Elective course catalogue for the Master´s Programme Plant Sciences

The Elective Course Catalog lists individual courses offered in the Master of Science Plant Sciences, including course instructors, descriptions of course contents and qualification goals. Courses are grouped according to subject, according to lectures, seminars and practical courses (in that order). Practical research courses (lab rotations) are listed exemplarily since they vary according to current topics in faculty research groups.

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Lectures, Seminars, Practical courses

Winter term

Main Topic Molecular Plant Sciences

Title	Lecture: An Introduction to Electron Microscopy
Content	The major components and working principles of an electron microscope will be demonstrated. Furthermore, the function and resolution of scanning and transmission electron microscopes as well as selected preparation and analytical methods will be explained in more detail.
Learning outcomes	The lecture should enable the students to understand the basic principles of electron microscopy and electron optics. This includes a deeper insight into the respective literature and publications. This lecture provides sufficient knowledge to successfully carry out internships and practical courses in the field of electron microscopy. Furthermore, students passing this lecture will be able to evaluate electron micrographs and the potential application of the presented methods in their own projects.
Responsible contact	Klingl, Andreas

Title	Lecture: Current topics in plant sciences
Content	This lecture series introduces the current research topics which are investigated within the groups of Molecular Plant Sciences. The module aims to significantly deepen and expand knowledge and understanding in the areas of photosynthesis, light signaling, signaling between plastid and nucleus or mitochondria and nucleus, regulation of metabolism, inheritance of organelles, “omics”-approaches, molecular mechanisms of stress adaptation, and the control of gene expression by non-coding RNAs.
Learning outcomes	Students obtain first-hand insights into the major research topics of the Molecular Plant Sciences section. They gain knowledge on current fundamental questions in plant molecular biology and physiology and different experimental approaches in plant model species. This introduction to on-going studies will help

	to obtain the fundamental knowledge required to participate in further specialized courses and to make decisions on the research topics and different laboratories for their final master's thesis.
Responsible contact	Bolle, Cordelia; Leister, Dario; Kleine, Tatjana; Meurer, Jörg; Schneider, Anja; Frank, Wolfgang; Geigenberger, Peter; Lehmann, Martin; Klingl, Andreas

Title	Lecture: From cannabis and nicotine to anti-cancer drugs - plant derived drugs and how they function in plants and in humans
Content	The powerful and often well-known plant-derived drugs interact with molecular and cellular mechanisms in animals, including humans. As an interdisciplinary approach between plant and animal cell biology, it covers, on the one hand, cellular signal transduction mechanisms in animals, concentrating on seven-transmembrane receptors (GPCRs) and ion channels, but also on cancer cell growth. On the other hand, it describes how and why plants produce these secondary metabolites. The interplay between these topics is illustrated by elaboration on prominent plant-derived drugs that constitute potent plant toxins, pharmaceutically used drugs to treat human disease as well as so-called recreational drugs.
Learning outcomes	The students wil be able to integrate knowledge in an interdisciplinary way learning also to understand how co-evolution can happen.
Responsible contact	Bolle, Cordelia; Böttger, Angelika

Title	Seminar: Design of experiments in plant science
Content	Research projects related to current questions in plant science are assigned to each participant. The aim is that the students research the topics independently by finding appropriate literature and resource. Then the students' task is to apply learned techniques to this topic and to propose how to address these scientific

	questions. Students consult regularly with the instructor.
Learning outcomes	Students need to apply (theoretically) acquired knowledge about techniques and methods to the scientific questions posed. This allows a transfer of knowledge and application of techniques learned in different lectures and practical courses. Furthermore, the students are introduced to library and internet resources, can sharpen presentation skills gained through speaking in front of a group and learn how to plan experiments is fundamental for a further scientific career.
Responsible contact	Bolle, Cordelia; Leister, Dario; Schneider, Anja

Title	Seminar: Hot topics in (cryo) electron microscopy
Content	The seminar covers the most recent and advanced developments and inventions in high-resolution (cryo) electron microscopy and closely related areas. It deals with the variety of advanced (cryo) methods applied in electron microscopy in general an which are partially also applied at our institute. These are methods like high-pressure freezing, imunogold localization, 3D structure of cells, SBF-SEM, FIB/SEM-tomography, TEM- and STEM-tomography or single particle analysis. In the seminar, students are working on a selected topic which includes the discussion on a current publication applying the respective method.
Learning outcomes	Within this seminar, students can intensify and deepen the knowledge gained in the lecture 'An introduction to electron microscopy'. They will get insight into the application of advanced methods, experience limitations and shortcomings of the techniques. After the seminar, students will be able to understand the technical principles and to discuss about the presented methods with other researchers in that scientific field.
Responsible contact	Klingl, Andreas; Pickl, Carolin

Title	Practical course and Seminar: Regulation of plant metabolism
Content	In the seminar, students present and discuss different topics related to the investigation of plant metabolism, its regulation in response to environmental and physiological signals, and its significance for plant function and application. It builds on the Bachelor's level and aims to deepen and expand knowledge about (i) methods in plant metabolism research, (ii) regulatory mechanisms and signals, (iii) relevance for plant performance and function, and (iv) significance to optimize output traits and human application. The practical course will focus on the analysis of the carbohydrate metabolism in plants and its regulation. Investigations will be done in the context of metabolic regulation in response to environmental signals, regulatory sites and mechanisms, and the influence of carbohydrate metabolism on plant development. For this purpose, the students will unravel the genetic background of Arabidopsis knock-out lines applying selected approaches for phenotypic analyses, extraction and photometric quantification of metabolites, and determination of the redox-state of proteins by conserving western blots. The qualitative and quantitative data thereby generated will be evaluated and discussed by the students.
Learning outcomes	Within the seminar, the students will be able to present and communicate theoretical basics of plant metabolism research in a clear and unambiguous manner. They will gain expertise in exchanging information and ideas on a scientific level with experts and with laypersons, and to transfer knowledge to actual problems in plant biology and human society. In the practical course the students will strengthen their skills for future lab work. They will be able to communicate, apply and evaluate enzyme-based methods for metabolite quantification and methods to analyze post-translational redox-modifications of proteins. They will learn basic principles how to plan and perform experiments to analyze plant metabolism and to investigate redox regulation. For submission of a detailed lab report, the students are expected to put the obtained results in a biological context and discuss them critically, whereby they will train their scientific writing skills.
Responsible contact	Paul, Melanie; Geigenberger, Peter

Title	Practical course: Molecular Plant Biology
Content	The aim of this course is to teach relevant methods within the background of fundamental principles in plant science. We compare Arabidopsis mutants with defects in the photosynthesis on the physiological (state transition measurements) and biochemical level. Participants are introduced to advanced biochemical techniques such as the isolation of protein complexes (photosystems) and to analyze them with Blue Native Gel analysis, 2D gel electrophoresis, and Western analysis. Furthermore expression patterns in the nucleus and the plastids are compared (Northern blot and RT PCR, non-radioactive labeling of probes). The emphasis lies on hands-on practice as the students are preparing every step of the experiment themselves, from making solutions to discussing the results. Furthermore, they are trained to compare different methods and to understand the biological and biochemical background of the methods used.
Learning outcomes	Students obtain necessary skills for future lab work, in particular in preparation for their master's thesis. The methods are taught in reference to the biological questions asked. Therefore, a transfer of theoretical knowledge to practical applications can be made. In working in small lab groups, social skills (teamwork, cooperation, fair play, work delegation, mutual respect), communication skills(rapport with instructors and fellow students, presentations, written lab reports), as well as organizational skills (efficient planning, documentation) are refined.
Responsible contact	Bolle, Cordelia; Leister, Dario; Schneider, Anja

Main Topic Cellular Plant Sciences

Title	Lecture: Biochemistry and cell biology of plants
Content	The lecture covers advanced aspects of cellular structures and metabolic pathways specific for plant cells and tissues such as special forms of photosynthesis, plant respiration, evolution and function of plant organelles, protein transport and intercellular communication.
Learning outcomes	At the end of the lecture the students have obtained fundamental knowledge about the particularity of the plant cell in structure and function. They are able to

	understand the specific function of plant specific organelles and metabolic processes for plant life.
Responsible contact	Geigenberger, Peter; Nägele, Thomas

Title	Seminar: Molecular and ecological aspects of biotechnology with microalgae and cyanobacteria
Content	In the seminar, the students present and discuss recent literature dealing with biotechnological and ecological aspects of algal cultivation. Topics are: Ecological optimization of algal mass cultivation in bioreactors and open pond systems; The use of micro-algae and cyanobacteria trait diversity to create product-tailored growth systems; Biotechnological optimization of algal mass cultivation in bioreactors; Modern methods of molecular plant sciences to optimize the yield of desired/valuable products in algal growth systems; The use of genetically modified microalgae and cyanobacteria for commercial algal growth systems. Risks and risk-evaluation of genetically modified algae and cyanobacteria for natural aquatic systems.
Learning outcomes	The students will be able to present the content of scientific publications in a clear and focused manner within a given time frame. Students will be able to integrate knowledge from Molecular Plant Sciences and Ecology and to apply it to modern approaches in Biotechnology but also Environmental Sciences. Students will be able to exchange information and arguments about genetically modified organisms on a scientific level with experts and with laypersons.
Responsible contact	Stibor, Herwig; Nickelsen, Jörg

Title	Practical course and Seminar: Systems Biology
Content	The seminar introduces theoretical basics of systems biology and builds on Bachelor's level in biochemistry, molecular biology and mathematics. Further, it introduces to computational approaches of metabolic modelling. Addressed topics are (i) metabolic networks, (ii) enzyme kinetics, (iii) biochemical regulation, (iv) kinetic modelling and (v) statistics. The

	practical course will introduce to experimental analysis in plant systems biology. The students will apply experimental methods of enzyme kinetics, metabolite quantification and flux measurements of CO2 uptake and release via photosynthesis and respiration. The practical course will introduce to buffer systems for enzyme extraction, photometric metabolite quantification and infrared spectroscopy. Experimental parameters will be computationally analysed using software packages for metabolic modelling.
Learning outcomes	After participating in the semeinar the students will be able to integrate quantitative data on metabolism, e.g. enzyme kinetics and proteomics data, in context of metabolic regulation. They will be able to communicate and present their conclusions in an unambiguous manner. They will gain expertise in exchanging information on a scientific level with experts in the research field of systems biology. The practical course will enable the students to quantify diurnal dynamics and environmental stress effects on plant metabolism, e.g. due to low temperature. They will learn how to apply experimental data for computational analysis of complex biological systems. Students will learn to scientifically present and communicate their findings to researchers in the field of systems biology.
Responsible contact	Nägele, Thomas; Fürtauer, Lisa

Main Topic Systematic Plant Sciences

Title	Lecture: about dispersal biology of flowering plants Vorlesung: Einführung in die Ausbreitungsbiologie der Samenpflanzen und mikroskopische Techniken
Content	The lecture builds on the Bachelor's level and covers the basic principles of dispersal biology in plants as well as optical microscopy. The following topics are addressed: Dispersal, anemo- and hydrochory; epi- and endozoochory.
Learning outcomes	Students are proficient in the contents of dispersal biology in plants as well as basic light microscopy techniques. Students obtain the fundamental knowledge required to participate in further specialized courses. This competence is the basis to make scientifically sound decisions in the areas of Systematic Biology.
Responsible contact	Facher, Eva-Justina; Gottschling, Marc

Title	Lecture: morphology and diversity of eucaryotic algea - Vorlesung: Morphologie und Diversität der eukaryotischen Algen und mikroskopische Techniken
Content	The lecture builds on the Bachelor's level and covers the morphological and molecular diversity of eukaryotic algae (e.g., red algae, green algae, brown algae, dinophytes) based on phylogenetic analyses published in the past years.
Learning outcomes	Students are proficient in eukaryotic phycology as well as basic light and electron microscopy techniques. Students obtain the fundamental knowledge required to participate in further specialized courses and are equipped with the basic knowledge prerequisite to scientific research in this topic. This competence is the basis to make scientifically sound decisions in the areas of Systematic Biology.
Responsible contact	Facher, Eva-Justina; Gottschling, Marc

Title	Lecture: Systematic Data and Evidence
Content	A series of lectures will discuss the following topics: paleontological and biogeographical data; speciation and radiations; diversity hotspots; principles of phylogenetic tree inference; introduction to biological collecting and collections (including visits to the Bavarian Natural History collections); taxon-specific approaches and problems (e.g., species concepts in bacteria, species concepts in higher organisms, the morpho species concept in paleobiology); role of organismal interactions in the evolution of adaptation; role of systematics in evolutionary biology; the meaning of classification, indentification, nomenclature and taxonomy.
Learning outcomes	Participants will acquire an understanding of the kinds of data used to infer phylogenetic relationships and macroevolution. They will also understand and be able to discuss some problems in systematics and will know

	the role of systematics in evolutionary biology. Two-three short essays are part of the course requirements.
Responsible contact	Krings, Michael; Haszprunar, Gerhard; Renner, Susanne; Grupe, Gisela

Title	Seminar: Any Plan(t)s for Climate Change? - The impact of global warming on plant communities
Content	Selected topics will be discussed in the seminar, such as: "Venoms and toxins", "Basic Toxicology", "Algae blooms", "Plant Acids", "Saponins", "Alkaloids", "First Aid", "Genotoxic plants", "Allergic shock", "Genetically modified plants"
Learning outcomes	Skills: - Acquire competence in extracting information from various sources and to study about an external subject - Learn how to structure and present scientfic data - Practice your presentation skills, communication techniques and body language - Learn to give a stimulating oral presentation in front of a critical audience and to appreciate feedback - Secure your knowledge competences in plant abiotic stress responses and environmental biology
Responsible contact	Wanke, Dierk

Title	Seminar: Toxins - Toxic plants - Plant toxins
Content	Selected topics will be discussed in the seminar, such as: "Venoms and toxins", "Basic Toxicology", "Algae blooms", "Plant Acids", "Saponins", "Alkaloids", "First Aid", "Genotoxic plants", "Allergic shock", "Genetically modified plants"
Learning outcomes	Skills: - Acquire competence in extracting information from various sources and to study about an external subject

	- Learn how to structure and present scientfic data - Practice your presentation skills, communication techniques and body language - Learn to give a stimulating oral presentation in front of a critical audience and to appreciate feedback - Secure your knowledge competences on plant secondary metabolism - Learn about the biology of venoms, poisons and toxins
Responsible contact	Wanke, Dierk

Title	Seminar: Tropical Rainforests: Ecology, Conversion, Conservation
Content	Students read, explain and present scientific publications on the basic ecology of tropical rain forest ecosystems, on processes which lead to degradation and deforestation, the role of tropical deforestation for climate change and on potentially successful strategies to protect the remaining forests. The literature consists mainly on recent articles published in renowned scientific journals but includes also some selected grey literature such as NGO reports and internet resources of official bodies such as UNFCCC and FSC.
Learning outcomes	The students prepare and give a PowerPoint presentation on a selected topic based on a scientific article and additional material (photographs, graphs, illustrations) from internet resources. They will respond to questions from the audience and lead the discussion.
Responsible contact	Siegert, Florian

Title	Practical course: about dispersal biology of flowering plants - Praktikum: Einführung in die Ausbreitungsbiologie der Samenpflanzen und mikroskopische Techniken
Content	In the practical course, students are introduced to step-by-step procedures for anatomical studies, including

	detailed observation, embedding and sectioning of specimens as well as standard visualization techniques using light microscopy. Emphasis is put on the relevance and hands-on practice with these microscopic techniques, and interpretation and presentation of data.
Learning outcomes	Students obtain skills for future lab work (particularly in preparation for their master's thesis), whereas the techniques of microtomy have diverse applications in biology and medicine. Students are well-trained in good general lab practice, including standard safety procedures, precise handling of chemicals and instruments and conscientious documentation of lab procedures. By working in small lab groups, social skills (teamwork, cooperation, fair play, work delegation, mutual respect), communication skills (rapport with instructors and fellow students, presentations, written lab reports) as well as organizational skills (efficient planning, documentation) are refined.
Responsible contact	Facher, Eva-Justina; Gottschling, Marc

Title	Practical course: about the diversity of lichens II - Übung und Seminar zur Artenvielfalt von Flechten II
Content	The aim of this course is to obtain practical expertise in identifying lichens with the standard identification keys and techniques.
Learning outcomes	Students get an overview of the most important groups of lichen-forming fungi, and learn in depth how to identify these fungi. Moreover, they obtain an overview of the common lichens in Bavaria.
Responsible contact	Werth, Silke; Resl, Philipp

Title	Practical course morphology and diversity of eukaryotic algea - Praktikum: Morphologie und Diversität der eukaryotischen Algen und mikroskopische Techniken

Content	In the practical course, students are introduced to step-by-step procedures for light and electron microscopy, including detailed observation, fixation and preparation of specimens as well as standard visualization techniques using light and scanning electron microscopy. Emphasis is put on the relevance and hands-on practice with these microscopic techniques, and interpretation and presentation of data.
Learning outcomes	Students obtain skills for future lab work (particularly in preparation for their master's thesis), whereas the techniques of microscopy have diverse applications in biology and medicine. Students can apply theoretical and practical knowledge to approach biological questions in independent work. Students are well-trained in good general lab practice, including standard safety procedures, precise handling of chemicals and instruments and consciencious documentation of lab procedures. In working in small lab groups, social skills (teamwork, cooperation, fair play, work delegation, mutual respect), communication skills (rapport with instructors and fellow students, presentations, written lab reports) as well as organizational skills (efficient planning, documentation) are refined.
Responsible contact	Facher, Eva-Justina; Gottschling, Marc

Title	Botany-bird excursion to Mallorca with preparatory seminar
Content	We will explore the typical ecosystems of Mallorca, such as maquis shrubland, coastal pine forests, and dune habitats, but also the species rich ecosystems of the cultural landscape. The main focus is on typical Mediterranean and endemic Balearic plants. We will also look at lichens and birds. With a visit to S'Albufera, a protected area featuring many endangered or rare bird species, rich in migratory birds.
Learning outcomes	Students obtain knowledge of the species diversity of a Mediterranean island, with its characteristic species, featuring many endemics and typical Mediterranean plants and birds. They moreover learn how to analyze and recognize the typical plant communities of the region.
Responsible contact	Werth, Silke

Main Topic Organismic interaction in Plants

Title	Lecture: Genomes and Gene regulation
Content	the lecture will cover the following topics: - genomes (ploidy, content, organization, structure) - accessory genomes, extrachromosomal elements, sex chromosomes - Cell cycle regulation - Mitosis and meiosis - transcription and transcriptional regulation (promotors, regulatory elements, transcriptionfactors and regulatory RNAs, processing of RNAs) - epigenetics - translation and regulation of translation - - small RNAs
Learning outcomes	Students will obtain the following skills: - knowledge of the basic genetic and molecular principles of the content above - understanding of the regulatory mechanisms underlaying these principles - - transferknowledge to related biological systems
Responsible contact	Boshart, Michael; Parniske, Martin; Marin, Macarena; Hann, Dagmar

Title	Lecture: Recent discoveries in host-microbe interactions
Content	the lecture will cover the following topics: - plant endosymbiosis - plant immunity - plant disease - soil microbiomes - bacterial entry - small RNAs in host-microbe interactions - Trypanosoma as a model system - cAMP singling in Trypanosoma - - allelopathic interactions

Learning outcomes	Students will obtain the following skills: - knowledge of advanced genetic and molecular principles of the content above - understanding of the regulatory mechanisms underlaying these principles - - transfer knowledge to related biological systems
Responsible contact	Brachmann, Andreas; Parniske, Martin; Marin, Macarena; Weiberg, Arne; Robatzek, Silke

Title	Seminar: Food and genes
Content	Life is specified by genomes. Every organism, including the crops that produce our daily foods, has a genome that contains all the biological information—the DNA—needed to build and maintain a living example of that organism. The biological information contained in the DNA is divided into genes, discrete units of the genome. The complete set of genes represents the genetic constitution that makes up the genotype of an organism. Crops often have complex genomes to achieve desired agronomic traits. Yet, crop genomes often exhibit specified genetic diversity to maintain desired agronomic traits. This makes crops vulnerable to infection by co-evolving pests and pathogens and poses ongoing challenges in modern crop breeding to keep up with demands from an increasing world population.
Learning outcomes	This aim of this seminar is to develop an understanding of the unique genetic makeup of our foods and co-evolving pests and pathogens. Evaluating the origin of modern cops and the way they have been bred over centuries to perform best for productivity, human-desired traits, and resistance to environmental stress will be used to gain knowledge on genome architecture and genes regulating agronomic traits. This will be complemented by looking at the genetic diversity present in crops, and evaluating the genomes of co-evolving pests and pathogens to recognise the challenges in food security. A basis for this seminar are the lectures "Genomes" and "Forward and Reverse Genetics".
Responsible contact	Robatzek, Silke

Title	Seminar: Genetics and Society The human genome and its implications for mankind (seminar longitudinal to the lecture genomes and genomics)
Content	The overarching theme of this seminar is "The human genome project and its implications for mankind". You will learn the genetics principals and findings related to this topic and discuss the resulting implication for society as well as legal aspects. The following topics will be discussed: - the human genome project - CRISPR/Cas - fingerprinting - personalized medizine - pre-implantation diagnostics - ExAc project - epigenetics - 24 and me
Learning outcomes	Students will obtain the following skills: - presentation skills - literature search and evaluation - design of scientific questions - literature-based argumentation - moderation of discussionsobtain
Responsible contact	Boshart, Michael; Parniske, Martin; Hann, Dagmar

Title	Seminar: Pseudowissenschaft in Theorie und Praxis
Content	Die Medizin ist nur eines von vielen Beispielen, die zeigen, wie wichtig die Unterscheidung zwischen Wissenschaft und Pseudowissenschaft ist. Wer wissenschaftlich erforschte Arzneimittel verwendet, der maximiert seine Chance auf Heilung. Wer sich dagegen auf pseudowissenschaftliche Präparate verlässt, der verschenkt diese Chance oder schadet sich sogar. Aus diesem Grund sind Pseudowissenschaften nicht nur von wissenschaftsphilosophischem Interesse. Es handelt sich dabei außerdem um ein wichtiges, lebenspraktisches Thema.
Learning outcomes	Im Seminar wollen wir sowohl über die Theorie als auch über die Praxis der Pseudowissenschaften sprechen. Es soll also einerseits um die philosophische Frage nach dem Wesen und den Merkmalen von

	Pseudowissenschaften gehen. Andererseits wollen wir konkrete Pseudowissenschaften aus verschiedenen Bereichen mithilfe eines wissenschaftsphilosophischen Methodenarsenals diskutieren.
Responsible contact	Brachmann, Andreas; Mukerji, Nikil

Title	Practical course and Seminar: How to design experiments and write a project proposal
Content	The course will cover the following topics: - Sustainable development goals of the united nations and their relevance for agriculture - plant root endosymbiosis - Root nodule symbiosis (cell biology, genetics and signaling) - Transcriptional regulation of root nodule symbiosis - genetic diversity in root nodule symbiosis
Learning outcomes	Students will obtain the following skills: - advanced understanding of literature search and evaluation - advanced understanding of scientific writing skills - knowledge of DFG-style proposals - knowledge of correct citation principles - applied knowledge of methods in plant root nodule symbiosis and experimental planning - detailed project calculation - understanding of the peer-review process
Responsible contact	Parniske, Martin; Marin, Macarena; Hann, Dagmar

Title	Practical course and Seminar: Small RNAs in Plant Microbe Interactions
Content	Small RNAs are non-coding gene regulatory units existing in all kind of life. In this regard, small RNAs are important moderators during the interaction of microbes with their host organisms. In plants, small RNAs regulate immunity by fine-tuning gene expression. However, Pathogens evolved “sneaky” strategies to mimic plant small RNAs in order to transmit them into their hosts to manipulate host immunity for infection. In this course, we will introduce

	you into the exciting but rather unexplored field of small RNA trans-kingdom communication and to the ways pathogens use small RNAs to invade their hosts.
Learning outcomes	In this course you will study two plant pathogen models, the gray mold pathogen Botrytis cinerea and the downy mildew pathogen Hyaloperonospora arabidopsidis, which use small RNAs for host colonization, by means of modern, state-of-the-art techniques involved in small RNA research and in molecular plant pathology. You will receive hands-on training in the following techniques: -Fungal culturing and plant infection assays -Pathogen quantification assays -How to deal with (tall) RNAs and small RNAs -Pathogen and plant microRNA and siRNA detection and analysis -Quantification of gene expression (real-time PCR)
Responsible contact	Parniske, Martin; Weiberg, Arne

Title	Practical course: Plant molecular cell biology (non-coding, regulatory RNAs in Physomitrella patens)
Content	Participants are introduced to step-by-step procedures for the isolation of plant DNA and RNA, cDNA preparation, real time PCR detection and quantification of small RNAs and mRNAs, and analysis of cleavage products of small RNA target genes via Rapid Amplification of cDNA Ends (RACE) PCRs. Specific small RNA biogenesis pathways will be analysed at the molecular level in Physcomitrella patens mutant lines that are affected in essential proteins of the small RNA processing machinery (e.g. DICER-LIKE knockout mutants).
Learning outcomes	Students are trained in general lab practice, including standard safety procedures, handling of chemicals and instruments, and documentation of lab procedures. Students obtain the fundamental knowledge and hands-on practice on basic molecular biological methods required for future master's thesis research in the field of Plant Molecular Biology. Students will work in small groups, so they will get awareness about the team-work, cooperation and mutual respect which are desired characteristics for succeeding in any field.

	Students obtain a basic knowledge to write a scientific research report which is the basis for writing a scientific publication.
Responsible contact	Frank, Wolfgang; Arif, Muhammad

Title	Practical course: Molecular biology and biochemistry of photoautotrophic microorganisms
Content	The course imparts knowledge about the principles of plastidic gene expression. Students will work with the unicellular green alga Chlamydomonas reinhardtii and analyze different strains with regard to their gene expression at the level of transcription as well as translation. Applied methods comprise reporter gene expression analysis, nuclear transformation of C. reinhardtii, and testing of growth under photoautotrophic conditions. Emphasis will lie on molecular methods, like the isolation and detection of DNAs (Southern blot), RNAs (Northern blot) as well as proteins (Western blot), respectively. Based on the performed phenotypical and molecular analyses of different strains the students will be able to draw conclusions on the identity of the investigated mutants.
Learning outcomes	After participation in this course, students will know how to combine different methods to address a specific scientific question. They will be able to summarize, present, and discuss the outcome. Furthermore, they can distinguish different regulatory levels of gene expression and integrate the obtained results in an overall context. Methodically, they have deepened skills in Southern, Northern and Western analysis and will have gained insights into basic working practice with unicellular green algae.
Responsible contact	Bohne, Alexandra-Viola; Heinz, Steffen; Nickelsen, Jörg

Title	Seminar: Genetics and Society 1 - Biotechnology
Content	In the media we again and again hear buzzwords like „genefood“, „green genetics“ or „cloned animals“. In this seminar, we will not only discuss the scientific background but also ethical, economical and legal

	consequences of genetic research and its implementation.
Learning outcomes	Students will learn how to independently research broad and complex scientific topics: starting from the technological principles, they need to assess their political, moral, and ethical implications for society. Furthermore, students will learn how to reduce the complexity of these topics such that they can be presented in a relatively short time frame. Because the seminar topics are often controversial, the final goal of the seminar is to train the students in building an opinion and on scrutinizing it in discussing with the fellow students.
Responsible contact	Becker, Claude

Title	Practical course: and seminar: Eukaryotic transcription and regulation
Content	Classical forward genetics continues to be a powerful approach to find genes involved in chosen biological processes and to obtain unequivocal information about gene products that provide the molecular basis of biological phenomena and/or functions. Research in molecular biology therefore strongly benefits from a good knowledge of genetic techniques. Traditionally, genes required for a chosen process are searched for by a forward genetic screen for aberrant phenotypes in a population of mutants, which is followed by the identification of the causal mutation by genetic mapping. Nowadays, the efficiency and speed of genetic mapping is highly increased by Next Generation Sequencing (NGS). NGS allows rapid and low cost sequencing of the complete genome of a given mutant and identification of the mutation by bioinformatic comparison of the mutant to the WT genome. Plants interact with a myriad of microorganisms of which some act as parasitic pathogens and others as beneficial symbionts. In this course we will focus on plant genetics of two root symbioses with microorganisms, the arbuscular mycorrhiza (AM) and the root nodule symbiosis (RNS). These symbioses are on one hand of agricultural interest because they provide mineral nutrients to the plant. On the other hand they are of great biological interest because they represent fascinating examples for reciprocal signal exchange between two organisms that leads to

	compatibility and extraordinary reprogramming and restructuring of the plant cell, that allows the intracellular accommodation of an "alien" microsymbiont.
Learning outcomes	In this course you will learn how to use forward genetics to find mutated gene(s). By performing segregation analysis and genetic mapping of a segregating population of a symbiotic Lotus japonicus mutant you will gain practical hands-on experience in finding a candidate region in the genome in which your mutation resides. Furthermore, you will bioinformatically analyze NGS data to find the mutation underlying a symbiotic phenotype. We will perform segregation analysis and mapping with a nodulation mutant of which we do not know the locus responsible for the phenotype. Therefore, in this part of the course you will get involved in a "real research situation". Furthermore, you will learn how to extract nodulation signaling factors from Rhizobia and test their activity using a reporter-gene assay. You will also learn how to microscopically recognize features of rhizobial colonization (infection threads and nodules) and respective mutant phenotypes.
Responsible contact	Parniske, Martin; Hann, Dagmar

Summer Term

Main Topic Molecular Plant Sciences

Title	Lecture: Advanced topics about (cryo) electron microscopy
Content	The lecture builds on the lecture 'An introduction to electron microscopy'. It will deepen the knowledge about the physical principles in electron microscopy and how one can use this for improving the resolution limits in (cryo) electron microscopic applications like TEM-, STEM- and FIB/SEM-tomography, electron crystallography or single-particle analysis. Amongst others, the lecture will deal with topics like electron guns, detectors, EM lenses, energy filters, image formation, fourier transforms, reciprocal space and electron waves, convolution and cross-correlation, contrast (contrast transfer function, CTF) and CTF-correction.
Learning outcomes	The lecture will lead to a deeper understanding of the mathematical and physical background of resolution and how it can be influenced and improved in electron microscopy. Following this lecture, students will be able to develop new and own ideas and experiments not just in the application of already existing techniques but also in the developmental area, e.g. correctors for spherical aberration in TEMs. Attendees of the lecture will not just be provided with broad expertise but they will also be ideally primed as potential future employees in (electron) microscopy companies and related fields.
Responsible contact	Klingl, Andreas

Title	Lecture: Interactions of plants and environment
Content	Plants as sessile organisms react on adverse environmental conditions by a diversity of physiological adaptations. This lecture covers the basics in the interaction of plants with the environment and the specific responses to different kinds of stimuli and stresses. Adaptation mechanisms will be reviewed in depth to be able to teach biochemical and molecular

	mechanisms in more detail and to reinforce recurring mechanisms.
Learning outcomes	Students obtain the fundamental knowledge required to participate in further specialized courses and are able to depict basic principles.
Responsible contact	Bolle, Cordelia; Leister, Dario; Kleine, Tatjana; Schneider, Anja; Frank, Wolfgang; Geigenberger, Peter; Arif, Muhammad; Rühle, Thilo

Title	Lecture: Eukaryotic gene regulation
Content	The lecture starts by revisiting the molecular principles of gene expression, from transcription initiation to the end of translation. It then covers the different levels of gene regulation, from transcriptional to post-transcriptional to translational and post-translational regulation. The true focus throughout the lecture is on the methods employed in modern biology to study gene expression at these different levels. The theoretical background of the techniques is covered, as are their practical limitations, their caveats and benefits.
Learning outcomes	- Theoretical knowledge on the molecular mechanisms underlying gene expression and its regulation. - Knowledge of key historical experiments and discoveries in the field of gene expression and regulation. - Knowledge of the fundamental differences between gene expression in pro- and eukaryotes. - Awareness and understanding of key molecular and computational methods that are employed in current research to study gene expression and gene regulation
Responsible contact	Becker, Claude

Title	Seminar: Current methods in electron microscopy
Content	The seminar covers the most recent and advanced developments and inventions in high-resolution (cryo) electron microscopy and closely related areas. It deals

	with the variety of advanced (cryo) methods applied in electron microscopy in general an which are partially also applied at our institute with a main focus on the preparational background. These are methods like high-pressure freezing, imunogold localization, 3D structure of cells, SBF-SEM, FIB/SEM-tomography, TEM- and STEM-tomography or single particle analysis. In the seminar, students are working on a selected topic which includes the discussion on a current publication applying the respective method highlighting the advantages and disadvantages of the application.
Learning outcomes	Within this seminar, students can intensify and deepen the knowledge gained in the lecture 'An introduction to electron microscopy'. They will get insight into the application of advanced methods, experience limitations and shortcomings of the techniques. After the seminar, students will be able to understand the technical principles and to discuss about the presented methods with other researchers in that scientific field.
Responsible contact	Klingl, Andreas

Title	Seminar: Mechanisms of plant gene regulation
Content	In the seminar, the students critically discuss diverse mechanisms of gene regulation in plants. Specifically, the students select a topic, search, select and read a recent relevant publication and present the results and outcome of this publication in this seminar. Ideally, several new topics including gene regulation by non-coding RNAs, epigenetic mechanisms, post-transcriptional control, signals and triggers for gene expression will be discussed and presented.
Learning outcomes	The students will be able to communicate and to present the content of a recent scientific report or publication in a clear and unambiguous manner and to exchange information and general ideas on a scientific level with student fellows and experts in Plant Molecular Cell Biology.
Responsible contact	Frank, Wolfgang; Arif, Muhammad

Title	Seminar: Methods in transmission electron microscopy and their application
Content	Within this seminar and the corresponding practical course, the students will learn how to perform the preparation of a variety of biological specimens for subsequent transmission electron microscopy. Samples will include plant material, photosynthetic algae and prokaryotes. The applied methods will include chemical and cryo-fixation, embedding and thin section, negative staining, immunogold localization and 3D electron microscopy (e.g.: TEM tomography). As a final part of the course, data processing and analysis will play a central and important role.
Learning outcomes	The seminar will give the students the possibility to understand the sample preparation methods that they practically learn in the practical part of this module. In the end, it should enable the students to develop own ideas and experiments in this and realted fields and to carry out research internships or their master thesis in this scientific area.
Responsible contact	Klingl, Andreas; Pickl, Carolin

Title	Seminar: Molecular biology and genetic engineering
Content	In this seminar, current advances of the members in the Leister lab are presented. Topics related to current projects in the laboratory are assigned to each participant. Using recommended literature and resources, students independently research similar topics. In this way the students can deepen and expand their knowledge in the areas of photosynthesis, systemic biology, "omics"-approaches, thylakoid membrane function and signalling between plastid and nucleus. Additionally it allows them to understand better advanced methodes used in these fields.
Learning outcomes	The students will be able to extract relevant information from papers and communicate their conclusions in a clear and unambiguous manner. Students are proficient in presentation skills with different media, are introduced to library and internet resources, can assess and present a topic thoroughly and understandably to scientific peers.They gain inside in current scientific projects from the PhD students that present some of their project and can exchange

	information and ideas on a scientific level and discuss a project in a broad context.
Responsible contact	Bolle, Cordelia; Leister, Dario; Kleine, Tatjana; Meurer, Jörg; Schneider, Anja; Rühle, Thilo; Lehmann, Martin

Title	Practical Course: Methods in transmission electron microscopy and their application
Content	Within this practical course and the corresponding seminar, the students will learn how to perform the preparation of a variety of biological specimens for subsequent transmission electron microscopy. Samples will include plant material, photosynthetic algae and prokaryotes. The applied methods will include chemical and cryo-fixation, embedding and thin section, negative staining, immunogold localization and 3D electron microscopy (e.g.: TEM tomography). As a final part of the course, data processing and analysis will play a central and important role.
Learning outcomes	The practical course will give the students the possibility to practically learn the application of the diverse sample preparation methods for electron microscopy and the subsequent investigation of the samples in the respective microscope. It should enable the students to develop own ideas and experiments in this and realted fields and to carry out research internships or their master thesis in this scientific area.
Responsible contact	Klingl, Andreas; Pickl, Carolin

Main Topic Cellular Plant Sciences

Title	Lecture: Membranes - biological and physical aspects
Content	The lecture introduces to biochemical and physical aspects of biomembranes. Topics which are addressed are: Physical and chemical properties of lipids; Lipid biosynthesis; Membrane proteins; Function of biomembranes; Membrane transport of ions, metabolites and proteins; Vesicle transport; Methods in membrane research.

Learning outcomes	The students will obtain fundamental knowledge about molecular structure, composition and function of biomembranes in a cellular context. They will be able to understand how membranes are involved in cellular and signalling processes. They will learn to integrate and interpret information in the research field of biomembranes.
Responsible contact	Nägele, Thomas

Title	Seminar: Current topics in cell biology and physiology of plants
Content	In this seminar, current topics and research projects in cell biology and physiology of plants are presented and discussed. The students choose recently published research papers to give oral presentations followed by a discussion. Furthermore, students are encouraged to think critical and to participate in the discussions actively.
Learning outcomes	The students will be able to present and communicate current scientific literature in a clear and unambiguous manner. They will gain expertise in exchanging information and ideas on a scientific level with experts in the field of cell biology and physiology of plants, and to transfer knowledge to actual problems in plant biology and human society.
Responsible contact	Paul, Melanie; Geigenberger, Peter

Title	Seminar: Evolutionary cell biology of plants
Content	The seminar introduces to topics of current research in the field of plant biology. The topics which are addressed are: Plant evolution; Cell biology; Stress physiology; Plant development and ecology.
Learning outcomes	Students will be able to summarize and critically discuss literature on research in current plant biology. They will be able to communicate their conclusions in a clear and scientific manner for exchange of information

	and ideas with experts in the field of plant evolution and cell biology.
Responsible contact	Nägele, Thomas; Fürtauer, Lisa

Title	Seminar: Molecular and ecological aspects of biotechnology with micro-algae and cyanobacteria
Content	Participants get insights into current work in the field of molecular biology, biotechnology and ecology of cyanobacteria, algae, and cell organelles. They present results of a recommended publication in an oral presentation according to excellent scientific practice, to the entire group. After each talk, the subject is discussed in the whole group and the presenter is supposed to answer questions.
Learning outcomes	Students are introduced to current literature and learn how to independently research a topic. They improve their presentation skills and learn how to present scientific data. In addition, the discussion of the topics with other participants trains a critical review of illustrated data which is the basis for good scientific practice.
Responsible contact	Stibor, Herwig; Nickelsen, Jörg

Title	Seminar: Same but different - epigenetics in plants and humans
Content	Participants in the seminar "Same but different - epigenetics in plants and humans" obtain detailed knowledge on the similar and different epigenetic mechanism in plants and humans. The seminar is team-taught by plant- and human-biologists and aims to understand underlying evolutionary conserved epigenetic mechanism. Students are working in teams and should work out similarities/differences, with one student focusing on the plant and the other student focusing on the human mechanism. Content: - History of Epigenetics Discoveries - DNA Methylation Enzymes - DNA De-methylation - Epigenetic Changes during Development

	- Regulation of DNA Methylation by small RNA's - Imprinting - Transgenerational Epigenetics
Learning outcomes	Skills: - understanding of the molecular principles in respect to the content - relevant literature search - presentation skills - teamwork - scientific discussion and exchange - feedback
Responsible contact	Meilinger, Daniela; Bölter, Bettina

Title	Practical course: Methods for protein characterization
Content	2-week course on several methods applied for the in vitro characterization of proteins including: protein overexpression in E.coli, purification of recombinant proteins using chromatography and an FPLC system, isoelectric focusing, isolation of stromal proteins from plants, in vitro protein-protein interactions experiments are performed in groups of two following given protocols documentation and interpretation of results presentation of the results in written form talk about a topic related to the practical part: e.g. chromatography methods, crystallization approaches, antibody generation and chloroplast redox biology
Learning outcomes	Students who successfully completed this module are able to… - design and handle experiments with the techniques mentioned above (specifically they are able to work an ÄKTA FPLC system and the Unicorn software) - expand their theoretical knowledge on biochemical protein related methods to a practical level - analyze experimental results - prepare figures from the obtained data and describe aim and outcome of the experiments - Selecting and summarizing literature - Setting up a power point presentation - Speaking in front of other students within a limited time
Responsible contact	Soll, Jürgen; Schwenkert, Serena; Bohne, Alexandra-Viola; Nickelsen, Jörg

Title	Practical course: Protein transport
Content	In this course we will learn how to isolate organelles from plants, translate proteins in vitro including radioactive labelling and prepare in vitro import assays. For further characterization we will also perform fractionation of organelles into their subcompartments and follow the procedure by biochemical techniques such as SDS-PAGE and immuno blots. Practicals skills in these techniques are required to be accepted into the course.
Learning outcomes	Skills: - understanding of the molecular principles in respect to the content - presentation skills - scientific discussion and exchange
Responsible contact	Soll, Jürgen; Bölter, Bettina; Carrie, Christopher

Main Topic Systematic Plant Sciences

Title	Lecture: Alpine flora and vegetation
Content	In this lecture the students will learn about alpine flora and vegetation, i.e. the diversity, origin and ecology of alpine plants. The lecture covers (1) the geology, orogenesis and geomorphology of the European Alps, (2) physiological and ecological adaptations of plants to alpine conditions, (3) ecological aspects such as nutrient acquisition strategies under extreme conditions and pollination biology of high alpine plants, (4) the synecology of plants, alpine vegetation types and vegetation gradients, and (5) alpine biodiversity and origin of alpine flora elements. Effects of global change and human impact on alpine biodiversity will also be discussed in the lecture.
Learning outcomes	The students will learn to recognize the most characteristic alpine plant species, including their habitat needs and ecology; basic principles of synecology, vegetation ecology and floristics will be provided.
Responsible contact	Fleischmann, Andreas; Renner, Susanne

Title	Lecture: Flowers and pollinators - reproductive biology of higher plants
Content	The evolution of flowers and flowering plants is the result of mutualistic plant-animal interactions. The lecture covers all aspects of the function of flowers, integrating findings and approaches from ecology, plant physiology, and animal behavior. Topics to be discussed are (1) current hypotheses about the benefits of sexual reproduction, (2) the origins of insect pollination, (3) the production and ecological role of flower color, scent, and nectar, (4) deceptive pollination systems, (5) pollen-stigma interactions and incompatibility systems, (6) flowering plant mating systems (incl. selfing and apomixis), and (7) the main pollination syndromes.
Learning outcomes	The evolution of flowers --and of flowering plants-- is the result of plant/animal interactions. Practicing ecological field research.
Responsible contact	Renner, Susanne

Title	Lecture: Morphology, evolution and diversity of seed plants
Content	The lecture builds on the Bachelor's level and covers the morphological diversity and distribution of seed plants based on (also molecular) phylogenetic analyses published in the past years. The following topics are addressed: introduction to phylogenetics; phylogenetic relationships within spermatophytes, with a focus on gymnosperms, magnoliids, and monocots; phylogenetic relationships within eudicots (ranunculids, caryophyllids, rosids, asterids).
Learning outcomes	Students will be able to integrate solid and professional knowledge in morphology, diversity, and evolution of seed plants. This competence is the basis to make scientifically sound decisions in the areas of Systematic Biology for any further application of land plants using contemporary in vitro methods.
Responsible contact	Gottschling, Marc

Title	Lecture: Phylogeny, systematics and biogeography of bryophytes
Content	Liverworts, mosses, and hornworts are non-vascular land plants collectively known as bryophytes. They play a crucial role in land plant evolution, having diverged from other lineages during the earliest diversification of plants on land. The lecture covers the morphological and molecular diversity of bryophytes based on recently published phylogenetic reconstructions. Special attention is given to their fossil record and their evolution in time and space.
Learning outcomes	The students are proficient in morphology and evolution of bryophytes. They obtain the fundamental knowledge required to participate in further specialized courses.
Responsible contact	Lehnert, Marcus

Title	Seminar: Bryophyte evolution
Content	Herbarium specimens of the main lineages of mosses, liverworts and hornworts are studied and identified using floras and field guides. All specimens are well labelled and students are allowed to take duplicates for their own herbarium. We will also study several amber inclusions of bryophytes (Eocene Baltic amber) and discuss their importance for biogeographical reconstructions. The second half of the course entails practice in phylogenetic reconstruction and molecular clock dating using real datasets and programmes such as MrBayes, Paup*, Garli, RaxML, and BEAST.
Learning outcomes	Students obtain knowlegde on the global bryophyte diversity and analytical skills for future lab work, in particular in preparation for their bachelor's or master's thesis. The course consists lectures, class discussions (based on original literature) and practical exercises.
Responsible contact	Lehnert, Marcus

Title	Seminar: for practical course: Knowledge of selected useful and toxic plants/ Seminar zum Praktikum Kenntnis ausgewählter Nutz- und Giftpflanzen, Systematik, Biologie, Geschichte, Verwendung, Morphologie der genutzten Teile.
Content	Participants are introduced to a great variety of useful plants and a comprehensive selection of standard and current literature. Emphasis is placed on comparative morphological and anatomical studies concerning the whole organism. Students practice critical evaluation and interpretation of data as a basis for careful and relevant conclusions. Conclusions should include especially systematic classification and morphological determination of the used parts.
Learning outcomes	At the end of the course the students should have a well-founded introduction to the topic, an extensive overview of the wide range of useful plants. Students gain a general overview of systematic useful plants. Students improve their skills in observation, scientific drawing and general knowledge in systematic botany. Working in a group, they learn documentation, interpretation and discussion of the observations.
Responsible contact	Bayer, Ehrentraud

Title	Seminar: Morphology, evolution and diversity of seed plants
Content	The seminar covers current topics related to seed plants evolution. Students will prepare an oral (PowerPoint) presentation based on own literature search. Afterwards, we the talk will be discussed with regards to content and methodological approach.
Learning outcomes	The students will gain professional knowledge in spermatophyte morphology, diversity, and evolution. This competence is the basis for any further application of organisms using contemporary in vitro methods. Students are proficient in presentation skills with different media, are introduced to library and internet resources, can assess and present a topic thoroughly

	and understandably to scientific peers. Students sharpen communication and presentation skills gained through speaking in front of a group. Students are introduced to current events in systematic biology and can discuss this in a broad context.
Responsible contact	Gottschling, Marc

Title	Practical course: Flora and vegetation of the European Alps
Content	In the practical excursion, the students will learn about alpine flora and vegetation directly in the field, during a one-week excursion to the Central Alps/Eastern Alps or South-western Alps. The covered topics during field excursions cover the synecology of plants, alpine vegetation types and vegetation gradients with elevation, as well as ecological aspects, such as adaptations of plants to alpine conditions, adaptation to different soil types (basic knowledge of geology and geomorphology of the European Alps will be given), nutrient acquisition strategies under extreme conditions, and pollination biology of high alpine plants. The course will train plant identification skills, and will give basic knowledge in plant collection, documentation, herborization for taxonomy and scientific use, and additionally illustrates to the students how to do vegetation mapping and floristic surveys (including georeferetiation of biological observations and specimen data).
Learning outcomes	The students will be able to identify the most characteristic alpine plant species, learn about habitat needs and ecology of high alpine plants, and do their own floristic survey, which will be published in a common excursion report.
Responsible contact	Facher, Eva-Justina; Renner, Susanne

Title	Practical course: Flowers and pollinators - reproductive biology of higher plants. (Blüten und Bestäuber)

Content	The evolution of flowers --and of flowering plants-- is the result of plant/animal interactions. This course explores all aspects of the function of flowers, integrating findings and approaches from ecology, physiology, and animal behavior. Topics that will be covered are (1) hypotheses about the benefits of sexual reproduction, (2) the origins of insect pollination, (3) the production and ecological role of flower color, scent, and nectar, (4) deceptive pollination systems, (5) pollen-stigma interactions and incompatibility systems, (6) flowering plant mating systems incl. selfing and apomixis, and (7) the main pollination syndromes.
Learning outcomes	The evolution of flowers --and of flowering plants-- is the result of plant/animal interactions. Practicing ecological field research.
Responsible contact	Facher, Eva-Justina; Renner, Susanne

Title	Practical course: Knowledge of selected useful and toxic plants/ Praktikum zur Kenntnis ausgewählter Nutz- und Giftpflanzen, Systematik, Morphologie, Biologie, Geschichte, Verwendung
Content	Participants are introduced to a great variety of useful plants and a comprehensive selection of standard and current literature. Emphasis is placed on comparative morphological and anatomical studies concerning the whole organism. Students practice critical evaluation and interpretation of data as a basis for careful and relevant conclusions. Conclusions should include especially systematic classification and morphological determination of the used parts.
Learning outcomes	At the end of the course the students should have a well-founded introduction to the topic, an extensive overview of the wide range of useful plants. Students gain a general overview of systematic useful plants. Students improve their skills in observation, scientific drawing and general knowledge in systematic botany. Working in a group, they learn documentation, interpretation and discussion of the observations.
Responsible contact	Bayer, Ehrentraud

Title	Practical course: Morphology, evolution and diversity of seed plants
Content	The practical course is an exercise about seed plant diversity following the lecture and based on physical specimens (fresh material from the Botanical Garden Munich as well as pickled material). Students will prepare a report in form of detailed drawings and short descriptions of the specimens.
Learning outcomes	Preparing drawings trains the ability for accurate biological observation, and students will practice critical evaluation and interpretation of data in the discussions as a basis for careful and relevant conclusions in phylogenetic reconstructions. In working in small groups, communication skills (rapport with instructors and fellow students, presentations, written reports) as well as organizational skills (efficient planning, documentation) are refined.
Responsible contact	Gottschling, Marc

Title	Practical course: Bryophyte systematics
Content	Herbarium specimens of the main lineages of mosses, liverworts and hornworts are studied and identified using floras and field guides. All specimens are well labelled and students are allowed to take duplicates for their own herbarium. We will also study several amber inclusions of bryophytes (Eocene Baltic amber) and discuss their importance for biogeographical reconstructions. The second half of the course entails practice in phylogenetic reconstruction and molecular clock dating using real datasets and programmes such as MrBayes, Paup*, Garli, RaxML, and BEAST.
Learning outcomes	Students obtain knowlegde on the global bryophyte diversity and analytical skills for future lab work, in particular in preparation for their bachelor's or master's thesis. The course consists lectures, class discussions (based on original literature) and practical exercises.
Responsible contact	Lehnert, Marcus

Title	Practical course: Fern evolution
Content	Herbarium specimens of the main lineages of mosses, liverworts and hornworts are studied and identified using floras and field guides. All specimens are well labelled and students are allowed to take duplicates for their own herbarium. We will also study several amber inclusions of bryophytes (Eocene Baltic amber) and discuss their importance for biogeographical reconstructions. The second half of the course entails practice in phylogenetic reconstruction and molecular clock dating using real datasets and programmes such as MrBayes, Paup*, Garli, RaxML, and BEAST
Learning outcomes	Students obtain knowlegde on the global bryophyte diversity and analytical skills for future lab work, in particular in preparation for their bachelor's or master's thesis. The course consists lectures, class discussions (based on original literature) and practical exercises. Lecture and practical exercises are the basis for a written test.
Responsible contact	Lehnert, Marcus

Title	Botany-lichen excursion to Montenegro
Content	A mandatory seminar gives an overview of the area visited during the excursion and the students learn about Montenegro as a country, its geology and vegetation. During the excursion, sites with typical Mediterranean plant communities are visited and the students obtain knowledge in the flora of Montenegro, which features many endemic plants, and typical Mediterranean elements.
Learning outcomes	Students learn how to analyze plant communities and obtain in depth knowledge of the lowland and mountaneous habitats and their typical species on the Balkan peninsula.
Responsible contact	Werth, Silke; Resl, Philipp

Main Topic Organismic interactions of Plants

Title	Lecture: Genetics of plant-microbe interactions in sustainable agriculture
Content	Within the course the students will learn the following contents: - Sustainable development goals and agriculture - Challenges in agriculture and impact on the environment - Fertilization, pesticides, herbicides, soil erosion, water use - aspects of plant physiology: uptake of nutrients and nutrient use efficiencies - Plant disease and pesticides in agriculture - Genetic resources for sustainable agriculture
Learning outcomes	The students - develop a basic understanding of current agricultural practices and their environmental impact - learn about the technological advances in agriculture and their limitations - understand the molecular hurdles and the genetic resources to develop sustainable practices in agriculture.
Responsible contact	Parniske, Martin; Marin, Macarena; Hann, Dagmar

Title	Lecture: Plant innate immunity
Content	A wide range of epidermal and epithelial cells are continuously exposed to a variety of pathogenic and symbiotic microbes. The survival of such rather hostile environments requires the evolution of refined molecular mechanisms by eukaryotic cells to discriminate between friend and foe. The aim of this lecture is the comparative elucidation of molecular principles that enable eukaryotic host cells to control microbial infections. We will discuss everything from genetic aspects of pattern evolution to structural aspects in receptor-ligand binding to biochemical aspects of kinase signalling that all contribute to host adaptation and are key for immunity. While we focus on plant-microbe interactions, you will see that there are common principles that have evolved in most eukaryotic systems.
Learning outcomes	At the end of the courses, students will be able to:

	- Explain concepts and prime examples of the plant immune system, both in principle and theory. - Demonstrate a genetic, molecular, biochemical and cell biology understanding of plant-microbe interactions. - Discuss current knowledge and apply critical thinking to plant health and infectious diseases.
Responsible contact	Parniske, Martin; Robatzek, Silke

Title	Seminar: Molecular Biology at the LMU Biocenter: Junior Researchers
Content	In this seminar the most important eukaryotic model organisms for genetic research are presented with a special focus on their respective features, advantages, and limitations. Every seminar day deals with a different model organism, which is introduced by a recent publication that is a good example for the specific topics investigated in this system. Thereby a good overview on different areas of genetic research and especially relevant methods used in molecular genetics is provided. Each student prepares an oral presentation on one model organism using recommended literature and resources, with regular consultation with the instructor. Considerable focus is laid on presentation and discussion. Three separate seminar days cover the topics "How to read a scientific article", "How to make a good presentation", and "Scientific publishing".
Learning outcomes	Students know the most important model organisms for genetic research and their special features. They are exposed to current literature, gain insight into language and presentation formats required for peer-reviewed publication, and are able to discuss the scientific topic with their peers. Students are proficient in assessing and preparing a topic employing library and internet resources, can present this topic thoroughly and understandably, and are competent in communication and feedback.
Responsible contact	Brachmann, Andreas

Title	Seminar: Sustainable food production and global challenges
Content	Within the course the students will learn the following contents: - Plant Symbiosis and fertilization in agriculture - Plant disease and pesticides in agriculture - Genetic resources for sustainable agriculture
Learning outcomes	The students are capable of - literature search - discussion of scientific advances and societal impact - discussion of innovations in plant and agricultural sciences - writing of a scientific review
Responsible contact	Parniske, Martin; Marin, Macarena; Hann, Dagmar

Title	Seminar: What's New? Plants, microbes & immunity
Content	The outcome of plant infection by micro-organisms can be striking and essential for survival. But what are the molecular mechanisms, by which plants defend infectious pathogens while retaining the ability to associate with beneficial microbes? In this seminar series we will discuss the recent advances on the plant's immune system and the immunomodulatory signatures of microorganisms. Understanding, presenting and discussing the most recent research is used to gain knowledge on the state-of-the-art methodologies and recent theoretical perspective of molecular plant-microbe interactions.
Learning outcomes	At the end of the course, students will be able to: - Present and explain original research, both in principle and depth. - Demonstrate an understanding of original literature that addresses a scientific question in plant-bacterial interactions. - Apply critical thinking to published data and the published conclusions. - Discuss the scientific advances in the broader context.
Responsible contact	Robatzek, Silke

Title	Practical course and seminar: Molecular plant microbe interactions
Content	Within the course the students will learn the following contents: - Molecular biology and genetics of root nodule symbiosis and plant innate immunity - Root nodule symbiosis (cell biology, genetics and signaling) - genetic diversity in root nodule symbiosis
Learning outcomes	The students are capable of - literature search and presentation of scientific publications - cell biology of root nodule symbiosis (fluorescent microscopy, sections) - qPCR of plant defense marker genes - physiological response assays (ethylene reduction assay, ethylene production assay, ROS assay) - writing scientific reports (publication style)
Responsible contact	Parniske, Martin; Marin, Macarena; Hann, Dagmar

Title	Practical course and seminar: Plant innate immunity
Content	This combined practical and seminar course will address two important biological questions: Week 1: What is the genetic distribution of MAMP recognition systems across the plant kingdom? And what are the genetic components of plant immunity that can be utilised in agriculture? Week 2: What are the genetic components of pattern-triggered immunity (PTI) missing in mutants of the model system A. thaliana? And what are the genetic components pathogens use to suppress plant immunity? We will use a combination of phenotyping and genotyping analysis to shed light on these questions. For phenotyping, we will use characteristic bioassays to monitor the induction of plant immunity such as the ROS burst and the trade-off between plant immunity and growth. For genotyping, we will provide primers to PCR amplify potentially mutated PTI genes. For genetic manipulation, we transgenically express PTI components of plant species in another species, and use virus-induced gene silencing (VIGS) to knock-down expression of key PTI genes. The course requires that students work in groups of two, and each group designs and conducts their own experiments. An introduction into good laboratory

	practice and experimental design will be given. You will plan your own experiments with the help of supervisors. Standard methods will be provided, which need to be adapted for your own experimental designs. Following your experimental design, you will conduct the experiments. Each experiment and the obtained results need to be recorded. An introduction into scientific protocol writing will be given. Two weeks after the practical course you need to submit your final protocols. Although experiments will be conducted in groups of two, each participant will need to write and submit their individual protocol. For successful completion of the course the protocols need to be approved by the supervisors. Feedback on the protocols will be provided by the supervisors. In addition to pedagogical seminars given by the supervisors, we will have 5 student seminars during the practical course. The seminars all address a relevant topic related to the experiments performed during the course, covering both technical aspects and scientific findings. Each group will select one topic and present it to all students in the form of an oral presentation. Yet, all students have to be prepared for each seminar and contribute to the discussion! Students will will provide feedback to all presentations. Supervisors will be available for the seminar preparations ahead of presentations.
Learning outcomes	At the end of the courses, students will be able to: - Explain techniques used in genetics, molecular plant biology and cell biology, both in principle and practice. - Design and conduct original research to address a problem in plant-bacterial interactions. - Demonstrate an understanding of original literature. - Apply problem-solving skills in laboratory experimentation and results conclusions. - Discuss current knowledge and apply critical thinking to plant health and infectious diseases.
Responsible contact	Parniske, Martin; Robatzek, Silke; Rybak, Katarzyna

Research courses

Title	Research course: Plastid to nucleus signaling in plants
Content	Chloroplasts have retained their own gene expression system. We investigate specific aspects of chloroplast gene expression and how disturbances of this gene expression machinery are transduced to the nucleus (retrograde signaling). To this end, the research course student might investigate knock-down and overexpression lines of putative components with respect to plant growth and physiological parameters. Methods might include fluorsecence microscopy-based localisation studies, Western blotting, real-time PCR analysis and cloning.
Learning outcomes	Students will deepen their skills for future lab work. They will learn exact – and partly independent – working. This will include efficient planning and documentation of their work. Moreover, they will be encouraged to think critical and productive. The lab report will strengthen scientific and English writing skills and will be in the format of a small manuscript.
Responsible contact	Kleine, Tatjana

Title	Research course: Abiotic stress and non-coding RNA
Content	The aim is that the students understand the biological concept and molecular processes of abiotic stress adaptation. Alternatively, students will work on molecular principles of the regulatory role of small, non-coding RNAs. The students will work with plant model species and the methods vary from physiological, molecular to cellular and biochemical approaches and are aimed to elucidate signalling pathways, protective mechanisms in cell homeostasis, and the regulation of gene expression.
Learning outcomes	Students obtain necessary skills for future lab work, in particular in preparation for their masters´s thesis. Working in the laboratory involves practical skills in respect to how to apply methods and how to optimize them, but also social skills (teamwork, respect) and organizational skills (efficient planning and documentation). Especially with writing the lab report

	and the tending of a lab journal scientific writing skills in English are enforced.
Responsible contact	Frank, Wolfgang; Arif, Muhammad

Title	Research course: Development and signal transduction in higher plants
Content	The aim is that the students understand the biological concept of light-dependent regulation of plant development and transfer this knowledge to the practical applicatons. Methods vary from physiological, molecular to cellular and biochemical approaches and are aimed to elucidate signalling pathways in the light signalling pathway.
Learning outcomes	Students obtain necessary skills for future lab work, in particucar in preparation for their masters´s thesis. Working in the laboratory involves practical skills in respect to how to apply methods and how to optimize them, but also social skills (teamwork, respect) and organizational skills (efficient planning and documentation). Especially with writing the lab report and the tending of a lab journal scientific writing skills in English are enforced.
Responsible contact	Bolle, Cordelia

Title	Research course: Mass spectroscopy and biochemistry of organelles
Content	The aim is that the students understand the concept of the identification and quantification of proteins and/or metabolites. This knowledge will be transferred to practical applications in quantitative biology and biochemistry, in particular related to plant organelles. Methods comprise the generation of biological material including mutants, sample preparation, mass spectrometry analyses, data analysis and interpretation including the application of appropriate softwares and statistics.
Learning outcomes	Students obtain necessary skills for future lab work, in particular in preparation for their masters´s thesis. Working in the laboratory involves practical skills in

	respect to how to apply methods and how to optimize them, but also social skills (teamwork, respect) and organizational skills (efficient planning and documentation). Especially with writing the lab report and the tending of a lab journal scientific writing skills in English are enforced.
Responsible contact	Leister, Dario

Title	Research course: Regulation of photosynthesis
Content	The aim is that the students understand the concept of the dynamics, flexibility and complexity of the photosynthetic process. This knowledge will be transferred to practical applications in molecular biology and physiology of plants. Methods comprise the generation of biological material including mutants, physiological measurements, biochemical experiments and quantitative biology experiments, data analysis and interpretation, including the application of appropriate softwares and statistics.
Learning outcomes	Students obtain necessary skills for future lab work, in particular in preparation for their masters´s thesis. Working in the laboratory involves practical skills in respect to how to apply methods and how to optimize them, but also social skills (teamwork, respect) and organizational skills (efficient planning and documentation). Especially with writing the lab report and the tending of a lab journal scientific writing skills in English are enforced.
Responsible contact	Leister, Dario

Title	Research course: Molecular biology and biogenesis of plant organelles
Content	Our research focuses on various aspects of chloroplast biology, such as regulation of plastid gene expression. We use a wide range of basic (e.g. RNA and protein gel blot analysis, 2-D gel electrophoresis, gel filtration, sequence analysis, cloning, plant transformation) and advanced techniques (e.g. transcriptomics, proteomics, metabolomics, RIP-seq, RNA-seq, high-throughput

	data mining) to gain insights into the function of chloroplast RNA binding proteins and to identify their RNA targets and interaction partners.
Learning outcomes	Participants will be integrated in a team specialized in the plastid RNA metabolism and learn how to perform, optimize and plan the experiments independently in order to be well prepared for the Master's thesis. Experiments have to be documented, critically evaluated, discussed in a broader context and presented in a form of a seminar. Finally, the candidate has to prepare a protocol in the format of a scientific manuscript. This all will strengthen the methodological understanding of the experiments, team work as well as experimental and writing skills to widen the scientific perspective.
Responsible contact	Meurer, Jörg

Title	Research course: Membrane transport in plants
Content	- 8-week research project, approx. 8 hours per day - experience the daily life of scientific research (this includes working in the lab under supervision and also independently, joining lab meetings and discussions) - General methods in our group include heterologous expression of proteins in E. coli and purification with different column based approaches, protein-protein interaction studies with various methods (Co-IPs, Y2H, etc), molecular and biochemical characterization of Arabidopsis mutant lines, organelle isolation and in vitro experiments. - independent literature research - design of a research schedule
Learning outcomes	Students who successfully completed this module are able to… - work on a complex research project related to organellar plant biology - independently design and perform small scientific projects related to the topic of the module on a professional level - discuss the project with colleagues and present their finding in a concise manner - address scientific questions experimentally and analyze experimental results

	- apply the learning contents and skills from pre-connected modules and deepen their knowledge in the specific topic of the research group
Responsible contact	Soll, Jürgen; Schwenkert, Serena; Bölter, Bettina

Title	Research course: Plant metabolism
Content	In this research course, students will investigate various parameters of plant metabolism at different levels of control. Using physiological or genetic manipulations, the response of plants to specific perturbations of the metabolic network will be analyzed. The students will work in a research laboratory and apply selected methods and approaches in the physiological, cellular, molecular, metabolic and biochemical context. Within a research project, quantitative data will be generated and evaluated to explore metabolic regulation in the context of plant physiology.
Learning outcomes	Students will expand their knowledge about plant metabolism and methods for its investigation at the molecular level. The students will strengthen and extend their skills for future lab work and learn to document and organize their work efficiently. By writing a lab report, they will be able to analyze and evaluate quantitative data and to put their obtained results in a biological context to discuss them critically on a scientific basis.
Responsible contact	Paul, Melanie; Geigenberger, Peter

Title	Research Course: Biology of eukaryotic algae
Content	In the practical course, students are embedded in current research of unicellular algae. Methodologically, the work includes taxonomy and nomenclature, isolating and cultivating of protists, light and electron microscopy and/or molecular phylogenetics. Emphasis is put on the interpretation and presentation of data.

Learning outcomes	Students obtain skills for biological research including design, web lab work, presentation and scientific writing. Students can apply theoretical and practical knowledge to approach biological questions in independent work. Students are well-trained in good general lab practice, including standard safety procedures, precise handling of chemicals and instruments and consciencious documentation of lab procedures. In working in small lab groups, social skills (teamwork, cooperation, fair play, work delegation, mutual respect), communication skills (rapport with instructors and fellow students, presentations, written lab reports) as well as organizational skills (efficient planning, documentation) are refined.
Responsible contact	Gottschling, Marc

Title	Research course: Plant-microbe interactions
Content	- molecular regulation of the transcription factor CYCLOPS - promotor analysis of the NIN gene, a key factor of root nodule symbiosis. - Synthetic nodules in fragaria - CRISPR/Cas to manipulate/ mutate gene expression/ genes - Nuclear calcium signaling in Oomycete interactions
Learning outcomes	Skills: - cell biology - forward and reverse genetics - promotor analysis (computational and with reporter assays) - protein/protein interactions (Co-IP/ Yeast-two hybrid) - protein/ DNA interactions (Yeast-one hybrid) - hairy root transformation
Responsible contact	Parniske, Martin; Marin, Macarena; Hann, Dagmar

Title	Research course: Taxonomie und Morphologie ausgewählter Blütenpflanzen
Content	In the course, students are embedded in current research of flowering plants. Methodologically, the

	work includes taxonomy and nomenclature, herbarium study, biogeography (georeferencing), light and electron microscopy and/or molecular phylogenetics. Emphasis is put on the interpretation and presentation of data. The lab requires a detailed lab report, which can be a part of a future publication.
Learning outcomes	Students obtain skills for biological research including design, web lab work, presentation and scientific writing. Students can apply theoretical and practical knowledge to approach biological questions in independent work. Students are well-trained in good general lab practice, including standard safety procedures, precise handling of chemicals and instruments and consciencious documentation of lab procedures. In working in small lab groups, social skills (teamwork, cooperation, fair play, work delegation, mutual respect), communication skills (rapport with instructors and fellow students, presentations, written lab reports) as well as organizational skills (efficient planning, documentation) are refined.
Responsible contact	Gottschling, Marc

Title	Research course: Current topics in ultrastructural research in electron microscopy
Content	The students will get insight into various preparation and fixation methods for transmission and scanning electron microscopy. They will be trained in the respective equipment and microscopes. In addition, they will broaden their knowledge about the ultrastructure of plants, microbes or any other kind of cells and tissues snd the techniques, how thesecells can be investigated. A major focus will be on the 3-dimensional ultrastructure and correlative light and electron microscopy (CLEM). Therefore, the students will also be trained in advanced methods like TEM- and FIB/SEM-tomography, subsequent image processing and analysis.
Learning outcomes	The research course will lead to a fundamental understanding of the various preparation techniques and their necessity for the project. Furthermore, the students will gain general knowledge of the working principle of an electron microscope and the additional equipment used for sample preparation. In the end, they will be able to apply the methods independently and it will be possible for them to critically evaluate their results and especially their micrographs and

	discuss these results with other researchers within the field of electron microscopy and structural research. Furthermore, research students will be able to estimate a potential application of the used methods in their own future projects.
Responsible contact	Klingl, Andreas

Title	Research course: Metabolic acclimation to abiotic stress
Content	In this research course, students will investigate the response of plants to a change in the abiotic environment at the physiological and molecular level. The students will work in a research laboratory and apply selected methods and approaches in the physiological, cellular, molecular, metabolic and biochemical context. Within a research project, quantitative data will be generated and evaluated to explore regulatory mechanisms in abiotic stress responses of plants.
Learning outcomes	In this research course, students should gain advanced knowledge about biological principles of metabolic acclimation to abiotic stress in plants and their investigation at a physiological and molecular level. The students will strengthen and extend their skills for future lab work and learn to document and organize their work efficiently. By writing a lab report, they will be able to analyze and evaluate quantitative data and to put their obtained results in a biological context to discuss them critically on a scientific basis.
Responsible contact	Paul, Melanie; Geigenberger, Peter

Title	Research course: Small RNAs and host microbe interactions
Content	- Praktisches Arbeiten im Labor - Wöchentliches Arbeitsseminar - Wöchentliches Literaturseminar - Wöchentliche Diskussion mit dem Supervisor zum Arbeitsthema - Auswertung von eigens erzeugter Daten

	- Wissenschaftliches Schreiben: Literaturrecherche, Zitieren, schriftlicher Report über eigene praktische Arbeiten im Labor
Learning outcomes	Fähigkeiten: - Praktisches Arbeiten im molekularbiologischen Labor - Evaluation von Daten - Wissenschaftliches Schreiben - Präsentation wissenschaftlicher Daten
Responsible contact	Weiberg, Arne

Title	Research course: Plant immunity
Content	Our research course will explore the unique opportunity for interdisciplinary training across the boundaries of genetics, molecular plant biology and microbiology in an important area related to plant health. The course builds on the "Plant Innate Immunity" Lecture, the "Plant Innate Immunity" Practical Course, the "What's new? Plants, microbes & immunity" Seminar, and will be complemented with special interest seminars available from invited speakers. The research course will teach students in practical and theoretical aspects of molecular plant-microbe interactions. Students will perform experiments to learn about the plant immune system, how immune signaling is activated to defend infection and how virulent pathogens can circumvent the plant's immune system. Thereby, students will obtain a genetic, molecular and biochemical understanding of immune signaling, such as perception of microbial ligands, activation of immune receptors and substrates, and the trade-off with plant growth. Another important field is the discovery and utilization of microbial extracellular vesicles as immune modulators. The course benefits from integration into current research projects, group meetings, discussing own scientific findings and the relevant original literature. Being directly supervised by experienced researchers, the students will participate in a current research project allowing them to learn the most recent advances in molecular plant-microbe interactions, both in terms of experimental approaches and theoretical concepts. Thereby, students will contribute to current research projects, and have the possibilities to discuss research with experts in the field.

Learning outcomes	At the end of the courses, students will be able to: - Explain the techniques used in genetics, molecular plant biology and microbiology, both in principle and practice. - Design and conduct original research to address a problem in plant-bacterial interactions. - Demonstrate an understanding of original literature. - Apply problem-solving skills in laboratory experimentation and results conclusions. - Discuss current knowledge and apply critical thinking to plant health and infectious diseases.
Responsible contact	Parniske, Martin; Robatzek, Silke

Title	Research course: Gene expression in plastids
Content	Within the framework of this 8-week research course, students take over an individual project in the context of the basic research in the laboratory. In the green alga Chlamydomonas reinhardtii, the plastid proteome originates from a combination of nuclear as well as plastid encoded genes. This requires a highly sophisticated regulatory system in order to efficiently coordinate both gene expression machineries. Our group's research focusses on nuclear encoded proteins regulating plastid gene expression on multiple levels e.g. transcription, translation, RNA processing, stability or maturation. By analyzing these processes from a genetic, molecular biological as well as biochemical point of view, students will investigate specific aspects of plastid gene expression as an independent project. Besides the daily hands-on lab work of a scientific researcher, this includes independent literature research, design of research schedules, documentation, interpretation and discussion of results in scientific language as well as presentation of the research project both orally and in written form.
Learning outcomes	After successfully completing this research course, students deepened their knowledge on the cellular biology of green algae and are able to independently work on complex research projects. They have shown to design and perform experimental research in the course of the daily routine in a professional scientific laboratory. Therefore, the students can address scientific questions experimentally and interpret the result in the context of a broader research focus,

	thereby applying the learning contents and skills from pre-connected modules.
Responsible contact	Nickelsen, Jörg

Title	Research course: Functional genomics in cyanobacteria
Content	Within the framework of this 8-week research course, students take over an individual project in the context of the basic research in the laboratory. In the unicellular cyanobacterium Synechocystis sp. PCC 6803, genes of interest are routinely inactivated in order to create knock-out mutants involved in photosynthesis, membrane-shaping or other cellular processes. By analyzing these mutants from a genetic, molecular biological as well as biochemical point of view, students will investigate the function of the gene and its product as an independent project. Besides the daily hands-on lab work of a scientific researcher, this includes independent literature research, design of research schedules, documentation, interpretation and discussion of results in scientific language as well as presentation of the research project both orally and in written form.
Learning outcomes	After successfully completing this research course, students deepened their knowledge on cyanobacterial cellular biology and are able to independently work on complex research projects. They have shown to design and perform experimental research in the course of the daily routine in a professional scientific laboratory. Therefore, the students can address scientific questions experimentally and interpret the result in the context of a broader research focus, thereby applying the learning contents and skills from pre-connected modules.
Responsible contact	Nickelsen, Jörg

Title	Research course: Molecular plant-microbe interactions
Content	- molecular regulation of the transcription factor CYCLOPS

	- promotor analysis of the NIN gene, a key factor of root nodule symbiosis. - Synthetic nodules in fragaria - CRISPR/Cas to manipulate/ mutate gene expression/ genes - Nuclear calcium signaling in Oomycete interactions
Learning outcomes	Skills: - cell biology - forward and reverse genetics - promotor analysis (computational and with reporter assays) - protein/protein interactions (Co-IP/ Yeast-two hybrid) - protein/ DNA interactions (Yeast-one hybrid) - hairy root transformation
Responsible contact	Parniske, Martin

Title	Research course: Current topics in ultrastructural research on plant-microbe interactions
Content	The students will get insight into various preparation and fixation methods for transmission and scanning electron microscopy. They will be trained in the respective equipment and microscopes. In addition, they will broaden their knowledge about plant-microbe interactions and the techniques, how these associations can be investigated. A major focus will be on the 3-dimensional ultrastructure of the involved host and symbiont cells. Therefore, the students will also be trained in advanced methods like TEM- and FIB/SEM-tomography, subsequent image processing and analysis. Furthermore, the students will get insight into respective literature research, experimental design, data documentation and interpretation and the final project presentation.
Learning outcomes	The research course will lead to a fundamental understanding of the various preparation techniques and their necessity for the project. Furthermore, the students will gain general knowledge of the working principle of an electron microscope and the additional equipment used for sample preparation. In the end, they will be able to apply the methods independently and it will be possible for them to critically evaluate their results and especially their micrographs and discuss these results with other researchers within the field of electron microscopy and structural research. Furthermore, research students will be able to estimate

	a potential application of the used methods in their own future research projects.
Responsible contact	Klingl, Andreas

Title	Research course: Bioinformatic analysis of next generation sequencing
Content	DNA sequencing data from ongoing projects is analyzed in various ways to provide the students with proficiency in analysis of next generation sequencing data.
Learning outcomes	Students learn how to apply various analyses of next generation sequencing data to real-life data sets.
Responsible contact	Werth, Silke; Resl, Philipp

Title	Research course: Genetic diversity of lichens
Content	Genetic data are generated with methods routinely applied in the Werth lab. Students are involved in ongoing projects about the genetic diversity of lichenized fungi.
Learning outcomes	Students learn lab methods to quantify genetic variability of natural populations and learn basic population genetic data analyses and interpretation.
Responsible contact	Werth, Silke; Resl, Philipp

Title	Research course: Species diversity of lichens
Content	Species abundance data and ecological parameters are recorded in the field. Species are identified and the data is analyzed with typical community ecology methods.

Learning outcomes	Students learn how to reliably quantify the abundance of lichens in the field and how to record different environmental factors. They also learn statistical data analyses, including multivariate statistics and ordination.
Responsible contact	Werth, Silke; Resl, Philipp

Title	Research course: Bacterial cell entry
Content	- root nodule symbiosis (cell biology, genetics and signaling) - genetics and genomics of rhizobia - genetic diversity in root nodule symbiosis
Learning outcomes	Skills: - literature search and presentation of scientific publications - cell biology of root nodule symbiosis (fluorescent microscopy, sections) - mutagenesis - golden-gate cloning - writing scientific reports (publication style) - scientific data presentation
Responsible contact	Marin, Macarena

Title	Research Course: Biologie von Dinophyten
Content	In the course, students are embedded in current research of unicellular algae. Methodologically, the work includes taxonomy and nomenclature, isolating and cultivating of protists, light and electron microscopy and/or molecular phylogenetics. Emphasis is put on the interpretation and presentation of data. The lab requires a detailed lab report, which can be a part of a future publication.
Learning outcomes	Students obtain skills for biological research including design, web lab work, presentation and scientific writing. Students can apply theoretical and practical knowledge to approach biological questions in independent work. Students are well-trained in good general lab practice, including standard safety procedures, precise handling of chemicals and instruments and consciencious documentation of lab

	procedures. In working in small lab groups, social skills (teamwork, cooperation, fair play, work delegation, mutual respect), communication skills (rapport with instructors and fellow students, presentations, written lab reports) as well as organizational skills (efficient planning, documentation) are refined.
Responsible contact	Gottschling, Marc