
Course code:	N_DMA42	Credits:	5
Course type:	Compulsory		
Course instructor:	Viktória Kapcsándi PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to familiarize students with raw materials of animal-derived foods, their classification system, and other materials used in the production of the products. Through the steps of processing the raw materials, they learn about the technological steps used in the manufacture of products of animal origin and the various preservation procedures that determine the shelf life of the final products. During the teaching of the subject, they can gain insight into the fundamentals of the personal and material conditions necessary for the establishment of a food-processing plant, as well as the process of licensing a food producer. The subject also provides knowledge about aspects of handling and/or use of animal by-products.

Course content:

1.	Basic concepts related to the production of food of animal origin
2.	Personal and material conditions for processing food of animal origin, basic requirements for obtaining a food producer license
3.	Basic, additive, and auxiliary materials for the dairy industry, milk acceptance criteria, raw material classification, grouping of dairy products
4.	Basic operations of milk processing technologies and their impact on quality
5.	Preservation methods used in the dairy industry (physical, chemical, microbiological) and their effect on shelf life
6.	Technological steps in the dairy industry presented through the production technology of a specific product (cheese)
7.	Use and management of dairy by-products, environmental protection and sustainability aspects
8.	Basic, additive, and auxiliary materials used in the meat industry, meat classification system, grouping of meat industry products
9.	Basic operations of meat processing technologies (slaughterhouse processing steps) and their impact on quality
10.	Preservation methods used in the meat industry (physical, chemical, microbiological) and their effect on shelf life
11.	Presentation of the technological steps used in the meat industry through the production technology of a specific product
12.	Use and management of meat industry by-products, environmental protection and sustainability aspects

Requirements:
Oral and/or written examination, graded on a 5-point scale.

Required reading:
Hui, Y.H. (2012): Handbook of Meat and Meat Processing Technology (2nd ed.). CRC Press, Boca Raton, FL.
Ward, D. (2017): Dairy Science and Technology. Larsen and Keller Education, Edinburgh, UK.

Recommended literature:
Toldrá, F., Nollet, L.M.L. (2018): Advanced Technologies for Meat Processing (2nd ed.). CRC Press, Boca Raton, FL.
Walstra, P., Wouters, J.T.M., Geurts, T.J. (2005): Dairy Science and Technology (2nd ed.). CRC Press, Boca Raton, FL.

Course title:	Special aspects of quality assurance in food production		
Course code:	N_DMA43	Credits:	5
Course type:	Compulsory		
Course instructor:	Balázs Ásványi PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to familiarize PhD students with some elements of the certification and regulatory system of food raw materials and foodstuffs in European countries, and the importance of quality assurance in food production. In addition to this knowledge, the lectures also cover the legal regulation of quality assurance. The course is designed to help students apply the knowledge gained in the classroom to real life situations, *e.g.*, developing or operating various food quality management systems.

Course content:

1	Basic concepts of quality assurance
2	Characterization of quality management systems
3	Audit of quality management systems
4	Risk factors and their handling (management)
5	The HACCP system
6	The IFS/BRC system
7	The ISO international standard system
8	The ISO 9000 standards package
9	The ISO 14000 standards package
10	The ISO 22000 standards package
11	Total Quality Management
12	Evaluation of quality management systems

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Emmett, N. (2022): Food Quality Management. Larsen and Keller Education, Edinburgh, UK.
BRC global standards – Food.
IFS International standard for assessing product and process compliance in relation to food safety and quality, version 8.
ISO 22000:2018 - Food safety management systems.
ISO 22004:2014 - Food safety management systems.
ISO 22005:2007 - Traceability in the feed and food chain - General principles and basic requirements for system design and implementation.

Recommended literature:
Vasconcellos, A.J. (2005): Quality Assurance for the Food Industry: A Practical Approach. CRC Press, Boca Raton, FL.

Course title:	Phytochemistry		
Course code:	N_DMA97	Credits:	5
Course type:	Elective		
Course instructor:	Zsolt Ajtony PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The objective of the course is to acquaint students with the chemical properties of medicinally important compounds found in plants, their extraction, and their qualitative and quantitative determination. The course describes the preparatory procedures for examining herbal drugs. It presents analytical methods for quantitative and structural analysis, including ultraviolet and visible spectrophotometry, infrared spectrometry, mass spectrometry, gas chromatography, and liquid chromatography. It also discusses the chemical reactions and mechanisms of phytochemical identification of drugs as well as methods for the extraction and analysis of secondary metabolites.

Course content:

1	Sample preparation for drug testing: Sampling, drying, and shredding.
2	Extracting the active ingredients of drugs: The principles of extraction and practical implementation. Special extraction, targeted isolation and design, screening of herbs, drugs, and preparations.
3	Spectroscopic methods for drug testing including ultraviolet-visible spectroscopy, infrared spectroscopy, and mass spectrometry.
4	Separation techniques for drug testing: Gas chromatography and liquid chromatography.
5	Examination of carbohydrate-containing drugs. Examination of drugs containing organic and inorganic plant acids and their derivatives. Analysis of fatty oils.
6	Examination of drugs containing tanning substances. Examination of drugs containing anthraglycoside and anthraquinone derivatives.
7	Balsams, resins and terpenophenoloids and their analysis.
8	Testing essential oil-containing drugs.
9	Examination of drugs containing bitter substances. Examination of saponin-containing drugs. Examination of drugs containing cardiac glycosides.
10	Examination of drugs containing tropane alkaloids.
11	Examination of drugs containing quinoline, isoquinoline, and phenanthrene alkaloids.
12	Examination of drugs containing alkaloids with indole, purine, and other structures.

Requirements:
Oral examination, graded on a 5-point scale.

Required reading:
Shah, B., Seth A.K. (2019): Textbook of Pharmacognosy and Phytochemistry (2nd ed.). Oxford and IBH Publishers.

Recommended literature:
Farkas, Á., Horváth, Gy., Molnár, P. (2014): Pharmacognosy 1. University of Pécs, Pécs.
Horváth, Gy., Molnár, P., Bencsik, P. (2013): Pharmacognosy 1. University of Pécs, Pécs.

Course title:	Traceability in the food chain		
Course code:	N_DMA45	Credits:	5
Course type:	Elective		
Course instructor:	Erika Lakatos-Hancz PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The use of a traceability system creates a link between the product and the information associated with it, giving the "life cycle" of the product, the ingredients of the product, additives, by-products; it serves the flow of information between the different actors. The aim of teaching the subject is to familiarize PhD students with the importance of traceability at each point in the food chain. In doing so, it will provide knowledge on the history of traceability, the essential elements of traceability and its legislative background. The main bodies responsible for the official control of the food chain and their tasks will also be discussed. During the lessons, students will learn about the tasks of traceability, the possibilities for its implementation and current practices.

Course content:

1.	The concept and importance of monitoring
2.	The principle of monitoring
3.	General model of tracing, identification of the traceable goods, tracing process
4.	Legal background to tracking
5.	Internal monitoring
6.	External monitoring
7.	Tracking in crop production
8.	Tracking in animal production
9.	Documentation in monitoring, global standards
10.	Tools for automatic data collection
11.	IT tools for product tracking
12.	Tracking system evaluation

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Amaral, J.S. (2021): Target and non-target approaches for food authenticity and traceability. Foods 10 (1), 172.
McEntire, J., Kennedy, A.W. (Eds) (2019): Food Traceability: From Binders to Blockchain. Springer Nature Switzerland, Cham.
Montet, D., Ray, R.C. (Eds) (2021). Food Traceability and Authenticity: Analytical Techniques. CRC Press, Boca Raton, FL.

Recommended literature:
Galanakis, C.M. (2021): Food Authentication and Traceability. Academic Press, London, UK.

Course title:	Machinery, operations, and technologies in the dairy and meat industries		
Course code:	N_DMA98	Credits:	5
Course type:	Elective		
Course instructor:	Erika Lakatos-Hancz PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The primary purpose of the course is to familiarize PhD students with the production technologies of dairy and meat products. The course covers the production tasks of machines and equipment that play a fundamental role in the dairy and meat industry, the technological aspects of their operation, and alternatives to modern design solutions. The presentation of operations and machinery is an introduction to complex technological systems.

Course content:

1.	General milk processing operations 1: reception, storage, cleaning, skimming
2.	General milk processing operations 2: homogenization, recombination, reemulsification
3.	Manufacture of heat-treated drinking milk products and dairy preparations
4.	Manufacture of cultured milk and cream products, manufacture of sweet (nonfermented) cream products, operations, technologies and machinery for the manufacture of butter
5.	Manufacture of acid-coagulated cheeses and cheese preparations, manufacture of rennet-coagulated cheeses
6.	Overview of the effects on quality of post-consignment dismantling, boning, cutting, shaping, technological elements
7.	Packaging of meat products
8.	Slaughterhouse technology: poultry slaughterhouse, pig slaughterhouse, cattle slaughterhouse
9.	Meat industry technology: production of red meat products
10.	Meat industry technology: production of dry goods
11.	Meat quality requirements; canned meat; utilization of meat and poultry by-products
12.	Cured meat products in pieces; curing methods; curing equipment; biochemical principles of curing; practical application of curing

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Ward, D. (2017): Dairy Science and Technology. Larsen and Keller Education, Edinburgh, UK.

Recommended literature:
Singh, S. (2014): Dairy Technology, Volume 2: Dairy Products and Quality Assurance. New India Publishing Agency, New Delhi.

Course title:	Food microbiology		
Course code:	N_DMA99	Credits:	5
Course type:	Elective		
Course instructor:	László Varga DSc		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to provide PhD students with an understanding of the environmental conditions affecting the functioning of microorganisms of importance to the food industry. Areas of study include the ecology, metabolism, and reproduction of microbes. These will provide the basis for influencing the activity of both harmful and beneficial microorganisms, *i.e.*, destroying them and providing the conditions necessary for their optimum growth, respectively. A detailed overview of foodborne microorganisms will also be given.

Course content:

1.	Bacteria in foods and their raw materials
2.	Yeasts and molds in foods and their raw materials
3.	Viruses and protozoa in foods and their raw materials
4.	Microbial ecology of food
5.	Metabolism of microorganisms
6.	Reproduction and destruction of microorganisms
7.	Microbiological contamination and deterioration of foods of plant origin
8.	Microbiological contamination and deterioration of foods of animal origin
9.	Food-borne pathogens
10.	Microbiology of food processing
11.	Microbiological issues in food preservation
12.	Lactic acid bacteria and probiotic microorganisms

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Doyle, M.P., Diez-Gonzalez, F., Hill, C. (2019) Food Microbiology: Fundamentals and Frontiers (5th ed.) ASM Press, Washington, DC. 1093 pp.
Matthews, K.R., Kniel, K.E., Montville, T.J. (2017) Food Microbiology: An Introduction (4th ed.) ASM Press, Washington, DC, 597 pp.

Recommended literature:
Current articles in *Food Microbiology* and the *International Journal of Food Microbiology.*

Course title:	Food biotechnology		
Course code:	N_DMA100	Credits:	5
Course type:	Elective		
Course instructor:	Balázs Ásványi PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The objective of the course is to familiarize PhD students with the basic reaction kinetics of biotechnological processes in the food industry. The course is linked to the subjects "Applied microbiology" and "Food microbiology".

Course content:

1	Basic concepts in biotechnology and their practical applications
2	Optimization of environmental conditions for microorganisms
3	Evaluation of microbial metabolic processes from a biotechnological perspective
4	Influencing microbial production through genetic engineering using restriction endonucleases; production kinetics of primary and secondary metabolites
5	Modern biotechnological processes used in the food industry (types of fermenters, aeration methods, computer-aided process control, etc.)
6	Operation principles of aerobic, anaerobic, and immobilized fermentation systems
7	Biotechnological aspects of dairy foods production
8	Biotechnological aspects of manufacturing meat products
9	Biotechnological processes used in fermentation industries
10	Biotechnological aspects of wastewater management
11	Major food fermentation methods and separation techniques
12	Genetic modification (engineering) in food production

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Joshi, V.K., Singh, R.S. (2012): Food Biotechnology: Principles and Practices. I. K. International Publishing House, New Delhi, India.

Recommended literature:
Moo-Young, M. (2011): Comprehensive Biotechnology (2nd ed.), Vol. 1-6. Elsevier, Oxford, UK.
+ Original research papers and up-to-date reviews published in international scientific journals such as *Applied Food Biotechnology*, *Food Biotechnology*, *Food Science and Biotechnology*, *Food Technology and Biotechnology*, etc.

Course title:	Food physics		
Course code:	N_DMA101	Credits:	5
Course type:	Elective		
Course instructor:	Ottó Dóka CSc		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of teaching food physics is to familiarize PhD students with the physical properties of foods and the methods of measuring them. They should acquire knowledge of the physical methods used in the analysis of foodstuffs, the mechanical, thermal, electrical, optical, color, and rheological properties of foods and food raw materials, and the methods of measuring them. They should also be able to apply the physical properties of foods and food raw materials in quality control procedures.

Course content:

1	Physical and mechanical properties of food products and food raw materials
2	Methods for measuring physical and mechanical properties of foods and food raw materials
3	Optical characterization of foods: reflection, absorption, and emission
4	Color measurements and color measuring systems
5	Determination of color characteristics in foods
6	Optical spectroscopy
7	Infrared and NIR spectroscopy
8	Thermal properties: parameters of thermal conductivity (thermal conductivity, diffusivity, effusivity, etc.)
9	Methods for measuring the thermal properties of foods
10	Electromagnetic properties of foods: impedance spectra of foods, electrical permittivity, and electrical conductivity
11	Rheology and rheological models
12	Rheological properties of foods

Requirements:
Case study: quality assessment of a chosen food (raw material, basic material, or final product) using food physics methods. Oral examination: randomly selected from the above 12 topics, graded on a 5-point scale.

Required reading:
Figura, L.O., Teixeira, A.A. (2023): Food Physics: Physical Properties – Measurement and Applications (2nd ed.). Springer Nature Switzerland, Cham.
Rahman, M.S. (2005): Mechanical properties of foods. In: Food Engineering. Encyclopedia of Life Support Systems. Barbosa-Cánovas, G.V. (Ed.). UNESCO Publishing, Paris, pp. 87-104.
Schanda, J. (Ed.) (2007): Colorimetry: Understanding the CIE System. Wiley, Hoboken, NJ.

Recommended literature:
Mohsenin, N.N. (1984): Electromagnetic Radiation Properties of Foods and Agricultural Products. Gordon and Breach Science Publishers, New York, NY.
Steffe, J.F. (1996): Rheological Methods in Food Process Engineering (2nd ed.). Freeman Press, East Lansing, MI.

Course title:	Applied microbiology		
Course code:	N_DMA102	Credits:	5
Course type:	Elective		
Course instructor:	Babett Greff PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The primary purpose of this course is to help students develop an appreciation and understanding of the complex microbiological factors influencing feed and food quality during production and processing. Furthermore, the seminar also provides information on the basic procedures related to microbiology laboratory and explores various identification methods of important spoilage microorganisms and foodborne pathogens.

Course content:

1	Spoilage and pathogenic microorganisms in microclimate, feedstuffs, and waters
2	Microbiological aspects of processing and storing cereals and processed cereal products
3	Microbiological aspects of meat and egg processing, as well as milk production and processing
4	Microbiological aspects of refrigeration and frozen storage of food raw materials and processed products
5	Microbiology of the fermentation industries
6	Protection against microbiological hazards in the food production environment
7	Basics of practical microbiology
8	Quality control in the microbiological laboratory
9	Sampling methods and sample preparation
10	Assessment of the microbiological quality of foods using conventional and molecular techniques
11	Assessment of the microbiological quality of water
12	Detection and identification of spoilage and pathogenic microorganisms

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Cappuccino, J.G., Welsh, C. (2018): Microbiology: A Laboratory Manual (11th ed.). Pearson Education Limited, Harlow, UK.
Forsythe, S.J. (2020): The Microbiology of Safe Food (3rd ed.). Wiley-Blackwell, Chichester, UK.
Ray, B., Bhunia, A. (eds) (2013): Fundamental Food Microbiology (5th ed.). CRC Press, Boca Raton, FL.

Recommended literature:
McLandsborough, L. (2005): Food Microbiology Laboratory. CRC Press, Boca Raton, FL.

Course title:	Economics of sustainable food production		
Course code:	N_DMA103	Credits:	5
Course type:	Elective		
Course instructor:	Nóra Gombkötő PhD		
Co-instructor:	Károly Kacz, Jr. PhD		
Number of contact hours + individual study hours:	20 + 130		

Objectives of the course:
The aim of the course is to enhance the economic knowledge of students pursuing PhD studies in the Doctoral Program in Food Science with different backgrounds in sustainable food development and food production, and to present good practices. Related areas, such as the characteristics of different food supply chains, will also be explored as part of the module. Besides learning about the economics of the food economy as a system, the focus will be on the mastery of the planning, organisation, analysis and processes of sustainable food production. In addition to the basic concepts of these main topics, the course aims to provide doctoral students with an insight into the role and importance of the food industry in the national and global economy, in addition to the operational and company aspects.

Course content:

1	The strategic importance of the food industry and its role in the national economy
2	Current situation and opportunities of the domestic food industry: economic environment, food policy
3	System of food industry branches, sectors, main economic indicators
4	Regulation and institutional background of the domestic food economy
5	The concept and criteria of sustainable food production
6	Characteristics of food supply chains for sustainability
7	Main economic and financial indicators for food enterprises
8	The elements of food industry management
9	Role of human resources in the food industry
10	The current state of food marketing
11	Market relations and the importance of market types in the food economy
12	The main characteristics of Hungarian foreign food trade

Requirements:
Oral or written examination, graded on a 5-point scale.

Required reading:
Kay, R.D, Edwards, W.M., Duffy, P.A. (2016): Farm Management (8th ed.). McGraw Hill Education, New York, NY.

Recommended literature:
Key, N., Sneeringer, S., Maruyama, A. (2019): Industrialization and the sustainability of agriculture and food. Global Food Security 23, 188-195.
Swinnen, J. (2020): Economics of sustainable intensification in agriculture. Annual Review of Resource Economics 12, 63-79.