Inland Norway University of Applied Sciences

Curriculum PhD programme in Applied Ecology and Biotechnology

Name
PhD in Applied Ecology and Biotechnology

ECTS credits
An educational component consisting of 30 ECTS credits and a scientific dissertation.

Study level and organisation
A completed programme of study qualifies for the title PhD in Applied Ecology and Biotechnology, with specialisation either in Applied Ecology or in Biotechnology. The normative length of the PhD programme is 3 years full-time study, culminating with a doctoral dissertation for the degree of Philosophiae Doctor. For some PhD positions, the duration can be 4 years, including 25% teaching duties. The dissertation must be defended in public within 8 years following commencement of the programme.

The programme duration of 3 years consists of 2.5 years work, under supervision, on an individual research project, and a training component comprising 30 ECTS credits of post-graduate courses at the PhD level.

Within the training component, courses totalling 20 ECTS credits are mandatory, while the candidate chooses 10 ECTS credits of relevant elective courses in cooperation with the main supervisor.

As each study plan is individually adapted, please refer to individual course descriptions for teaching and learning methods. This is a campus-based programme of study and it is expected that PhD candidates admitted to the programme and employed full-time by Inland Norway University of Applied Sciences shall be present on-campus on a full-time basis with the exception of a possible international stay 2-6 months in duration.

Background
The PhD in in Applied Ecology and Biotechnology is an interdisciplinary PhD programme that will foster competence in sustainable management, production and utilization of biological resources. With biological resources we mean forests, wildlife, fish, cultivated plants, livestock animals, microorganisms and other bio based products in, or originating from, agriculture, forestry, aquatic systems and wildlife areas. Hence, we will focus on both the harvest and monitoring of biological resources in the training programme related to the specialisation in Applied Ecology. While the structure and function of biological macromolecules are focal points related to the specialisation in Biotechnology.

Applied ecology's background is in the fields of biology. Biotechnology also concerns living systems and organisms, focussing mainly on cells - plant cells, animal cells, microorganisms, and their components and macromolecules - to develop products and services. Biotechnology is a broad field of study whose methods are also used in research in applied ecology. Together, these different disciplines help solve local and global problems concerning the environment, food production and sustainability.

With the PhD programme in Applied Ecology and Biotechnology, we aim to optimize the management of agricultural -, forestry - and wildlife areas in a way to ensure production and utilization of biological resources in an ecologically, economically and socially sustainable manner. The biological resources, which are renewable, also make up the biomass or raw materials for today's commitment to bioeconomies.

Biotechnology represents another central bioeconomy, yielding both products and technologies paramount to innovation-based bioeconomies, for example food and feed, antibiotics and other bioactive molecules, diagnostic techniques, methodologies for improved breeding in agri- and aquaculture, in addition to processing and further distribution of biomass.

Today, adjacent industries such as nature-based tourism and other uses of nature for cultural activities such as sport and recreation may also be defined as part of the bioeconomies, and thus also represent potential research areas.

Our aim is to educate innovative PhD candidates who will develop a better management of nature ranging from the protection of biodiversity to innovation related the commercialization of biological resources in a sustainable manner for future generations.

The learning outcomes

After completing the PhD programme, the PhD-candidates should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge

The candidate:

- is in the forefront of applied ecology or biotechnology knowledge important to solve local and global problems concerning the environment, food production and/or sustainability
- shows intellectual independence in evaluating the appropriateness and applicability of different methods and processes in research projects
- can contribute to the development of new knowledge, theories, methods and interpretations concerning the environment, food production and/or sustainability

Skills

The candidate:

- can formulate research questions, plan and carry out research and development work within applied ecology or biotechnology conforming to high international standards
- can independently handle complex academic issues and challenge established knowledge and practices in applied ecology or biotechnology which are important to solve local and global problems concerning the environment, food production and/or sustainability
- is capable of utilizing, or of obtaining the necessary skills to utilize, the most advanced and specialized methods and techniques in applied ecology or biotechnology

General competence

The candidate:

- can identify new relevant ethical issues and carry out research with scholarly integrity
- can manage complex multi- or interdisciplinary scientific assignments related to the environment, food production and/or sustainability
- can assess the need for, and initiate, innovation
- has substantial scientific independence and authority to advice public management in problems concerning the environment, food production and/or sustainability
- can communicate research through recognized international peer-reviewed scientific journals
- can participate in relevant professional debates in international fora
- can communicate scientific actions to different target audiences, such as scientists within the candidate's field, scientists in other fields, users of the scientific results, and the general public

Target group

Our aim is to target students and professionals who have a dedicated interest in the interaction between man and the environment, and the sustainability of green restructuring. Primarily we target students with a master's degree in biology, ecology, biotechnology, evolution, environmental sciences or similar subjects, and who are interested in developing their research expertise within applied ecology or biotechnology. However, we encourage applicants with other bachelor's degrees, or who have earned an interdisciplinary bachelor's degree, as long as they fulfil the entrance requirements (see below). We also target professionals within conservation or public management of biological resources who want to extend their competence above the level of a master.

Qualifications

The PhD programme in Applied Ecology and Biotechnology qualifies for research activity of international standard and other work in society, which requires deep scientific insight and analytic thought, with proper scientific code and conduct. Hence, the PhD qualifies, for instance, for employment in:

- Research, communication and other scientific positions in educational, R & D institutions and industry. For employment as lecturers/instructors in educational institutions, additional pedagogic coursework may be needed
- Private enterprises and public management at all levels from licensees, local or regional authorities, and ministries
- Advisory services related to ecology, fish and wildlife, bioeconomy, biotechnology and sustainability

Requirements for admission

To enter the program, students are required to document their having achieved:

1. At least a Master's degree based on a 5-year cumulative period of study (including the Bachelor's degree) at a university, university of applied sciences or university college in biology, ecology, biotechnology, evolution, environmental sciences or similar subjects
2. An average weighted (ECTS credits) mark for the Master's degree programme of at least a B. In cases where all or part of the program is approved with the use of a Pass / Fail mark, the applicants may be admitted following individual assessment

Applicants with a Master's degree from another subject area (e.g. social sciences, economy) than is approved as basis for admission to the programme, or with lower average mark, may be admitted after special review. These applicants must be able to document that it is very likely that they will be able to complete the PhD study. If necessary, additional documentation or a preliminary examination will be required to evaluate the professional level. Such applicants may also, if necessary, be required to complete coursework in certain disciplines within a deadline to qualify for admission. Such coursework cannot count towards the training requirements for a doctoral degree.

English language requirements:

All non-native English speakers must provide official documentation of English language proficiency at a sufficiently high level.

We require one of the following English language tests with a minimum of the following scores:

- Toefl internet based: 80
- Toefl paper based: 550
- IELTS: 6

No exceptions are made for this requirement. Scores lower than 550/80 (TOEFL) or 6.0 (IELTS) will not be accepted. The TOIC test will not be accepted.

Teaching and training methods

The research project

The individual research project is an independent scientific work under supervision. A group of professionals collaborating on the project will provide supervision where one individual serves as the main supervisor. The team of supervisors is also responsible for introducing the candidate to the academic community. The research project culminates in a dissertation that is an independent, scientific work, which meets international standards with regard to scientific merit, methodology and ethical requirements[1]. It should contribute new scientific knowledge and achieve a level of scientific merit, which suggests that it could be published as part of the peer-reviewed scientific literature in the subject area.

The dissertation is normally a compilation of 3-5 interrelated, scientific publications or manuscripts for publication in internationally recognised scientific journals. It is required that at least one publication in the dissertation has been published or is accepted for publication. An introductory synthesis should generalize the topic and results into a broader academic context, and show the interrelation between the papers.

The individual papers may be written by several participants of a joint project, as long as it is possible to identify the individual contributions made by each author. Co-authorship must adhere to the norm commonly accepted in the international research community such as the Vancouver Convention.

The training component

The training component will give broad and in-depth insight into academic, methodological and ethical aspects in the field of applied ecology and biotechnology necessary to complete the dissertation. The training component will also give practice in written and oral communication of scientific results to both professional audiences and the general public.

The training component will be taught in ways that require prepared participation of the PhDcandidates, such as seminars, workshops, group work and laboratory exercises. The methods used vary between courses and will contribute to fulfil the learning outcomes of the PhD programme. The e-learning system will constitute an integrated part of the instruction.

Assessment methods

The PhD degree is conferred on the basis of satisfactory completion of the training component, an approved scientific dissertation, a trial lecture, and a successful PhD examination/defence.

Assessment of the various courses of the training component varies. At minimum mark of B is required to pass all courses.

Internationalization

A combination of national and international candidates creates a student environment that improves the quality of the study through discussions of various ‘schools’ in biology and human attitudes. We

[1] See for instance *Ethical guidelines for Hedmark University College* (http://www.hihm.no/om-hoegskolen/sentraledokumenter); Ethical guidelines for science and technology (http://www.etikkom.no/no/forskningsetikk/etiske)

will encourage and make allowances for candidates to study abroad for 2-6 months of their degree. Such an international experience is recommended to take place in the second half of the study.

All scientific literature in course syllabi will be in English. The PhD-candidate will also have to put his/her work in a broader academic context by presenting some of his/her results at international conferences. Candidates will also gain international experience through the international forum of the International Research School in Applied Ecology (IRSAE)[2] with several partner institutions from the European countries.

Information literacy

Candidates will develop skills in finding, assessing and exploiting academic information resources of high quality within their fields, both in education and professional practice. Information literacy is the ability to locate, evaluate and utilise information and technical material for one's own needs. This is key to professional competence and the basis for lifelong learning. The library at the Inland Norway University of Applied Sciences offers instruction in information literacy both on campus and online, and it will be included as part of the seminar courses in the PhD programme. Instruction emphasises reference material, citation of references, critical assessment of information sources, plagiarism and subject-specific searching. It is expected that all candidates have a critical attitude to information sources and use these sources correctly in all written work throughout the programme.

Content and structure of the training component of the study

The PhD consists of 2 specialisations: Applied Ecology and Biotechnology. Ten ECTS credits are compulsory for all PhD-candidates. An additional 10 ECTS and 10 ECTS credits are compulsory for each of the specialisations Applied Ecology and Biotechnology. The structure of the training component is illustrated in Figure 1.

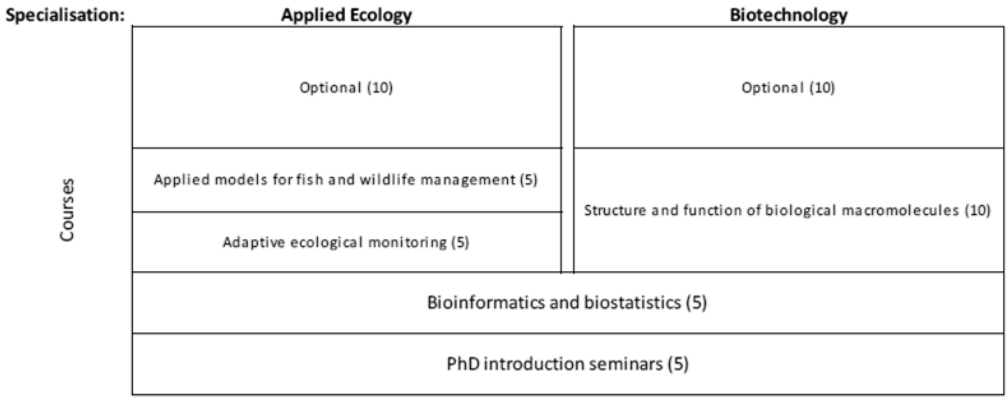

Figure 1. The structure of the PhD showing the compulsory courses for the 2 specialisations (Applied Ecology, and Biotechnology) provided by the Inland Norway University of Applied Sciences. Progression through the programme is bottom-up in this figure.

Inland Norway University of Applied Sciences will provide the following courses:

[2] See http://www.irsae.no

Course type and specialisation	ECTS	Course title
Compulsory for all	5	PhD introduction seminars
Compulsory for all	5	Bioinformatics and biostatistics
Compulsory for Applied Ecology, optional for others	5	Adaptive ecological monitoring
Compulsory for Applied Ecology, optional for others	5	Applied models for fish and wildlife management
Compulsory for Biotechnology, optional for others	10	Structure and function of biological macromolecules
Optional	5	Man and the environment
Optional	5	Seminars in bioprocess technology
Optional	5	Seminars in molecular biology
Optional	5	Seminars in reproduction biotechnology
Optional	5	Specialisation
Optional	2.5	Specialisation

The compulsory courses of the training component will be given every year, while optional courses will be offered ca. every second year, or when necessary dependent on the progress of candidates. All courses are open for external PhD-candidates.

In general, the courses are given as intensive courses with one-week long meetings separated with self-study or practical exercises.

The International Research School in Applied Ecology (IRSAE: see www.IRSAE.no) will provide an extensive curriculum with PhD-courses from all partner institutions, that may be chosen as optional courses. IRSAE-courses in transferrable kills, such as writing of proposals and communication skills are relevant both for those specialising in applied ecology or biotechnology. IRSAE also announces alternative PhD-courses from partner institutions that may be relevant either for candidates specialising in applied ecology or biotechnology. The PhD-candidates may also choose optional courses from other national or international universities, for instance the host university during the international stay. The selection of courses should be done in cooperation with the supervisor(s) of the research project.

PhD candidates that have the competence overlapping mandatory courses from previous education will be given the opportunity to exchange mandatory courses.

A total of maximum 3 ECTS credits may be accepted for presentation of papers at national (max 1 ECTS credit) or international (max 2 credits) conferences.

All courses are evaluated on a Pass/Fail basis.

The educational part has to be completed before the candidate submits the dissertation for evaluation.

Below we describe the courses available at Inland Norway University of Applied Sciences for the PhD programme in Life Sciences.

Description of courses

Course title
PhD introduction seminars

ECTS credits
5

Language
English

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD programme may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- appreciates how the forefront of knowledge within her/his research topic developed
- understands how new knowledge developes in the biological sciences
- understands how ecocentric to anthropocentric ethics relates to environmental ethics and environmental protection

General competence
The candidate:
- can identify new relevant ethical issues and carry out research with scholarly integrity
- can discuss academic issues and challenge established dogmas regarding knowledge and practice
- understands how scientific communication functions, including associated ethics, with impact factors, open access and scientific societies
- can contribute in the communication of scientific actions targeting different audiences, such as scientists within applied ecology or biotechnology, scientists in other fields, and users of the scientific results and laymen

Content
THE PHILOSOPHY OF BIOLOGICAL SCIENCE
- theories, hypotheses and models
- explanation, laws, prediction, causation and understanding
- scientific theories and models
- acquiring knowledge
- environmental ethics

NATIONAL AND INTERNATIONAL ETHICAL CONVENTIONS AND GUIDELINES
- good research practice and intellectual freedom
- ethical guidelines regarding the use of animals in research
- ethical guidelines regarding the use of questionnaires and interviews in research
- ethical guidelines for cooperation and authorship

SCIENTIFIC COMMUNICATION

- the structure of scientific papers and popular science
- characteristics of (good) review papers, original research papers, popular papers and other literature
- writing, reading and the oral presentation of scientific results for academics and laymen – the popular scientific presentations
- interactions and communications with the public media and on the world-wide web
- the peer-referee process

Teaching and training methods

Lectures, seminars and self-study.

The course will consist of one day to organise the course, followed by preparation for the course by self-study and one intensive seminar week. Each topic covered will start with a broad presentation by professional lecturers followed by group discussions and presentation by the course participants.

Required components

Participation in the intensive teaching week 80%

Evaluation

To pass the candidate has to pass evaluations of the following:

- One individual written essay reviewing the history of a topic within the individual field of expertise
- One individual oral presentation and introduction to discussion related to environmental ethics
- One individual oral presentation and introduction to discussion related to a scientific misconduct

Suggested reading list

SEMINARS ON THE PHILOSOPHY OF ECOLOGICAL AND BIOLOGICAL SCIENCE

- Chalmers, AF 2013. What is this thing called science. 4th edition. Open University Press, New York. Pp. 282. (Chapter 1, 2, 3, 4, 5, 8, 12: Pp:102).
- Desjardins. JR 2013. Environmental ethics: an introduction to environmental philosophy.Wadsworth Gengage Learning, Boston. Pp. 282.

LECTURES ON NATIONAL AND INTERNATIONAL ETHICAL CONVENTIONS AND GUIDELINES

- Ruse, M. and Wilson, E. O. 1998. The evolution of ethics. In Ruse, M. Philosophy of biology. Prometheus BookosNew York, US. Pp. 313-319.
- https://www.etikkom.no/en/

In addition the candidates will have individual reading lists connected to the specialisation of the candidate.

Course title
Bioinformatics and Biostatistics

ECTS credits
5

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- knows the forefront of statistical methods used in research related to applied ecology or biotechnology
- can independently evaluate how different statistical analysing methods fits to different study designs
- has knowledge of tools and methods in the field of bioinformatics

Skills
The candidate:
- can plan and carry out the analysing procedures in research and development work within applied ecology or biotechnology at high international standards
- can interpret advanced statistical methods, such as data analysis with hierarchical models
- has a thorough understanding regarding the usage of bioinformatics tools and methods associated with analysis and mining of big data

General competence
The candidate:
- can carry out research with scholarly integrity
- can make informed decision on which statistical approach that will be most suitable to address to complex scientific assignments
- can participate in professional debates which depend on complex biostatistical understanding
- can employ bioinformatics tools in their research work

Content
- Big data challenges including data capturing, storage, analysis, sharing, visualization, and information privacy
- Key concepts and methods in bioinformatics including major research topics like data mining, molecular phylogenetics and functional analysis of biological data
- Hierarchical models and Bayesian inference
- Maximum Likelihood Estimation, information theory
- General concepts, differences with the conventional approach,
- Fitting and understanding regression models in the Bayesian framework

- Fixed / random effects
- Longitudinal, clustered, nested data
- Flexibility of block-building hierarchical models

Teaching and training methods
Lectures and computer lab.

2 weeks intensive course.

Required components
Participation in 80% of the organised teaching

Evaluation
One individual written report of an assigned biological problem. Graded as passed or failed.

Suggested reading list
- Xiong J (2006). Essential Bioinformatics. Cambridge University Press. ISBN 978-0521600828.
- Bioinformatics and Functional Genomics – Jonathan Pevsner, 3rd Edition, Wiley-Blackwell, 2015. ISBN: 978-1-118-58178-0
- Next-Generation DNA sequencing informatics. Brown, 2015. Cold Spring Harbor Laboratory Press. ISBN 978-1-621821-23-6
- McElreath R., 2015. Statistical rethinking: A Bayesian course with R and Stan. Chapman & Hall / CRC.
- Gelman A., Hill J. 2007. Data analysis using regression and multilevel / hierarchical models. Cambridge University Press. [Examples are not drawn from ecology but rather from psychology and social sciences]
- Parent E., Rivot E. 2013. Introduction to hierarchical Bayesian modeling for ecological data. Chapman & Hall / CRC.

In addition, peer-reviewed articles and book chapter will also be provided to the students

Course title
Applied models for fish and wildlife management

ECTS credits
5

Language
English

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- has knowledge at the most advanced frontier in harvesting models in ecology
- can independently evaluate the appropriateness of different harvesting models in management

Skills
The candidate:
- can formulate problems in a way that is possible to analyse
- can handle the most advanced and specialized methods and techniques to develop and apply models for wildlife harvest management
- can utilize the most advanced harvesting models

General competence
The candidate:
- can participate in professional debates on harvesting models
- can assess the need for harvesting models and initiate innovation in management
- can communicate and discuss the applicability of harvesting models to different target audiences, such as scientists within applied ecology, scientists in other fields, users of the scientific results, and the general public

Content
- The theory on population dynamics and sustainable harvest
- Uncertainty in harvest strategies
- Adaptive (active) management approach integrating several different indicators of the ongoing processes
- Problems of scaling down general theory to applied management
- Risk analysis and decision theory
- Special focus on threshold management models.

Teaching and training methods

Lectures, seminars, computer lab and workshop. 2 weeks intensive course.

Required components
Participation in 80% of the organised teaching

Evaluation
One individual written report which explores alternative strategies of a given harvest management.

Graded as passed or failed.

Suggested reading list
- Reynolds, J.D. (2001). Conservation of exploited species. Cambridge Univ. Press, Cambridge, UK. Pp. 500
- Schneider, D.C. (2009) Quantitative Ecology. Academic Press, London, UK. Pp. 405
- Lebreton, J. (2005) Dynamical and statistical models for exploited populations. Australian & New Zealand Journal of Statistics, 47, 49–63.
- Millspaugh, J.J., Skalski, J.R., Townsend, R.L., Diefenbach, D.R., Boyce, M.S., Hansen, L.P. & Kammermeyer, K. (2009) An Evaluation of Sex-Age-Kill (SAK) Model Performance. Journal of Wildlife Management, 73, 442-451.
- Novaro, A., Funes, M. & Walker, R. (2005) An empirical test of source–sink dynamics induced by hunting. Ecology, 42, 910–920.

Course title
Adaptive ecological monitoring

ECTS credits
5

Language
English

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- knows the knowledge front related to the theory and practice of monitoring ecological systems
- can independently evaluate the appropriateness and applicability for management of different monitoring methods

Skills
The candidate:
- is able to design, analyse and interpret a rigorous monitoring program for management

- can independently handle complex issues and challenge established knowledge related to ecological monitoring programs
- is able to, or to obtain the necessary skills to, utilize monitoring data from genes to ecosystems

General competence

The candidate:

- can participate in professional debates on ecological monitoring
- demonstrate substantial professional authority to advice management with innovative ecological monitoring
- is able to communicate research and results based on ecological monitoring to different target groups

Content

- Monitoring at the genetic level: Ecological significance of and methods for monitoring of inbreeding, gene flow, genetic diversity etc.
- Monitoring ta the individual level: Ecological significance of and methods for monitoring of size and growth, reproduction, deceases, damage, survival
- Monitoring at the population level: Ecological significance of and methods for monitoring of population size and density (indices, density estimators, mark-recapture, distribution, etc), and population composition (age and sex composition)
- Monitoring at the community level: Ecological significance of and methods for monitoring of communities (taxonomic or functional groups); How to monitor taxonomic and functional composition, richness, dominance and diversity in plants and animals
- Monitoring at the ecosystem level: Ecological significance of and methods for monitoring of ecosystem function, decomposition, food webs, uptake and cycling of resources and contaminants from soil, water, and air.

Required components

Participation in 80% of the organised teaching

Evaluation

To pass the student has to pass the following evaluations:

- Completion of 1-3 individual assignments
- 2 individual oral presentations
- Final individual oral exam

Example of papers and books that could be part of the reading list

- Lindenmayer, DB, Likens, GE. 2010. Effective Ecological Monitoring. CSIRO publishing, Australia. Pp. 170.

Selections from the following books:

- Spellerberg, IF. 2005. Monitoring ecological change. Cambridge university press. Cambridge. Pp. 391.
- McComb, B, Zuckerberg, B, Vesely, D, Jordan, C. 2010. Monitoring animal populations and their habitats. A practitioners guide. CRC press. Boca Raton. Pp. 282.

Papers (the list below gives examples of papers which may be used)

- Amundsen, PA, Knudsen, R, Klemetsen, A. 2007. Intraspecific competition and density dependence of food consumption and growth in Arctic charr. Journal of Animal Ecology 76: 149-158.

- Bellemain, E., Swenson, J.E., Tallmon, D., Brunberg, S. & Taberlet, P. 2005. Estimating population size of elusive animals with DNA from hunter-collected feces: comparing four methods for brown bears. Conservation Biology 19: 150-161.
- Brøseth, H., Flagstad, Ø., Wärdig, C., Johansson, M. & Ellegren, H. 2010. Large-scale noninvasive genetic monitoring of wolverines using scat reveals density dependent adult survival. Biological Conservation 143: 113-120.
- Bustnes, JO, Yoccoz, NG, Bangjord et al. 2007. Temporal trends (1986-2004) of organochlorines and brominated flame retardants in tawny owl eggs from Northern Europe. Environmental Science & Technology 41: 8491-8497.
- Chapron, G, Andrén, H, Liberg, O. 2008. Conserving top predators in ecosystems. Science 320: 47.
- Eguchi, T, & Gerrodette, T. 2009. A Bayesian approach to line-transect analysis for estimating abundance. Ecological Modelling 220: 1620-1630.
- Elliot, J. 1986. Population regulation in contrasting populations of trout, Salmo trutta, in two Lake District streams. Journal of Animal Ecology 56: 83-98.
- Goetz, SJ, Steinberg, D, Betts, MG, et al. 2010. Lidar remote sensing variables predict breeding habitat of a Neotropical migrant bird. Ecology 91: 1569-1576.
- Gormley, A, Forsyth, D, Griffioen, P et al. 2011. Using presence-only and presence-absence data to estimate the current and potential distributions of established invasive species. Journal of Applied Ecology 48: 25–34.
- Guisan, A, Broennimann, O, Engle, R et al. 2006. Using niche-based models to improve the sampling of rare species. Conservation Biology 20: 501-511.
- Hannah, L, Midgely, GF, Millar, D. 2002. Climate change-integrated conservation strategies. Global Ecology and Biogeography II: 485-495.
- Hauser, CE, Pople, AR, Possingham, HP. 2006. Should managed populations be monitored every year? Ecological Applications 16: 807–819.
- Henden, JA, Ims, RA, Yoccoz, NG. 2009. Nonstationary spatio-temporal small rodent dynamics: evidence from long-term Norwegian fox bounty data. Journal of Animal Ecology 78: 636-645.
- Jones, JPG, Andriamarovolona, MM, Hockley, N et al. 2008. Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. Journal of Applied Ecology, 45: 1205–1212.
- Joseph, LN, Field, SA, Wilcox, C et al. 2006. Presence- absence versus abundance data for monitoring threatened species. Conservation Biology 20: 1679–1687.
- Kaji, K, Saitoh, T, Uno, H et al. 2010. Adaptive management of sika deer populations in Hokkaido, Japan: theory and practice. Population Ecology 52: 373-387.
- Karanth, KU, Nichols, JD, Kumar, NS et al. 2006. Assessing tiger population dynamics using photographic capture-recapture sampling. Ecology 87: 2925–2937.
- Larsen, DP, Kaufmann, PR, Kincaid, TM et al. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 61: 283-291.
- Larsen, DP. 1997. Sample survey design issues for bioassessment of inland aquatic ecosystems. Human and Ecological Risk Assessment 3: 979-91.
- Larsen, DP, Kincaid, TM, Jacobs, SE et al. 2001. Designs for evaluating local and regional scale trends. BioScience 51: 1069-1078.
- Larsen, DP, Urquhart, NS, Kugler, DL. 1995. Regional scale trend monitoring of indicators of trophic condition of lakes. Water Resources Bulletin 31. 117-40.
- Legg, CJ, Nagy, L. 2005. Why most conservation monitoring is, but need not be, a waste of time. Journal of Environmental Management 78: 194–199.

- Liberg, O, Andren, H, Pedersen, HC et al. 2005. Severe inbreeding depression in a wild wolf (Canis lupus) population. Biology Letters 1: 17-20.
- Lindenmayer, DB, Likens, GE. 2009. Adaptive monitoring: A new paradigm for long-term research and monitoring. TREE 24: 482-486.
- Lindenmayer, DB, Likens, GE. 2010. The science and application of ecological monitoring. Biological Conservation 143: 1317-1328.
- Lindenmayer, DB, Likens, GE. 2010. Improving ecological monitoring. TREE 25: 200-201.
- Lovett, GM, Burns, DA, Driscoll, CT. 2007. Who needs environmental monitoring? Frontiers in Ecology and the Environment 5: 253-260.
- Mackenzie, DI, Royle, JA. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology 42: 1105–1114.
- Mladenoff, DJ, Sickley, TA, Wydeven, AP. 1999. Predicting gray wolf landscape recolonization: Logistic regression models vs. New field data. Ecological applications 9: 37-44.
- Olsen, AR, Sedransk, J, Edwards, D et al. 1999. Statistical issues for monitoring ecological and natural resources in the United States. Environmental Monitoring and Assessment 54: 1-45.
- Ringold, PL, Alegria, J, Czaplewski, RL et al. 1996. Adaptive monitoring design for ecosystem management. Ecol. Applications 6: 745-747.
- Rouquette, JR, Thompson, DJ. 2007. Patterns of movement and dispersal in an endangered damselfly and the consequences for its management. Journal of Applied Ecology 44: 692–701.
- Royle, JA, Nichols, JD. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84: 777–790.
- Rönnegård, L, Sand, H, Andrén, H, et al. 2008. Evaluation of four methods used to estimate population density of moose Alces alces. Wildlife Biology 14: 358–371.
- Scholes, RJ, Mace, GM, Turner, W et al. 2008. Ecology – toward a global biodiversity observing system. Science 321: 1044–1045.
- Solberg, KH, Bellemain, E, Drageset, OM et al. 2006. An evaluation of field and non-invasive genetic methods to estimate brown bear (Ursus arctos) population size. Biological Conservation 128: 158-168.
- Tilman, D, May, RM, Lehman, CL et al. 1994. Habitat destruction and the extinction debt. Nature 371: 65-66.
- Urquhart, NS, Kincaid, TM. 1999. Designs for detecting trend from repeated surveys of ecological resources. Journal of Agricultural, Biological and Environmental Statistics. 4:404-414.
- Urquhart, NS, Paulsen, SG, Larsen, DP. 1998. Monitoring for policy-relevant regional trends over time. Ecological Applications 8:246-257
- Vøllestad, A, Molson, E. 2008. Non-additive effects of density-dependent and densityindependent factors on brown trout vital rates. Oikos, 117: 1752-1760.
- Wabakken, P, Sand, H, Liberg, O et al. 2001. The recovery, distribution, and population dynamics of wolves on the Scandinavian peninsula, 1978-1998. Canadian Journal of Zoology 79: 710-725.
- Yoccoz, NG, Nichols, JD, Boulinier, T. 2001. Monitoring of biological diversity in space and time. TREE 16: 446-453.

Course title
Man and the environment

ECTS credits
5

Language
English

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- understands connections between evolutionary processes, exploitation of ecosystem services, sustainability and human society
- can discuss the appropriateness and applicability of different methods and processes in research projects related to human impact and management of ecosystem services

Skills
The candidate:
- can handle interdisciplinary issues and challenge established knowledge and practice in relation to the bioeconomies

General competence
The candidate:
- can identify ethical issues and show intellectual integrity related to sustainability and the socioecological system
- can advice public management in issues related to economic, ecologic and social sustainability
- can participate in interdisciplinary debates related to economic, ecologic and social sustainability in national and international forums
- can assess the need for and initiate innovation related to ecosystem services
- can communicate scientific actions to different target audiences to users of the scientific results and the general public

Content
- The biological foundation for present ecosystems and ecosystem services and how this is changing
- The socio-ecological system and development of bioeconomy
- Technological solutions and innovations
- Discussions on international and national conventions and strategies, e.g. related to biodiversity and bioeconomy

- Ethical issues related to ecological, economic and social sustainability

Teaching and training methods

Lectures, seminars and workshops.

The course will consist of two intensive seminar weeks. Each topic covered will start with a broad presentation by professional lecturers followed by group discussions and presentation by the course participants. Students will have to do preliminary work to prepare for the course.

Required components

- Participation in 80% of the organised teaching
- 1 written essay written by a group of students for the general public and attempted published as a letter to editor in a newspaper or in a technical magazine
- 1-2 oral presentations

Evaluation

Individual oral exam evaluated as passed or failed

Example of papers and books that could be part of the reading list

- Mace, M.G et al. 2012. Biodiversity and ecosystem services: a multi-layered relationship. TREE 27: 19-26.
- Nesshöver, C. 2016. The network of knowledge approach: improving the science and society dialogue on biodiversity and ecosystem services in Europe. Biovidersity Conservation 25: 1215-1233.
- Chan, K.M.A. et al. 2006. Conservation planning for ecosystem services. *PLoS Biology* 4:2138-2152
- Dobson, A. & Lynes, L. 2008. How does poaching affect the size of national parks? *Trends in Ecology & Evolution* 23: 177-236
- Gereta, E. et al. 2002. Use of an ecohydrological model to predict the impact on the Serengeti ecosystem of deforestation, irrigation and the proposed Amala weir water diversion project in Kenya. *Ecohydrology & Hydrobiology* 2: 127-134.
- Gordon, I.J. 2007. Linking land to ocean: feedbacks in the management of socio-ecological systems in the Great Barrier Reef catchments. *Hydrobiologia* 591:25-33
- Hilborn, R. et al. 2006. Effective enforcement in a conservation area. *Science* 314: 1266
- Jefferies, R.L. et al. 2004. Agricultural food subsidies, migratory connectivity and large-scale disturbance in Arctic coastal systems: a case study. *Integrative and Comparative Biology* 44:130-139
- Kremen, C. et al. 2004. The area requirements of an ecosystem service: crop pollination by native bee communities in California. *Ecology Letters* 7:1109-1119
- Thirgood, S. et al. 2004. Can parks protect migratory ungulates? The case of the Serengeti wildebeest. *Animal Conservation* 7: 113-120.
- Berger, J. et al. 2006. Connecting the dots: an invariant migration corridor links the Holocene to the present. *Biology Letters* 2:528531
- Donlan, J. *et al*. 2005. Re-wilding North America. *Nature* 436:913-914
- Hannah, L. et al. 2002. Climate change-integrated conservation strategies. *Global Ecology & Biogeography* 11:485-495
- Kerr, J. et al. 2007. The macroecological contribution to global change solutions. *Science* 316:1581-1584
- Odling-Smee, L. 2005. Dollars and sense. *Nature* 437:614-616
- Orme, C.D.L., *et al*. 2005. Global hotspots of species richness are not congruent with endemism or threat. *Nature* 436:1016-1019

- Balmford, A. & Whitten, A. 2003. Who should pay for tropical conservation, and how could the costs be met? *Oryx* 37:238-250
- Bienen, L. & Tabor, G. 2006. Applying an ecosystem approach to brucellosis control: can an old conflict between wildlife and agriculture be successfully managed? *Frontiers in Ecology and the Environment* 4:319-327
- Brashares, J.S. et al. 2004. Bushmeat hunting, wildlife declines, and fish supply in West Africa. *Science* 306:1180-1183
- Ferraro, P.J. & Kiss, A. 2002. Direct payments to conserve biodiversity. *Science* 298:1718-1719
- Kremen, C. et al. 2000. Economic incentives for rain forest conservation across scales. *Science* 288:1828-1832
- Madhusudan, M.D. 2005. The global village: linkages between international coffee markets and grazing by livestock in a South Indian wildlife reserve. *Conservation Biology* 19:411-420
- Berger, K. M. 2006. Carnivore-livestock conflicts: effects of subsidized predator control and economic correlates on the sheep industry. *Conservation Biology* 20:751-761
- Naidoo, R. et al. 2006. Integrating economic costs into conservation planning. *Trends in Ecology and Evolution* 21:681-687
- Smith, R.J. et al. 2003. Governance and the loss of biodiversity. *Nature* 426:67-70
- Solberg, S.Ø. et al. 2014. Future opportunities for bioeconomy in the west nordic countries. Mattis report.
- Trebilco, R. et al. 2013. Ecosystem ecology: size-based constraints on the pyramids of life. TREE 28: 423-431.
- Goodland, R. & Daly, H. 1996. Environmental sustainability: Universal and non-negotiable. Ecological Applications 6: 1002-1017.
- Melville, M.P. 2010. Information systems innovation for environmental sustainability. MIS quarterly 34: 1-21.
- The Quintessence Consortium 2016. Networking our way to better ecosystem serviced provision. TREE 31: 105-115.
- Monastersky, R. 2014. Life – a status report. MacMillan publishers Limited.
- Nelson E. 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity, production, and tradeoffs at landscape scales. Ecosystem Services 7: 4-11.
- ten Brink, B. et al. 2010. Rethinking Global Biodiversity Strategies: Exploring structural changes in production and consumption to reduce biodiversity loss. A contribution to the project on The Economics of Eocystems and Biodiversity (TEEB). www.pbl.nl/en
- Reid et al. 2005. Ecosystems and human well-being. Millenium Ecosystem assessment. Island Press, Washington, DC.
- Willer, H. 2013. The world of organic agriculture. Statistics and emerging trends 2013.
- Hughes, L. 2000. Biological consequences of global warming: is the signal already. TREE 15: 56-61.
- Tucker, A. & Duplisea, D. 2012. Bioinformaticstools in predictive ecology: applications to fisheries. Phil. Trans. R. Soc. B. 367: 279-290.
- Rockström, J. et al. 2009. A safe operating space for humanity. Nature 461, 472-475.
- OECD 2009. The bioeconomy of 2030. http://www.oecd.org/futures/longtermtechnologicalsocietalchallenges/42837897.pdf.
- European commission. 2012. Innovating for sustainable growth: a bioeconomy for Europe. http://ec.europa.eu/research/bioeconomy/pdf/201202_innovating_sustainable_growth.pd.
- Levers, C. et al. 2014. Drivers for forest harvesting intensity patterns in Europe. Forest ecology and management 315: 160-172.

- Haddad et al. 2015. Habitat fragmentation and its lasting impact on earths ecosystem. Science Advances 2015; 1:e1500052
- Vilén, T. et al., 2012. Reconstructed forest age structure in Europe 1950–2010. Forest Ecology Management. 286: 203–218.
- Jandl, R. et al. 2007. How strongly can forest management influence soil carbon sequestration? Geoderma 137: 253–268.
- Nabuurs, G.-J. et al.. 2013. First signs of carbon sink saturation in European forest biomass. Nature Climate Change 3: 792-796. 11 Luyssaert, S. et al. 2007. The European land and inland water CO2, CO, CH4 and N2O balance between 2001 and 2005. Biogeosciences 9, 3357–3380.
- Paillet, Y. et al. 2010. Biodiversity differences between managed and unmanaged forests: metaanalysis of species richness in Europe. Conservation Biology 24, 101–112.
- Stork, N.E. et al. 2015. New approaches narrow global species estimates for beetles, insects, and terrestrial arthropods. PNAS 112: 7519-7523.
- Seidl, R., Schelhaas, M-J., Lexer, M.J. 2011. Unravelling the drivers of intensifying forest disturbance regimes in Europe. Global Change Biology 17: 2842-2852.
- Gamfeldt, L. et al. 2013. Higher levels of multiple ecosystem services are found in forests with more tree species. Nature Communication 4: 1340.
- Barnosky, AD, et al. 2011. Has the Earth's sixth mass extinction already arrived? Nature 471: 51–57.
- Pimm, S.L. et al. 1995. The future of biodiversity. Science 269: 347–350.
- Dirzo, R., Raven, P.H. 2003. Global state of biodiversity and loss. Annual Review Environment and Resources. 28: 137–167.
- Hooper, D.U. et al. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs 75: 3-35.
- The European Environmental Agency. 2013. Towards a common international classification of ecosystem services. http://cices.eu/.
- Bishop, J. (ed.) 2013. The economics of ecosystems and biodiversity in business and enterprise. Earthscan London. 259pp.
- Secretariat of the Convention on Biological Diversity. 2010. Global Biodiversity Outlook 3. Montréal. http://www.cbd.int/gbo3/.
- European commission. 2012. Our life insurance, our natural capital: an EU biodiversity strategy to 2020. European parliament resolution of 20 April 2012. 20 pp.
- Hansen et al. 2013. Global Forest Change http://earthenginepartners.appspot.com/science-2013-global-forest
- Batker et al. 2014. Natures value in the Colorado River Basin. Earth Economics. http://www.eartheconomics.org/FileLibrary/file/Reports/Earth%20Economics%20Colorado%20River%20Basin%20ESV%20FINAL.pdf
- Rautiainen, A. et al. 2011. A National and International Analysis of Changing Forest Density; 2011; PLoS ONE 6(5): e19577.
- Reid, W.V. 2005. Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. http://www.millenniumassessment.org/documents/document.356.aspx.pdf.
- Castro, A. et al. 2014. Multidimensional approaches in ecosystem service assessment. In: Earth Observation of Ecosystem Services, pp. 427-454.
- Biological Diversity. 2010. Global Biodiversity Outlook 3. Montréal, 94 pages. http://www.cbd.int/gbo3/.

Course title

Structure & Function of Biological Macromolecules

ECTS credits
10

Language
English

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- has an advanced knowledge in state-of-the art methods and interdisciplinary strategies employed to study biological macromolecules
- has in-depth knowledge of biophysicochemical properties that govern the structure, behaviour and function of biological macromolecules in diverse biological and methodological processes

Skills
The candidate:
- can formulate research questions, plan, assess and execute experimental and academic development projects in biotechnology with a focus on the structure, behaviour and function of biological macromolecules
- can critically evaluate and apply results from experimental research published in internationally recognised journals
- can cope with complex technical questions, and utilise advanced and specialised methods and techniques within the field of biotechnology employed to study the structure, behaviour and function of biological macromolecules

General competence
The candidate:
- can formulate novel, cutting-edge research questions and develop and pursue his/her research with professional and ethical integrity
- can manage complex and synergistic interdisciplinary tasks and research/development projects encompassing the structure, behaviour and function of proteins, nucleic acids and/or chromatin in diverse biological and methodological processes
- can analyse, synthesise and communicate results from relevant research and development from and through recognised national and international channels
- can assess the need for, initiate and drive, innovation processes relevant to research regarding the structure, behaviour and function of proteins, nucleic acids and/or chromatin in diverse biological and methodological processes

Content

- Protein structure and function
    - Protein structure: prediction, analysis and functional relevance
    - Surface properties important in interactions with substrates, cofactors, binding partners, matrices in analysis methods and purification pipelines
    - Protein classes, domains and structural motifs, production, localisation and degradation with emphasis on functional relevance as exemplified from specific pathways
- Nucleic acid structure and function
    - Structural and functional organisation of DNA in genomes
    - RNA structure and function: small RNAs, RNA editing, production, modification/transport and degradation represent examples of topics that may be presented and discussed
- Chromatin structure and function
    - Chromatin types and structures
    - Chromatin proteins: scaffold proteins, histones, protamines, regulatory proteins
    - Structure and function of histone modifications
    - Structure and function of DNA modifications in chromatin
- Structure and function of other relevant biological (macro)molecules (e.g. lipids, carbohydrates) and strategies for their purification may also be addressed
- Selected advanced, cutting-edge methodologies, both *in silico* and wet-lab, concerning all the above-mentioned classes of biological macromolecules will be addressed through introductory lectures and a review of the current scientific literature

Teaching and training methods
Lectures, seminars and demonstrations.

The course will consist of two intensive weeks.

Required components
- Approval of an individual portfolio including a written report
- Participation in 80% of the organised teaching

Evaluation
Individual oral exam evaluated as passed or failed

Example of papers and books that could be part of the reading list
General reference text for review:

- Alberts B, *et al.* (2014) *Molecular Biology of the Cell, Sixth Edition* (Taylor & Francis Group).

A suitable selection of articles and/or book chapters/excerpts from each of the sections listed below.

Protein structure and function (including analysis methodologies)

- Almo SC, et al. (2013) Protein production from the structural genomics perspective: achievements and future needs. Current opinion in structural biology 23(3):335-344.
- Azeloglu EU & Iyengar R (2015) Signaling networks: information flow, computation, and decision making. Cold Spring Harbor perspectives in biology 7(4):a005934.
- Bornberg-Bauer E & Albà MM (2013) Dynamics and adaptive benefits of modular protein evolution. Current opinion in structural biology 23(3):459-466.
- Chung WK, Freed AS, Holstein MA, McCallum SA, & Cramer SM (2010) Evaluation of protein adsorption and preferred binding regions in multimodal chromatography using NMR.

Proceedings of the National Academy of Sciences of the United States of America 107(39):16811-16816.
- Collins GA & Goldberg AL (2017) The Logic of the 26S Proteasome. Cell 169(5):792-806.
- Kessel A & Ben-Tal N (2010) Introduction to Proteins: Structure, Function, and Motion (CRC Press).
- Lees JG, Dawson NL, Sillitoe I, & Orengo CA (2016) Functional innovation from changes in protein domains and their combinations. Current opinion in structural biology 38:44-52.
- Regnier FE (1987) The role of protein structure in chromatographic behavior. Science (New York, N.Y.) 238(4825):319-323.
- Scaiewicz A & Levitt M (2015) The language of the protein universe. Current opinion in genetics & development 35(Supplement C):50-56.
- Schlessinger J (2014) Receptor tyrosine kinases: legacy of the first two decades. Cold Spring Harbor perspectives in biology 6(3).
- Scopes RK (2013) Protein Purification: Principles and Practice (Springer New York).
- Sleator RD (2012) Proteins: Form and function. Bioengineered Bugs 3(2):80-85.
- Smidsrød O, Moe S, & Moe ST (2008) Biopolymer Chemistry (Tapir Academic Press).
- Tosti E & Menezo Y (2016) Gamete activation: basic knowledge and clinical applications. Human reproduction update 22(4):420-439.

Nucleic acid structure and function (including analysis methodologies)

- Bohmdorfer G & Wierzbicki AT (2015) Control of Chromatin Structure by Long Noncoding RNA. Trends in cell biology 25(10):623-632.
- Borges F & Martienssen RA (2015) The expanding world of small RNAs in plants. Nature reviews. Molecular cell biology 16(12):727-741.
- Castel SE & Martienssen RA (2013) RNA interference in the nucleus: roles for small RNAs in transcription, epigenetics and beyond. Nature reviews. Genetics 14(2):100-112.
- Cech TR & Steitz JA (2014) The noncoding RNA revolution-trashing old rules to forge new ones. Cell 157(1):77-94.
- Franchini LF & Pollard KS (2017) Human evolution: the non-coding revolution. BMC biology 15(1):89.
- Franchini LF & Pollard KS (2017) Human evolution: the non-coding revolution. BMC biology 15(1):89.
- Gallo A, Vukic D, Michalik D, O'Connell MA, & Keegan LP (2017) ADAR RNA editing in human disease; more to it than meets the I. Human genetics.
- Goodwin S, McPherson JD, & McCombie WR (2016) Coming of age: ten years of next-generation sequencing technologies. Nature reviews. Genetics 17(6):333-351.
- Keegan L, Khan A, Vukic D, & O'Connell M (2017) ADAR RNA editing below the backbone. RNA (New York, N.Y.) 23(9):1317-1328. Matzke MA, Kanno T, & Matzke AJ (2015) RNA-Directed DNA Methylation: The Evolution of a Complex Epigenetic Pathway in Flowering Plants. Annual review of plant biology 66:243-267.
- Meadows JRS & Lindblad-Toh K (2017) Dissecting evolution and disease using comparative vertebrate genomics. Nature reviews. Genetics 18(10):624-636.
- Morris KV & Mattick JS (2014) The rise of regulatory RNA. Nature reviews. Genetics 15(6):423-437.
- Nguyen HQ & Bosco G (2015) Gene Positioning Effects on Expression in Eukaryotes. Annual review of genetics 49:627-646.
- Pombo A & Dillon N (2015) Three-dimensional genome architecture: players and mechanisms. Nature reviews. Molecular cell biology 16(4):245-257.
- Quinodoz S & Guttman M (2014) Long noncoding RNAs: an emerging link between gene regulation and nuclear organization. Trends in cell biology 24(11):651-663.

- Rowley MJ & Corces VG (2016) The three-dimensional genome: principles and roles of longdistance interactions. Current opinion in cell biology 40:8-14.
- Shi Y (2017) The Spliceosome: A Protein-Directed Metalloribozyme. Journal of molecular biology 429(17):2640-2653.
- Singh V, Braddick D, & Dhar PK (2017) Exploring the potential of genome editing CRISPR-Cas9 technology. Gene 599:1-18.
- Stella S, Alcon P, & Montoya G (2017) Class 2 CRISPR-Cas RNA-guided endonucleases: Swiss Army knives of genome editing. Nature structural & molecular biology.
- Teotia S, Singh D, Tang X, & Tang G (2016) Essential RNA-Based Technologies and Their Applications in Plant Functional Genomics. Trends in biotechnology 34(2):106-123.
- Vergara Z & Gutierrez C (2017) Emerging roles of chromatin in the maintenance of genome organization and function in plants. Genome biology 18(1):96.
- Wang J & Song Y (2017) Single cell sequencing: a distinct new field. Clinical and translational medicine 6(1):10.
- Yamamura S, Imai-Sumida M, Tanaka Y, & Dahiya R (2017) Interaction and cross-talk between non-coding RNAs. Cellular and molecular life sciences: CMLS.

Chromatin structure and function (including analysis methodologies)

- Akalin A, et al. (2012) methylKit: a comprehensive R package for the analysis of genome-wide DNA methylation profiles. Genome biology 13(10):R87.
- Bao J & Bedford MT (2016) Epigenetic regulation of the histone-to-protamine transition during spermiogenesis. Reproduction (Cambridge, England) 151(5):R55-70.
- Bohmdorfer G & Wierzbicki AT (2015) Control of Chromatin Structure by Long Noncoding RNA. Trends in cell biology 25(10):623-632.
- Brickner J (2017) Genetic and epigenetic control of the spatial organization of the genome. Molecular biology of the cell 28(3):364-369.
- Canovas S & Ross PJ (2016) Epigenetics in preimplantation mammalian development. Theriogenology 86(1):69-79.
- Champroux A, Torres-Carreira J, Gharagozloo P, Drevet JR, & Kocer A (2016) Mammalian sperm nuclear organization: resiliencies and vulnerabilities. Basic and Clinical Andrology 26.
- D'Urso A & Brickner JH (2014) Mechanisms of epigenetic memory. Trends in genetics : TIG 30(6):230-236.
- Dekker J & Misteli T (2015) Long-Range Chromatin Interactions. Cold Spring Harbor perspectives in biology 7(10):a019356.
- Friedman N & Rando OJ (2015) Epigenomics and the structure of the living genome. Genome research 25(10):1482-1490.
- Krueger F & Andrews SR (2011) Bismark: a flexible aligner and methylation caller for Bisulfite-Seq applications. Bioinformatics 27(11):1571-1572.
- Maurer-Alcala XX & Katz LA (2015) An epigenetic toolkit allows for diverse genome architectures in eukaryotes. Current opinion in genetics & development 35:93-99.
- Messerschmidt DM, Knowles BB, & Solter D (2014) DNA methylation dynamics during epigenetic reprogramming in the germline and preimplantation embryos. Genes & Development 28(8):812-828.
- Rathke C, Baarends WM, Awe S, & Renkawitz-Pohl R (2014) Chromatin dynamics during spermiogenesis. Biochimica et Biophysica Acta (BBA) - Gene Regulatory Mechanisms 1839(3):155-168.
- Sequeira-Mendes J & Gutierrez C (2016) Genome architecture: from linear organisation of chromatin to the 3D assembly in the nucleus. Chromosoma 125(3):455-469.
- Tollefsbol TO (2011) Handbook of Epigenetics, (Academic Press, San Diego).

- Zini A & Agarwal A (2011) Sperm Chromatin: Biological and Clinical Applications in Male Infertility and Assisted Reproduction (Springer New York).

Course title
Seminars in molecular biology

ECTS credits
5

Language
English

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- is in the forefront of current topics in molecular biological research and knowledge of stateof-the-art methods employed in molecular biological research
- can evaluate, plan and implement the application of different cutting-edge approaches and methods in molecular biology

Skills
The candidate:
- can formulate research questions, plan, assess and execute experimental and academic development projects in molecular biology
- can critically evaluate and implement results from experimental research published in internationally recognised journals
- can cope with complex technical questions, and utilise the most advanced and specialised methods and techniques within the field of molecular biology

General competence
The candidate:
- can participate in international discourse in the field of molecular biology
- can communicate, both orally and in writing, results from published scientific research to colleagues and peers
- can critically evaluate experimental research in molecular biology published in internationally recognised journals and lead a plenary discussion thereof
- can analyse, synthesise and communicate results from research and development in molecular biology through recognised national and international channels

Content

- The seminar course will have a focus on one single main research question or approach/technology within the general field of molecular biology, including, but not limited to, chiefly one of the following specific research areas:
    - DNA technologies
    - Microbiota analyses
    - Molecular biology of development, abiotic and/or biotic interactions in plants
    - Gene regulation & expression (hereunder also epigenetics)
    - Protein expression (hereunder also recombinant protein expression) & function
    - other relevant topics
- Strategies for effective critical analysis of scientific literature
    - Critically evaluating experiments and results that are explicitly reported and discussed
    - Elucidating and exploring the ramifications of what was not reported from experiments that were performed in molecular biological studies
- Presentation strategies and techniques
    - Strategies for effective written communication of scientific results
    - Strategies for effective oral communication of scientific results
    - Duration-dependent presentation strategies
    - Audience-dependent customising of content

Teaching and training methods

Each student will, depending on the number of course participants, be assigned 1-5 research articles from the primary literature. During hourly meetings each week, one article will be presented by the student responsible who will then lead a plenary discussion and critical analysis. Prior to each meeting the responsible student will also submit a single-page synopsis of the article including a brief critical analysis. A single-page summary of the plenary discussion including any new points raised/addressed should also be submitted by the responsible student within one week following presentation and discussion of the article. These two written documents are considered part of the presentation requirements.

Required components

Passed /not passed evaluation scheme based on compulsory attendance (minimum 80 %) and presentation of all articles assigned.

Evaluation

Individual oral exam evaluated as passed or failed

Example of papers and books that could be part of the reading list

General reference text for review:

- Alberts B, *et al.* (2014) *Molecular Biology of the Cell, Sixth Edition* (Taylor & Francis Group).

A suitable selection of articles and/or book chapters/excerpts from one or more of the sections listed below.

DNA technologies

- Chen CY (2014) DNA polymerases drive DNA sequencing-by-synthesis technologies: both past and present. Frontiers in microbiology 5:305.
- Goodwin S, McPherson JD, & McCombie WR (2016) Coming of age: ten years of next-generation sequencing technologies. Nature reviews. Genetics 17(6):333-351.

- Grover A & Sharma PC (2016) Development and use of molecular markers: past and present. Critical reviews in biotechnology 36(2):290-302.
- Heather JM & Chain B (2016) The sequence of sequencers: The history of sequencing DNA. Genomics 107(1):1-8.
- Liao Y, et al. (2013) Combination of fluorescence color and melting temperature as a twodimensional label for homogeneous multiplex PCR detection. Nucleic acids research 41(7):e76.
- Rasheed A, et al. (2017) Crop Breeding Chips and Genotyping Platforms: Progress, Challenges, and Perspectives. Molecular plant 10(8):1047-1064.
- von Thaden A, et al. (2017) Assessing SNP genotyping of noninvasively collected wildlife samples using microfluidic arrays. Scientific reports 7(1):10768.
- Wang J & Song Y (2017) Single cell sequencing: a distinct new field. Clinical and translational medicine 6(1):10.

Microbiota analyses

- Avershina E, et al. (2016) Transition from infant- to adult-like gut microbiota. Environmental microbiology 18(7):2226-2236.
- Casen C, et al. (2015) Deviations in human gut microbiota: a novel diagnostic test for determining dysbiosis in patients with IBS or IBD. Alimentary pharmacology & therapeutics 42(1):71-83.
- Chanclud E & Lacombe B (2017) Plant Hormones: Key Players in Gut Microbiota and Human Diseases? Trends in plant science 22(9):754-758.
- Cristescu ME (2014) From barcoding single individuals to metabarcoding biological communities: towards an integrative approach to the study of global biodiversity. Trends in Ecology & Evolution 29(10):566-571.
- Escobar-Zepeda A, Vera-Ponce de Leon A, & Sanchez-Flores A (2015) The Road to Metagenomics: From Microbiology to DNA Sequencing Technologies and Bioinformatics. Frontiers in genetics 6:348.
- Krautkramer KA, Rey FE, & Denu JM (2017) Chemical signaling between gut microbiota and host chromatin: What is your gut really saying? The Journal of biological chemistry 292(21):8582-8593.
- Lozupone CA, Stombaugh JI, Gordon JI, Jansson JK, & Knight R (2012) Diversity, stability and resilience of the human gut microbiota. Nature 489(7415):220-230.
- Rodriguez JM, et al. (2015) The composition of the gut microbiota throughout life, with an emphasis on early life. Microbial ecology in health and disease 26:26050.

Molecular biology of development, abiotic and/or biotic interactions in plants

- Antolin-Llovera M, Ried MK, Binder A, & Parniske M (2012) Receptor kinase signaling pathways in plant-microbe interactions. Annual review of phytopathology 50:451-473.
- D'Ario M, Griffiths-Jones S, & Kim M (2017) Small RNAs: Big Impact on Plant Development. Trends in plant science.
- Evangelisti E, Rey T, & Schornack S (2014) Cross-interference of plant development and plant– microbe interactions. Current Opinion in Plant Biology 20(Supplement C):118-126.
- Finkel OM, Castrillo G, Herrera Paredes S, Salas Gonzalez I, & Dangl JL (2017) Understanding and exploiting plant beneficial microbes. Curr Opin Plant Biol 38:155-163.
- Haak DC, et al. (2017) Multilevel Regulation of Abiotic Stress Responses in Plants. Frontiers in plant science 8:1564.
- Krejci A & Tennessen JM (2017) Metabolism in time and space - exploring the frontier of developmental biology. Development (Cambridge, England) 144(18):3193-3198.

- Libault M, Pingault L, Zogli P, & Schiefelbein J (2017) Plant Systems Biology at the Single-Cell Level. Trends in plant science.
- Wang J, Meng X, Dobrovolskaya OB, Orlov YL, & Chen M (2017) Non-coding RNAs and Their Roles in Stress Response in Plants. Genomics, proteomics & bioinformatics.
- Yadav V, Hemansi, Kim N, Tuteja N, & Yadav P (2017) G Quadruplex in Plants: A Ubiquitous Regulatory Element and Its Biological Relevance. Frontiers in plant science 8:1163.
- Yruela I (2015) Plant development regulation: Overview and perspectives. Journal of Plant Physiology 182(Supplement C):62-78.
- Zogli P & Libault M (2017) Plant response to biotic stress: Is there a common epigenetic response during plant-pathogenic and symbiotic interactions? Plant science: an international journal of experimental plant biology 263:89-93.

Eukaryotic gene regulation & expression (hereunder also epigenetics)

- Crocker J & Ilsley GR (2017) Using synthetic biology to study gene regulatory evolution. Current opinion in genetics & development 47:91-101.
- Lai WKM & Pugh BF (2017) Understanding nucleosome dynamics and their links to gene expression and DNA replication. Nature reviews. Molecular cell biology 18(9):548-562.
- Li X, Xiong X, & Yi C (2016) Epitranscriptome sequencing technologies: decoding RNA modifications. Nature methods 14(1):23-31.
- Roundtree IA, Evans ME, Pan T, & He C (2017) Dynamic RNA Modifications in Gene Expression Regulation. Cell 169(7):1187-1200.
- Staby L, et al. (2017) Eukaryotic transcription factors: paradigms of protein intrinsic disorder. The Biochemical journal 474(15):2509-2532.
- Varshavsky A (2017) The Ubiquitin System, Autophagy, and Regulated Protein Degradation. Annual review of biochemistry 86:123-128.
- Vera M, Biswas J, Senecal A, Singer RH, & Park HY (2016) Single-Cell and Single-Molecule Analysis of Gene Expression Regulation. Annual review of genetics 50:267-291.
- Wang J & Song Y (2017) Single cell sequencing: a distinct new field. Clinical and translational medicine 6(1):10.
- Yao J (2017) Imaging Transcriptional Regulation of Eukaryotic mRNA Genes: Advances and Outlook. Journal of Molecular Biology 429(1):14-31.

Course title
Seminars in bioprocess technology

ECTS credits
5

Language
English

Prerequisites
The course is a PhD-level course. National and international students admitted to the PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- is in the forefront of knowledge in how to efficiently apply advanced cultivation, separation and bioconversion methods, and how knowledge-based approaches can be used for optimizing the performance of various unit operations.

Skills
The candidate:
- can carry out advanced research of a high international standard on the processing of bioproducts from microbes, plants and various biomass raw materials into value added products.

General competence
The candidate:
- can discuss aspects of performance and characteristics of key unit operations or process phenomena based on a profound knowledge in bioprocess technology
- can assess the potential of bioprocessing in valorizing biomass resources
- can participate in debates about bioprocess technology in international forums

Content
- Fermentation technology; microbial growth models, mass and dynamic balancing, reactor design and control
- Adsorption chromatography; resin and mobile phase chemistry, protein binding kinetics and isotherms (Langmuir, Freundlich), particle mass transport, column designs and operation modes
- Membrane separation; fouling dynamics, cross flow filtration systems, single- and multistage systems, performance calculations
- Solute extraction and solubility; solute parameters, phase diagrams, solvent systems, reactor designs
- Enzymology and -technology; kinetic models of one- and two substrate reactions, stability vs. activity, substrate conversion, catalyst immobilization
- Use of bioprocessing in value-added processing of by-products and waste materials. Practical examples of valorizing biomass

Teaching and training methods
Individual reading and seminars

Required components
- An individual report dealing with one of the main topics or a specific bioprocess. Passed or failed.
- Participation in 80% of the organised teaching

Evaluation
Individual oral exam evaluated as passed or failed

Suggested reading
Seminar readings will encompass selected chapters from the following books to provide principles of the listed main topics:

- Brazinha, C., Cassano, A., Charcosset, C., Conidi, C., Crespo, J. G., Cuperus, F. P., ... & Gani, R. (2014). *Integrated membrane operations: in the food production*. Walter de Gruyter.
- Doran, P. M. (2013). *Bioprocess engineering principles*. 2nd ed. Academic Press.
- Karlsson, E. and I. Hirsh (2011). *Ion Exchange Chromatography*. In Protein Purification : Principles, High Resolution Methods, and Applications.3rd ed. J.-C. Janson. Hoboken, John Wiley & Sons**:** p.93-133.
- Katoh, S., Horiuchi, J. I., & Yoshida, F. (2015). *Biochemical engineering: a textbook for engineers, chemists and biologists*. John Wiley & Sons.
- Lucia, L. A., & Ayoub, A. S. (Eds.). (2017). *Introduction to Renewable Biomaterials: First Principles and Concepts*. John Wiley & Sons.

Journal articles will be selected in collaboration with students to give in-depth knowledge on specific topics; shown here a selection for 'protein adsorption mechanisms':

- Chung, W.K, et al. (2010). "Evaluation of protein adsorption and preferred binding regions in multimodal chromatography using NMR." PNAS **107**(39): 16811-16816
- Gao, D., D. Q. Lin, et al. (2008). "Patch controlled protein adsorption in mixed-mode chromatography with benzylamine as functional ligand". *Biochemical Engineering Journal* **38**(3): 355-361.
- Hahn, R. (2012). "Methods for characterization of biochromatography media. "*Journal of Separation Science* **35**(22): 3001-3032.
- Hubbuch, J. et a.l. (2003). "Mechanism and kinetics of protein transport in chromatographic media studied by confocal laser scanning microscopy: Part I. The interplay of sorbent structure and fluid phase conditions". *Journal of Chromatography A,* **1021**: 93-104.
- Jungbauer, A. (2005). "Chromatographic media for bioseparation. Review Article". *Journal of Chromatography A,* **1065**: 3-12
- Li, S. J., P. C. Chen, et al. (2006). "Establishing mathematical and physical models for the adsorption of biomacromolecules." *Applied Biochemistry and Biotechnology* **134**(2): 165-178.
- Regnier, F. E. (1987). "The role of protein structure in chromatographic behavior." *Science*, **238** (4825): 319-323.

Course title
Seminars in reproduction biotechnology

ECTS credits
5

Language
English

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- has state-of-the-art knowledge of the most advanced relevant techniques in cell and reproductive biotechnologies and gamete characterizing, including research methods used in reproduction biotechnology

Skills
The candidate:
- can analyze and use relevant scientific literature through in-depth knowledge in reproduction biotechnology
- can plan and perform advanced experiments within reproduction biotechnology and evaluate the results

General competence
The candidate:
- can participate in professional debates on reproduction biotechnology, the application and needs thereof in AI and breeding industry, veterinary and human medicine, and in science
- can communicate and discuss scientific questions related to reproduction biotechnology

Content
The following focus areas will be addressed:
- The theory of fertilizing capacity of gametes and germplasm in mammals and fish
- State-of-the-art concerning fertility phenotypes associated to genotypes
- Techniques to identify phenotypic traits important to fertilizing capacity
- The principles for preservation technologies
- The principles of *in vitro* fertilization models
- The principles of analysing the influence of reproduction technologies on fertility
- Experimental design, models and data mining for studies in reproduction biotechnology

Teaching and training methods
Intensive course with lectures and workshops

Required components
Participation in at least 80% of lectures and workshops

Evaluation
Individual oral exam evaluated as passed or failed

Suggested reading list

- Baldi, E. (2014). *Genetic Damage In Human Spermatozoa* (Vol. 791). New York: Springer.
- Birkhead, T. R., Hosken, D. J., & Pitnick, S. (2009). *Sperm biology: an evolutionary perspective*. Amsterdam: Elsevier.
- Chenoweth, P. J., & Lorton, S. P. (2014). *Animal andrology: theories and applications*. Wallingford: CABI.
- Constantinescu, G. M., Schatten, H., & Wiley, I. (2007). *Comparative reproductive biology*. Ames, Iowa: Blackwell Pub.
- Fazeli, A. (2017). *Periconception In Physiology and Medicine*: Springer.
- Hafez, E. S. E., & Hafez, B. (2000). *Reproduction in farm animals* (7th ed. ed.). Philadelphia: Lippincott Williams & Wilkins.
- Ginsburg, E. S., Racowsky, C., & ebrary, I. (2012). *In Vitro Fertilization: A Comprehensive Guide*: Springer New York: Imprint: Springer.

Journal articles will be selected in collaboration with students to give in-depth knowledge on specific topics, examples given:

- Aitken, R. J., Baker, M. A., & Nixon, B. (2015). Are sperm capacitation and apoptosis the opposite ends of a continuum driven by oxidative stress? *Asian J Androl, 17*(4), 633-639. doi:10.4103/1008-682x.153850
- Jenkins, T. G., Aston, K. I., James, E. R., & Carrell, D. T. (2017). Sperm epigenetics in the study of male fertility, offspring health, and potential clinical applications. *Syst Biol Reprod Med, 63*(2), 69-76. doi:10.1080/19396368.2016.1274791
- Ferraz, M., Henning, H. H. W., Costa, P. F., Malda, J., Melchels, F. P., Wubbolts, R., . . . Gadella, B. M. (2017). Improved bovine embryo production in an oviduct-on-a-chip system: prevention of poly-spermic fertilization and parthenogenic activation. *Lab Chip, 17*(5), 905-916. doi:10.1039/c6lc01566b
- Gadella, B. M., & Boerke, A. (2016). An update on post-ejaculatory remodeling of the sperm surface before mammalian fertilization. *Theriogenology, 85*(1), 113-124. doi:10.1016/j.theriogenology.2015.07.018
- Gadella, B. M., & Luna, C. (2014). Cell biology and functional dynamics of the mammalian sperm surface. *Theriogenology, 81*(1), 74-84. doi:10.1016/j.theriogenology.2013.09.005
- Galli, C., Duchi, R., Colleoni, S., Lagutina, I., & Lazzari, G. (2014). Ovum pick up, intracytoplasmic sperm injection and somatic cell nuclear transfer in cattle, buffalo and horses: from the research laboratory to clinical practice. *Theriogenology, 81*(1), 138-151. doi:10.1016/j.theriogenology.2013.09.008
- Kumaresan, A., Johannisson, A., Al-Essawe, E. M., & Morrell, J. M. (2017). Sperm viability, reactive oxygen species, and DNA fragmentation index combined can discriminate between above- and below-average fertility bulls. *J Dairy Sci, 100*(7), 5824-5836. doi:10.3168/jds.2016-12484
- Li, C.-j., Wang, D., & Zhou, X. (2016). Sperm proteome and reproductive technologies in mammals. *Anim Reprod Sci, 173*(Supplement C), 1-7. doi:https://doi.org/10.1016/j.anireprosci.2016.08.008
- Mandawala, A. A., Harvey, S. C., Roy, T. K., & Fowler, K. E. (2016). Cryopreservation of animal oocytes and embryos: Current progress and future prospects. *Theriogenology, 86*(7), 1637-1644. doi:10.1016/j.theriogenology.2016.07.018

- Mazur, P., Leibo, S. P., & Seidel, G. E., Jr. (2008). Cryopreservation of the germplasm of animals used in biological and medical research: importance, impact, status, and future directions. *Biol Reprod, 78*(1), 2-12. doi:10.1095/biolreprod.107.064113
- Tollner, T. L., Bevins, C. L., & Cherr, G. N. (2012). Multifunctional glycoprotein DEFB126--a curious story of defensin-clad spermatozoa. *Nat Rev Urol, 9*(7), 365-375. doi:10.1038/nrurol.2012.109.

Course title
Specialisation

ECTS credits
2.5 or 5

Prerequisites
No special requirements.

The course is a PhD-level course. National and international students admitted to a PhD program, or others fulfilling the requirement for admission to the PhD program may apply for admission to the course.

Learning outcome
After completing the course, the students should have the following learning outcomes with regard to knowledge, skills and general competence:

Knowledge
The candidate:
- has an in-depth understanding of a selected topic in a topic within life sciences

Skills
The candidate:
- is able to read and critically evaluate scientific publications concerning the specialization topic
- can apply this knowledge to other ecological or societal systems

General competence
The candidate:
- can discuss issues related to the specialisation based on a profound knowledge in the topic of the specialisation

Content
Individual readings as agreed by the student and the supervisor of the PhD consisting of 200-500 pages for 2.5 credits and 450-900 pages for 5 credits. The number of pages depend on the nature of the readings (less pages for very technical chapters and/or scientific publications than for general book chapters).

Teaching and training methods
Individual reading

Required components
None

Evaluation
Individual oral exam evaluated as passed or failed