Elective course catalogue for the Master´s Programme Evolution, Ecology and Systematics

The Elective Course Catalog lists individual courses offered in the Master of Science Evolution, Ecology and Systematics, 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.

Modules and Lectures Winter term

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: Animal Communication
Content	The study of animal communication requires a broader set of perspectives than nearly any other topic in biology. Relevant disciplines include physics, chemistry, neurobiology, cognitive science, evolutionary biology, behavioral ecology, and economics. This lecture on Animal Communication integrates all of these approaches in its treatment of animal signal evolution. The taxonomic scope is kept broad, and all sensory modalities are discussed. Topics begin with the physics and physiology of signal production, propagation, and reception, turn to the behavioural ecology of cooperating communicators, and end with the complications arising when sender and receiver do not have identical interests during communication.

Learning outcomes	Physical and chemical modes of animal communication Sensory ecology and its neurobiological foundations Behavioural ecological foundations of cooperation and conflict in communication
Responsible contact	Leitner, Stefan; Gahr, Manfred; Goymann, Wolfgang; Prinzessin von Bayern, Auguste; Hoffmann, Susanne; Görlitz, Holger

Title	Lecture: Aquatic Ecology
Content	The lecture is based on knowledge in biology, chemistry and physics acquired at the Bachelor`s level. It is divided into three parts.- In part 1 students are learning about special features of aquatic habitats such as effects of the molecular structure of water and related vertical gradients. Concepts of water chemistry, limnophysic and physical oceanography will be discussed in detail. In part 2 students are learning about how the features of aquatic habitats affect the individual in its habitat, populations and interactions (competition, predation,symbiosis, parasitism). In part 3 students are confronted with an ecosystem perspective of aquatic ecology, including biogeochemical cycles and flows of energy and matter.
Learning outcomes	The students will be able to integrate knowledge from various disciplines such as biology, chemistry and physics to deal with the complexity of aquatic systems and their various ecosystem functions and services. Based on this, students will be able to apply these capabilities to estimate how anthropogenic disturbances (global change, eutrophication) affect aquatic ecosystems services considering scientific evidence.
Responsible contact	Stibor, Herwig; Stockenreiter, Maria

Title	Lecture: Comparative Anatomy and Evolution of Vertebrates
Content	The lectures provide theoretical background on evolutionary issues of the vertebrate body. This will be presented within the scope of animal evolution in general. In conjunction with paleontological evidence, evolutionary changes of the skeleton will be covered. Furthermore, molecular mechanisms of evolutionary

	alterations will be discussed. A special focus of the lectures will be on brain evolution.
Learning outcomes	The lectures will enable students to understand and describe changes of anatomical and physiological characteristics of living and extinct vertebrates in the context of evolution. The students will understand general evolutionary ideas and learn to discuss them with scientists and laypersons in theory as well as by using vertebrate examples.
Responsible contact	Grothe, Benedikt

Module: Computational Methods in Population Genetics

Module parts

Course type	Course (mandatory)	Rotation	Contact hours	Self-study hours
Vorlesung (Lecture)	Vorlesung Computational Methods in Population Genetics	Most winter terms	30 h (2 SWS)	60 h
Übung (Tutorial)	Übung Computational Methods oin Population Genetics	Most winter terms	30 h (2 SWS)	60 h

For successful completion of the module **6 ECTS** credits have to be acquired. Class attendance averages about 4.5 contact hours. Including time for self-study, 180 hours have to be invested.

Module type	Compulsory elective module with mandatory course
Usability of the module in other Programmes	Please check with study coardinators or examination board of your study prgram
Elective guidelines	
Entry requirements	None
Semester	Recommended semester: 3
Duration	The completion of the module takes 1 semester.
Content	Contents are maximum likelihood methods and Bayesian approaches for the estimation of population

	genetic parameters (e.g. population structure, growth and migration rates). In the lecture, the underlying models (e.g. coalescent and ancestral recombination graph), statistical principles, and computational strategies (e.g. importance sampling and MCMC) are discussed. During the exercises, students will analyse the methods learned in the corresponding lectures. They will also try out various software packages (e.g. Hudson's MS, LAMARC, GENETREE, IMa2) and explore by computer simulation studies under which circumstances they are appropriate. Further exercises will help the students to improve their comprehension of the lecture's content. In depth we treat state-of-the art data analysis methods for special problems in population genetics as for example novel variants of Approximate Bayesian Computation (ABC), Approximations of the Ancestral Recombination Graph, the Ancestral Selection Graph and/or novel methods for analyzing genome-wide sequence data. Contents are also the theoretical models and algorithms underlying these methods, such as Markov-Chain Monte Carlo methods (MCMC) and different variants of Hidden Markov Models (HMM) as used in programs such as STRUCTURE and PHASE. In the tutorial the students learn to use software to analyze data with the methods learned in the corresponding lecture. They test these methods with empirical and simulated data. Theoretical exercises will help the students to improve their understanding of the lecture's contents.
Learning outcomes	The students will have the theoretical background in order to interpret and critically judge the results of population genetic analyses. In addition, students are able to infer evolutionary and ecological features, using various software packages, methods and models. As basis for their scientific specialization, students achieve an in-depth understanding of special computational methods for analyzing population genetic data. This knowledge will enable them to acquire the comprehension of related methods from the current literature. In addition, the students will learn to perform data analyses with the methods learned in the lecture and to critically interpret the results of such analyses.
Type of examination	Written exam (90 Minutes)
Type of assessment	The successful completion of the module will be graded.
Requirements for the gain of	ECTS credits will be granted when the module examination (or the examination of pertinent mandatory

ECTS credits	and potential elective compulsory module parts) has/have been completed successfully.
Responsible contact	Metzler, Dirk
Language(s)	English
Additional information	See https://evol.bio.lmu.de/_statgen/compevol/

Title	Lecture: Human genomics
Content	This lecture covers the basics of human genomics and their biomedical relevance. This includes basics in the underlying computational aspects and High throughput sequencing technologies.
Learning outcomes	The students will learn the experimental and computational foundations of how the human genome was sequenced and how current genomic methods and resources are used to study human genetics.
Responsible contact	Enard,Wolfgang

Title	Lecture: Mechanism of Animal Development: Invertebrate Models
Content	This course covers fundamental mechanisms of animal development, as determined using the model invertebrates, Drosophila melanogaster and Caenorhabditis elegans. Basic principles are discussed, as are the experimental methodologies that have led to key discoveries.
Learning outcomes	The students are proficient in the basic developmental biology (embryology and fate maps) of Drosophila and C. elegans. Students are familiar with the genetic, molecular, and experimental methods used to elucidate principles of development. Students are able to interpret novel data sets, formulate hypotheses, and suggest experimental approaches that could be used to test these hypotheses. Students are able to integrate knowledge from lecture

	with information obtained through online data searches.
Responsible contact	Zhang, Natascha, Mikeladze-Dvali, Tamara

Title	Lecture: morphology and diversity of eukaryotic algae - 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

Module: Phylogenetics

Module parts

Course type	Course (mandatory)	Rotation	Contact hours	Self-study hours
Vorlesung (Lecture)	Vorlesung Computational Methods in Population Genetics	Most winter terms	30 h (2 SWS)	60 h
Übung (Tutorial)	Übung Computational Methods oin Population Genetics	Most winter terms	30 h (2 SWS)	60 h

For successful completion of the module **6 ECTS** credits have to be acquired. Class attendance averages about 4.5 contact hours. Including time for self-study, 180 hours have

to be invested.

Module type	Compulsory elective module with mandatory course
Usability of the module in other Programmes	Please check with study coardinators or examination board of your study programme
Elective guidelines	
Entry requirements	None
Semester	Recommended semester: 3
Duration	The completion of the module takes 1 semester.
Content	The course covers the following topics: maximum likelihood-based methods for inferrence of phylogeny from genetic data, comparison to parsimonious and distance based approaches, theoretical and mathematical backgrounds, such as stochastic models of sequence evolution, application of software packages such as PHYLIP and RAxML. The lecture is accompanied with practical sessions. Further topics are Bayesian Methods, including statistical-bioinformatic methods for special areas of phylogenetics as, for example, relaxed molecular clocks for fossil-based time calibration, evolution of quantitative traits, reconciliation of gene trees and species trees, or phylogenetic alignment. The theoretical models and algorithms underlying the methods are also treated. The theoretical backgrounds of Markov-Chain Monte-Carlo (MCMC) methods are discussed, as well as aspects of their application. The participants will use the knowledge gained in the lecture and apply this to actual data sets. They will learn to use phylogentic software like RAxML and BEAST or similar programs. They perform simulation studies for various scenarios to assess whether and how the methods can be applied. The students will solve theoretical exercises to improve their comprehension of the lecture's contents. The lecture is accompanied with practical sessions.
Learning outcomes	After taking this course and passing the exam, students will - understand principles and rationales underlying the most important methods of phylogeny -- inferrence, - be able to perform basic phylogenetic analyses with available software packages, - understand which fundamental problems in phylogenetics are efficiently solvable and which are computationally intractable, - understand the strengths and weaknesses of

	different approaches and be able to judge which method is appropriate for which dataset, - understand theoretical background (including most important bioinformatic algorithms in phylogentics) and mathematical notations that are necessary to read software documentantion and publications on phylogenetic analyses. As a basis for their scientific specialisation, students achieve an in-depth comprehension of advanced phylogenetic methods. They will have the fundamental knowledge to acquire related methods from the literature. The students learn to perform data analyses with the methods taught in the lecture and to interpretate and critically judge the results of such analyses.
Type of examination	Written exam (90 Minutes)
Type of assessment	The successful completion of the module will be graded.
Requirements for the gain of ECTS credits	ECTS credits will be granted when the module examination (or the examination of pertinent mandatory and potential elective compulsory module parts) has/have been completed successfully.
Responsible contact	Metzler, Dirk
Language(s)	English
Additional information	See https://evol.bio.lmu.de/_statgen/compevol/

Title	Vorlesung Arthropoda
Content	Die Vorlesung deckt alle Aspekte der Funktionsmorphologie, mikroskopischen Anatomie, Ontogenese und Phylogenie, sowie diverse Aspekte der Ökologie von Arthropoden ab. Ziel der Vorlesung ist es, dass die Studierenden die Körperorganisation verschiedener Arthropodengruppen verstehen und wie sich diese im Verlauf der Evolution verändert hat. Der Kurs ist Teil einer Serie von Kursen zu Morphologie und Phylogenie der Tiere, die alle grundlegende Kenntnisse über die verschiedenen Großgruppen vermitteln. Zusammen bilden diese Kurse einen knappen, aber vollständigen Überblick über alle Metazoen-Gruppen ("Niedere Evertebraten", Arthropoda, Mollusca, Deuterostomia, Vertebrata). Dieser Kurs besteht aus einer Vorlesung, die von einem Praktikum begleitet wird. Vorlesung und Praktikum sind

	stark miteinander verbunden. Vorlesung und Praktikum werden als 3-Wochen-Block abgehalten. Das Modul wird mit einer Klausur abgeschlossen.
Learning outcomes	Ziel des Kurses ist es die grundlegenden Kenntnisse der Arthropoden-Biologie zu vermitteln (Funktionsmorphologie, mikroskopische Anatomie, Ökologie, Ontogenese, grundlegende Physiologie). Das im Kurs erworbene Wissen befähigt die Studierenden dazu ihr Theorie-Wissen praktisch anzuwenden, vor allen Dingen um morphologische Strukturen bei verschiedenen Arthropoden zu erkennen, zu analysieren und in einen phylogenetisch-evolutionären Zusammenhang zu setzen. Damit erwerben die Studierenden Fähigkeiten für zukünftige Laborarbeiten, welche sie insbesondere für die Anfertigung von Abschlussarbeiten oder Promotionen verwenden können.
Responsible contact	Melzer, Roland; Haug, Carolin; Haug, Joachim

Title	Vorlesung: Einführung in die Meeresbiologie
Content	Die Vorlesung vermittelt Einblicke in die vielfältigen Bereiche des komplexen Wissensgebietes der Meeresbiologie. Behandelt werden folgende Themen: (1) Geschichte und Methoden der Meeresforschung, (2) Ozeanographie, Klimatologie, (3) Osmoregulation und Atemphysiologie, (4) Übersicht marine Lebensräume + Pelagial, (5) Lebensraum Felslitoral und Seegraswiese, (6) Meeresfische, Fischerei, Überfischung, (7) Lebensraum Korallenriff, (8) Lebensraum Antarktis, (9) Lebensraum Tiefsee, (10) Lebensraum Wattenmeer, (11) Lebensraum Mangrove, (12) Marine Biodiversität, (13) Bedrohung der Meere, (14) Artifizielle marine Systeme.
Learning outcomes	Der globale Überblick über das Ökosystem Meer und die in ihm wirkenden Kräfte, seine Lebensräume, seine typischen Organismen und ihre Anpassung an die jeweils spezifischen Bedingungen soll erfasst werden.

	Ebenso soll ein realistisches Bild von der Vielfalt, Einzigartigkeit und Unwiederbringlichkeit der Habitate und Arten - speziell im Hinblick auf die destruktiven Einflüsse des Menschen – vermittelt werden. Die Studierenden sollen sich das Nachdenken über Verantwortung, Handlungsbedarf und Handlungsoptionen im Sinne eines nachhaltigen Umgangs mit der Biosphäre des Planeten zu eigen machen und zum Weiterlernen in eigenen meeresbiologischen Interessensgebieten angeregt werden. Die Vorlesung wird als Vorbereitung zur Teilnahme an den meeresbiologischen Freilandpraktika (Sylt, Roscoff, Banyuls-sur-Mer, Piran) nachdrücklich empfohlen.
Responsible contact	Schrödl, Michael; Melzer, Roland; Heß, Martin; Neusser, Timea

Modules and Lectures summer term

Courses in Systematic Botany	**Taught by**
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 Outcome** 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.	Fleischmann, Andreas
Practical course: Plant Adaptation to extreme environments **Content** The course introduces and investigates the biology (morphology, anatomy, physiology, ecology, reproduction) of plants living under extreme growing conditions, such as hydrophytes, halophytes, xerophytes, epiphytes, carnivorous plants, parasitic plants, alpine and arctic plants and lichens.	Beck, Andreas; Fleischmann, Andreas; Kadereit, Gudrun; Zerdoner Calasan, Anže
Field Course: Flora and vegetation of the European Alps	Fleischmann, Andreas;

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 Outcome** 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.Knowledge about ecological and physiological adaptations to an important habitat type: interpretation of growth forms, ecology, environmental factors, and anthropogenic influences. Students work in teams, with each team having to give an oral presentation about observations in the field (incorporating literature that is provided by the instructors).Teamwork, coope-ration and communication with the other teams are essential.	Kadereit, Gudrun
Physio-evo seminars: discussing plant biodiversity and metabolism **Content** Plant physiology spans across several metabolic processes, including growth, development, movements, water and nutrient acquisition, photosynthesis, and reproduction. The currently known biodiversity of plants is the result of several lineage-specific metabolic adaptations that sometimes evolved independently and resulted in a similar phenotype, or evolved into very distinct phenotypes in closely related species. The goal of this seminar is to discuss plant physiology in an evolutionary context. By addressing how common physiological processes vary across diverse plant groups, students will be able to expand their textbook definitions and reflect on the importance of biodiversity. Each participant will be assigned a published work and will prepare a 20-minute presentation on its findings, including a short theoretical background. Participation in the course requires in-person group discussions for peer-reviewing presentations. This seminar is open to all students and MSc students of Biology, including aspiring teachers.	Kadereit, Gudrun; Callegari Ferrari, Renata

As specific learning outcomes, students will be able to summarize and communicate scientific information in a clear and unambiguous manner and further develop their critical thinking. More information will be provided upon registration and in the preliminary meeting (May 6). There may be room for date adjustment according to the participants' availability.	
Seminar: Plant Adaptation to extreme environments **Content** Each student selects a scientific publication focused on plant adaptation to one or more extreme environmental stressors (e.g., drought, salinity, heat, cold, nutrient limitation, high UV exposure, flooding) and prepares a presentation summarising the study's objectives, methods, key findings, and significance. Individual presentations are followed by discussion, where peers critically evaluate the study, discuss broader ecological and evolutionary implications, and compare with other known adaptations.	Beck, Andreas; Fleischmann, Andreas; Kadereit, Gudrun; Messerschmid, Thibaud; Zerdoner Calasan, Anže
Seminar for bachelor, master, and doctoral students and for Zulassungskandidaten of the AG Systematics, Biodiversity and Evolution of Plants	Kadereit, Gudrun
Seminar: Current topics in systematic biology **Content** A seminar series with different speakers of different organismic backgrounds from all over the world, presenting their recent research.	Kadereit, Gudrun; Beck, Andreas; Gottschling, Marc; Werth, Silke
Seminar: Ökologie der Pilze / Seminar: Ecology of fungi **Content** The aim of this course is to obtain knowledge about the diversity and evolution of fungi. For all students of biology (Bachelor, Master's, teachers). Language: German, or English on demand, depending on if all participants understand German. Students will acquire knowledge about fungal diversity and evolution by preparing presentations on the diversity and evolution of specific fungal groups. **Learning outcomes** Students will obtain in-depth knowledge of the most important groups of fungi and about their biology.	Beck, Andreas; Werth, Silke
Research course: Biology of C4 and CAM plants	Kadereit, Gudrun; Callegari Ferrari, Renata; Messerschmid, Thibaud
Research course: Molecular phylogenetics and trait evolution of plants	Kadereit, Gudrun; Briones-Morales, Diego

Research course: Biology of lichens	Beck, Andreas
Research course: Biology and systematics of carnivorous plants	Fleischmann, Andreas

Title	Lecture: Advanced Evolutionary Genomics
Content	Students will be taught in evolutionary genomics, in particular in comparative genomics, evolution of genome size, repetitive DNA, gene and genome duplication, isochores, GC content, codon bias and evolution of gene expression.
Learning outcomes	Students gain further knowledge of issues in evolutionary genomics. They are able to study more advanced issues in the field.
Responsible contact	Parsch, John

Module: Conservation Genetics

Assigned courses

Course type	Required course	Rotation	Class attendance	Preparation (ECTS)	ECTS
Seminar	P. X Concepts	SS	15 h (1 SWS)	45 h (2)	(2)
Practical	P. X Field	SS	45 h (3 SWS)	0 h (1)	(1)
Practical	P. X Computer	SS	15 h (1 SWS)	60 h (3)	(1)

This module is comprised of 6 ECTS points. Class attendance is 5 SWS; total time, including preparation time, is 180 h.

Type of module	Compulsory elective module with required courses
Applicability to other degree programs	
Elective guidelines	None
Entry requirements	WP1 Evolutionary Genetics
Level	Recommended semester: 2
Duration	The module spans 1 semester.
Content	The module accommodates various aspects of conservat-ion genetics including a field excursion to the threatened habitat of the alpine/nival zone, interaction with con-servation practitioners from the governmental Bavarian Environment

	Agency (Landesamt für Umweltschutz) and computational conservation genetic analyses. The module combines elements of a seminar, field work and a computer lab.
Qualification goals	In this module, you will familiarize yourself with conservation genetic concepts, get first-hand insight into conservation practice and train to work with genetic datasets.
Module assessment	Presentation and report
Grading	The module is graded.
Pass/fail conditions for ECTS points	ECTS points are awarded for passing the assessments, which are allocated to the module.
Responsible person	Wolf, Jochen
Language	English

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;

Title	Lecture: Human Evolution
Content	This lecture covers genetic, paleaoanthropological, archaeological, cultural, psychological and

	epistemological aspects of human evolution.
Learning outcomes	An interdisciplinary view on human evolution.
Responsible contact	Enard, Wolfgang

Title	Lecture: Architecture of visual systems
Content	This lecture deals with the molecular, cellular and organic evolution of vision and the diversity of “eyes” in the animal kingdom. The principles of biological optics are explained. the morphologies of (1) cup ocelli, (2) pinhole eyes, (3) different kinds of lense eyes and (4) compound eyes with their supporting structures are presented, and discussed in the sense of functional morphology and adaptation. The issue is completed by views on the vertebrate retina and on central visual systems of groups with higher visual capacities.
Learning outcomes	The aims of this lecture are to learn (1) how vision came into existence on this planet, (2) that it is rather the rule than the exception throughout all metazoan groups, (3) how the respective structures adapted/improved depending on photic habitat and visually oriented behavior, (4) and how we can make reliable assumptions about the visual capabilities of a given animal. Knowledge and enthusiasm about the fascinating structure-function relationships of visual organs are to be imparted, as well as the subjectivity of human vision – generally seen upon as the golden standard.
Responsible contact	Heß, Martin

Title	Lecture: Basic Evolutionary Genomics
Content	Students will be taught in genome analysis, in particular in genome sequencing and assembly, genome annotation, forward and reverse genetics, transcriptomics, interactomics and proteomics.
Learning outcomes	Students are introduced to evolutionary genomics, with examples from prokaryotes and eukaryotes and will receive an overview of the main methods used in the

	field.
Responsible contact	Parsch, John

Title	Lecture: Bioimaging (imaging techniques in bio-sciences)
Content	The character of analogue and digital images, overview on macroscopic and microscopic imaging methods in bio-medical science, technique and applications of widefield microscopy (from basics to structured illumination), laser scanning microscopy (CLSM, 2PM and various special techniques), scanning and transmission electron microscopy, FIB-BFSEM, tomography (CT, MRT), selected methods of digital imaging (e.g. image parameter optimization, deconvolution, 3D-reconstruction, spectral unmixing, spatial frequency filtering).
Learning outcomes	Getting an overview and deepened insight into the field of (mostly microscopic) imaging and the variety of applications, getting a feeling for the explanatory power of 2D to nD measurements, their visualization and possible manipulations, developing own ideas for own projects, reading and summarizing an advanced paper about a selected bioimaging technique/application.
Responsible contact	Heß, Martin

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; Hann, Dagmar

Title	Lecture: Genomics of Human Diseases
Content	This lecture builds on knowledge obtained in molecular biology and genetics on the Bachelor's level and partly on knowledge from Human Genomics (winter term). It aims to deepen knowledge on the structure and content of the human genome, mapping of disease genes and characterizing cancer. The following topics are addressed: Comparative Genomics, identifying function in the genome, regulatory regions of the genome, genetic variation, linkage anaylsis, GWAS studies, Cancer genomics.
Learning outcomes	The students will be able to describe and understand fundamental and advanced principles of human genomic research. They will acquire the basic and advanced background knowledge to apply genomic technologies.
Responsible contact	Enard, Wolfgang

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

Seminars winter term

Title	Seminar: Contemporary Questions in Behavioral Ecology
Content	For this course, each week we invite an international speaker at the forefront of contemporary behavioral ecology research. The speaker will give a presentation,

	which is followed by a Q&A session. Students prepare for the lecture as they will be provided with PDFs of 1-2 key papers ahead of time. Students will use these to prepare questions.
Learning outcomes	Students are taught in a wide variety of contemporary topics in behavioral ecology. They are exposed to a large range of presentation styles, research paradigms, and research methodologies used in this field. They learn also about personal work-life decisions and career decisions made by scientists.
Responsible contact	Dingemanse, Niels; Scharf, Hannah

Title	Seminar: Behavioral Ecology Lab Seminar
Content	Lab seminar meetings consists of research talks from the behavioral ecology group, paper discussions on new and exciting topics in behavioral ecology, and invited talks from international scientists. This seminar is also attended by other postdocs, PhD students, or visiting scientists in the behavioral ecology group.
Learning outcomes	The purpose of this course is to increase participation from young scientists. Students will learn how science works at the higher academic level, how to participate in group discussions, and how to ask insightful questions.
Responsible contact	Dingemanse, Niels; Scharf, Hannah

Title	Seminar: Current Literature in Aquatic Ecology
Content	The seminar will introduce students to the scientific literature in aquatic ecology, both from the limnic and marine ecosystems. Special focus is given to current research in plankton ecology. Timely research questions related to the diversity, distribution and life cycles of phytoplankton and zooplankton are addressed with publications from field and experimental studies. Changes in the structure and the dynamics of aquatic communities due to environmental forcing and anthropogenic impacts are discussed.
Learning outcomes	The seminar builds on previous knowledge in general ecology and/or marine biology. Participants will be familiarized with relevant journals and scientific language of the aquatic sciences. Reading and presenting the publications will allow them to identify key concepts and open questions in plankton/aquatic ecology, as well as timely methods (experimental, analytical, statistical) for acquiring and analyzing data to

	achieve progress in this area of research.
Responsible contact	Stibor, Herwig

Title	Seminar: Hot Topics in Ecology
Content	In the seminar “hot topics in ecology“, students critically discuss problems related to current topics ecology. The students present scientific publications from the last two years in high impact journals describing current experiments and observational studies. Covered topics are from aquatic and terrestrial ecology, behavioral ecology, and evolutionary ecology. Specifically, the students select a topic, read the publication and prepare a talk. Students need to introduce into the topic by reading further material on their own. Further on, students prepare questions for discussing the publication afterwards with the whole group. Besides the main message of the publications, students need to critically discuss methods, statistics, experimental design etc. of the study based on their basic knowledge about ecology.
Learning outcomes	The students will learn to interpret new research findings in the field of ecology by extracting main outcomes of scientific publications and present it to an audience. They will be able to lead discussions about experiments/analysis of a wide field of ecological topics and exchange their ideas.
Responsible contact	Stockenreiter, Maria

Title	Seminar: Human evolution
Content	This seminar discusses genetic, paleaoanthropological, archaeological, cultural, psychological and epistemological aspects of human evolution and how these could be presented in the lecture Human Evolution. .
Learning outcomes	The students will get an overview on the field of human evolution and will be able to understand, present, discuss and critically judge current literature in the field.
Responsible contact	Enard, Wolfgang

Title	Seminar: Evolution of sex, sexes and sex determination systems
Content	In the seminar, the students discuss topics associated with the evolution of sexual reproduction, the rise of sexes and the evolution of systems that determine sexes. The topics that are discussed are: The origins of sexual reproduction; Costs and benefits of recombination; Outbreeding: the role of mating types and sexual incompatibility; Anisogamy and sexes; Hermaphroditism and Gonochorism/Monoecy; The varieties of Sex Determination Systems; Sexual selection and sexual antagonism. Specifically, each student will prepare a presentation that summarizes the topic of a specific seminar based on their own research of relevant and current publications. The students will then discuss recent literature or seminal papers on the topic of the seminar.
Learning outcomes	The students will learn the role of basic molecular and population genetics such as meiosis, epistasis, linkage and drift in the context of recombination, and be able to integrate this knowledge and apply it to evolving systems to understand the consequences of sexual reproduction for adaptation and evolution.
Responsible contact	Nieuwenhuis, Bart

Title	Seminar: Genetics and Society The human genome and its implications for mankind (seminar longitudinal to the lecture genomes and genomics)
Content	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	Skills: - presentation skills - literature search and evaluation - design of scientific questions - literature-based argumentation - moderation of discussions

Responsible contact	Parniske, Martin; Hann, Dagmar

Title	Seminar: Journal Club Adaptive Radiation
Content	Adaptive radiation is the evolutionary process that leads to rapid diversification of groups of organisms along with ecological adaptations. Prominent examples of this process include Darwin's Finches on the Galapagos Islands, cichlid fishes in the East African Great Lakes, or plants called silverswords on Hawaii, but the exact definition of this process and its pervasiveness have long been debated. In this journal club, we read, present, and discuss current literature on adaptive radiation to learn about the state of the art of research on this topic.
Learning outcome	Students will learn to read and understand scientific articles, both for theoretical studies as well as for studies using modern genomic methodology to gain insights into evolution.
Responsible contact	Matschiner, Michael; Muschick, Moritz

Title	Seminar: Genomics of Adaptation and Speciation
Content	Species formation has fascinated evolutionary biologists for centuries. How does natural selection lead to local adaptation? Can genetic incompatibilities maintain species borders? How do these processes interact during the continuum of species formation? Answers to these questions have remained unanswered largely due to the lack of genomic tools that can be applicable across species. The recent advent of high-throughput sequencing has unlocked these limitations and allows applications to virtually any kind of organism. In this seminar, we will discuss the most recent papers defining new benchmarks in genomics of speciation. We will discuss foundational theory supporting new research questions, advantages of current genomic methodologies, and the limitation defining future advances of the field. Specifically, we cover eleven topics: 1. Demographic history of divergence; 2. Post-zygotic intrinsic isolation; 3. Cyto-nuclear incompatibilities; 4. Pre-zygotic isolation; 5. Genetic basis of adaptation; 6. Postzygotic extrinsic isolation; 7. Chromosomal speciation; 8. Genomic landscape of speciation; 9. Ecological speciation; 10. Evolutionary consequences of hybridization; 11. Hybrid zones.
Learning outcomes	In this master-level course, the students will: - Present and discuss concepts from diverse fields that contribute to evolutionary biology (genomics, genetics, behaviour, ecology, etc…)

	- Get familiar with long standing questions and theory on speciation research; - Understand the advantages and limitations of new genomics methods; - Identify opportunities for future research.
Responsible contact	Wolf, Jochen;

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. Students will prepare a topic, search and read relevant publications and present a talk.
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	Seminar: Conservation Biology (3 ECTS)
Content	Students read, explain and present scientific publications on basic topics of conservation biology. The structure is based on the book “Conservation Biology” by Fred Van Dyke & Rachel L. Lamb (2020) but consists mainly on recent articles published in renowned scientific journals.
Learning outcomes	The students prepare and give a PowerPoint presentation on a selected topic of the book or a scientific article. They will respond to questions from the audience and lead the discussion. Students are required to actively participate in the discussion and read the respective papers or chapters.
Responsible contact	Goymann, Wolfgang; Casagrande, Stefania

Title	**Seminar Diversity of Fishes**
Content	A series of lectures will discuss the evolutionary history and systematics of fishes and the morphology, physiology, behaviour and ecology of select groups. The local Bavarian fish fauna will be highlighted and placed within the systematic context. Complementing these lectures will be a series of block seminars focused on recent insights into fish diversity. To round off the course, a visit to Sea Life Munich will illustrate the fish diversity presented in lectures.
Learning outcomes	Students will gain foundational knowledge on the diversity of fishes through lectures, the presentation and discussion of recent, relevant publications and by visiting the Sea Life Munich.
Responsible contact	Muschick, Moritz

Seminars summer term

Title	Seminar: Current topics in Statistical Genomics
Content	We discuss actual papers in our field of Primate Genomics. This covers especially papers addressing biological questions using whole genome data. Therefore statistical and computational methods will take a prominent part in the Seminar series in addition to papers covering human brain evolution and primate stem cell technologies. Students will be given one current research article for presentation, but they will also have to prepare one research paper of their own choosing to be presented.
Learning outcomes	The students will get a detailed view on actual topics in the field and will strengthen their abilities to critically evaluate the genomic and evolutionary literature.
Responsible contact	Enard, Wolfgang; Hellmann, Ines

Title	Seminar: Topics in evolutionary developmental biology
Content	The seminar covers developmental biological aspects of different arthropod groups in an evolutionary context (EvoDevo). The students present different examples of arthropod EvoDevo research based on current scientific literature. The results of the presented studies are discussed in an evolutionary context.
Learning outcomes	The students learn how to perform literature research and practise to give oral presentations. Furthermore, they learn how to present their acquired knowledge within a set time frame to an audience with limited background knowledge. Finally, the students learn how to discuss scientific data in a broader evolutionary context. Giving oral presentations is a skill necessary for presenting the results of the own thesis, as is the ability to discuss results in an evolutionary context. Also literature research is useful for future research internships and theses.

Responsible contact	Zhang, Natascha, Mikeladze-Dvali, Tamara

Title	Seminar and Practical course Experimental Behavioral Ecology
Content	Students study scientific methods used in behavioral ecological research. They plan, conduct and analyse a number of behavioral experiments. They are required to apply knowledge from the course “Principles of behavioral ecology” to understand and interpret the experiments belonging to different research fields within behavioral ecology, such as sexual selection, socio-biology or species interactions. The lab requires a detailed lab report according to excellent scientific practice.
Learning outcomes	Students learn to design and carry out behavioral experiments. In working in small lab groups, social skills are refined. They also learn about data analysis and interpretation of results, and they improve their scientific writing skills.
Responsible contact	Dingemanse, Niels; Scharf, Hannah

Title	Seminar Biomolecular Anthropology: Diet, Microbes and Human Evolution
Content	This seminar examines how dietary change has shaped human biology, health, and the gut microbiome from the Neolithic Revolution to today. The shift from foraging to farming transformed human evolution, affecting stature, disease, and genetic adaptation. Innovations like dairying and cereal cultivation drove traits such as lactase persistence and higher amylase gene copies. Meanwhile, the gut microbiome co-evolved with diet and environment. Modern industrial “Western” diets, highly processed and low in fiber, have disrupted this balance, contributing to chronic inflammatory and metabolic diseases. Through interdisciplinary study, the seminar explores diet’s ongoing role in human evolution, health, and ecological adaptation.
Learning outcomes	The students will get an overview on the field of Biomolecular Anthropology, diet/human/gut microbiome evolution and will be able to understand, present,

	discuss and critically judge current literature in the field.
Responsible contact	Zink, Albert

Title	Seminar: Functional morphology of social insects
Content	In the seminar, different aspects of functional morphology of insects and the possible implications on their ecology are discussed. The students perform literature research, especially including published illustrations, which are the basis for a functional morphological analysis. The shape of the structures of interest is analysed with a computer programme, for example, based on digital drawings performed by the students in a standardised way. The results of the analysis are discussed in an ecological context.
Learning outcomes	The students acquire skills in literature research and critical evaluation of literature data. They learn how to use computer software to analyse shapes of structures. Furthermore, they understand functional morphological implications on the ecology of different insects. The skills how to perform literature research and handle different types of data sources can be used in future research internships and theses. The discussion of functional morphology in an ecological context can be helpful for further ecological courses.
Responsible contact	Carolin Haug; Joachim Haug

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: 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: 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	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; Hann, Dagmar

Title	Seminar: Wadden sea

Content	see "Practical course Wadden sea" Seminar can only be taken in connection with practical course Wadden sea
Learning outcomes	see "Practical course Wadden sea" Seminar can only be taken in combination with practical course Wadden sea
Responsible contact	Heß, Martin

Title	Seminar: zur Hochalpenexkursion (nur in Kombination mit der Exkursion), Seminar accompanying excursion to the alpine upland
Content	Mandatory seminar to „excursion to the alpine upland". Topics are the genesis of the alps, physical factors of altitudinal belts, geology and glaciology, habitats and communities of alpine plants and animals, biology of selected animal species, use and threat by humans, signs of climatic change, and the significance of national park installations.
Learning outcomes	The student is supposed to holistically experience a selected part of the alpine world with its landscape, dimensions, physical conditions, and organisms together with fellow students and supervisor – by walking, looking, thinking and talking. She/he should learn to get an unerring eye for characteristic species, how to name them, their preferred habitats, and ecological interdependencies. Knowledge from detailed facts to global context is obtained by immediate perception and by theoretical involvement. A talk has to be prepared and given, the talks of other students have to be heard and discussed. Realistic scientific research conditions in the field, the responsibility of the scientist for the preservation of pristine nature and biodiversity, the enthusiasm for authentic biological activities and a sense of community play major roles.
Responsible contact	Heß, Martin

Practical courses winter term

Title	Comparative Anatomy and Evolution of the Vertebrates
Content	Based on the theoretical knowledge and paleontological evidence taught in the accompanying lecture, the students will dissect and analyse representative species of major vertebrate groups (e.g. chondrichthyes, osteichthyes, amphibians, lepidosaurs, birds, mammals). Additional anatomical and physiological knowledge will be provided in the daily introduction. The dissections will be performed with the focus on one organ system on each day (e.g. digestive tract, heart and vascular system, swim bladder, lungs & gills, urogenital system, sensory organs and brain, skull, skeleton, musculature). An important component of the course is the presentation of the dissected animals by the students and its discussion within the context of evident evolutionary changes. The course includes short talks given by students on important issues related to the respective organ systems. In addition, there will be a museum visit to focus on the fossil evidence of evolution.
Learning outcomes	The course will enable students to understand and describe evolutionary changes of organ systems in different vertebrates based on their dissection of these animals. The students will be exposed to a variety of vertebrates, including established model systems used in biomedical and basic research (e.g. teleost fish, frogs and rodents), widening the systemic viewpoint for their future experimental work. The students' presentations of theoretical knowledge and of the results of the dissections will enable them to intellectually embrace their work.
Responsible contact	Grothe, Benedikt; Kunz, Lars Rainer; Behrend, Stephan Oliver

Title	Practical course: about dispersal biology of flowering plants - Praktikum: Einführung in die Ausbreitungsbiologie der Samenpflanzen und mikroskopische Techniken (Ergänzungsveranstaltung)
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. The lab requires a detailed lab report according to excellent scientific practice.
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

Title	Practical course: Bioimaging
Content	The character of analogue and digital images, overview on macroscopic and microscopic imaging methods in bio-medical science, technique and applications of widefield microscopy (from basics to structured illumination), laser scanning microscopy (CLSM, 2PM and various special techniques), scanning and transmission electron microscopy, FIB-BFSEM,

	tomography (CT, MRT), selected methods of digital imaging (e.g. image parameter optimization, deconvolution, 3D-reconstruction, spectral unmixing, spatial frequency filtering).
Learning outcomes	Getting an overview and deepened insight into the field of (mostly microscopic) imaging and the variety of applications, getting a feeling for the explanatory power of 2D to nD measurements, their visualization and possible manipulations, developing own ideas for own projects, reading and summarizing an advanced paper about a selected bioimaging technique/application.
Responsible contact	Heß, Martin

Title	Practical course: Experimental Plankton Ecology
Content	In addition to our field based courses students learn to perform experiments specifically in laboratory microcosms. Introductory lectures will deal with principles of experimental designs, the construction and operation-modi of microcosms (batch, semi continuous batch, chemostat), the assembly of appropriate culture media, the laboratory cultivation of phyto- and zooplankton and modern methods of ecophysiological and ecological data acquisition. Based on the knowledge gained from the introductory lectures students will develop their own experiments and work in small groups. After performing the experiments students will analyse their data with univariate and multivariate statistical methods. Finally students have to present their findings oral talks and a written report.
Learning outcomes	Students will have to transform tests of basic ecological concepts into experimental designs and experiments. Students will be able to work in teams and coordinate various tasks such as constructing experimental microcosms, making culture media, cultivate plankton organism, measure responses of experimental manipulations on various levels and share and analyse data. Students will be able to evaluate and confront their results with the experimental hypotheses and defend their arguments in scientific discussions.

Responsible contact	Stibor, Herwig; Stockenreiter, Maria

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 and diversity of eukaryotic algea - Praktikum: Morphologie und Diversität der eukaryotischen Algen und mikroskopische Techniken (Ergänzungsveranstaltung)
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	Practical course: Phylogenomics
Content	Advances in high-throughput sequencing and genomics have revolutionized research in evolutionary biology and systematics. The use of genomics data in phylogenetic analyzes has brought new challenges in terms of data handling and analysis. This course aims to help those who have basic experience in bioinformatics and molecular phylogenetics, and have projects focused on high-throughput sequencing data and phylogenetics, to become acquainted with tools, programs and pipelines for phylogenomics and want to conduct phylogenomic studies beyond the standard, also addressing potentially confounding biases in their datasets.
Learning outcome	Students will gain an understanding of phylogenetics and will learn to develop simple bioinformatic pipelines to analyze and simulate genomic datasets.
Responsible contact	Matschiner, Michael

Title	Practical course: Scientific investigations in natural history museum collections with excursion
Content	The students visit the collections of a natural history museum for one week. During that time, they inspect

	the specimens stored in the collections, select specimens, and mount and document these with high-resolution composite digital macro-photography. This part of the course includes careful handling of collection specimens, data organisation including archiving, mounting small specimens under the microscope with fine pincers in storage liquid (alcohol), and using state-of-the-art photographic equipment. During the week after the excursion, the students meet in a seminar room at the LMU Biocenter to process the images. The image stacks produced at the museum collections are fused and stitched to high-resolution compound images and processed further. Each student receives part of the image stacks to process to receive high-quality images. The resulting images and the morphological characters they show are discussed.
Learning outcomes	The students visit the collections of a natural history museum for one week. During that time, they inspect the specimens stored in the collections, select specimens, and mount and document these with high-resolution composite digital macro-photography. This part of the course includes careful handling of collection specimens, data organisation including archiving, mounting small specimens under the microscope with fine pincers in storage liquid (alcohol), and using state-of-the-art photographic equipment. During the week after the excursion, the students meet in a seminar room at the LMU Biocenter to process the images. The image stacks produced at the museum collections are fused and stitched to high-resolution compound images and processed further. Each student receives part of the image stacks to process to receive high-quality images. The resulting images and the morphological characters they show are discussed. The major aim of the course is to learn how to work in scientific museum collections, including archiving, documentation and image processing. The students learn how to manage larger data sets and how to organise an efficient work flow in a group. Furthermore, they achieve additional morphological knowledge on the studied animals. The students learn documentation methods and data organisation, which they can use during later research internships and theses. Also the general use of museum collections can be used for later internships, for example, at the Zoological State Collection Munich (ZSM).
Responsible contact	Haug, Carolin; Haug, Joachim

Title	Seminar and Practical course: Computational analysis of RNA-Seq data
Content	Whole transcriptome analysis by RNA-seq is on the verge of becoming a standard analysis in many molecular biology laboratories. As it is the case for many next generation sequencing (NGS) based methods, the analysis of the data is often more complex than the generation of the data and biologists often (wrongly) believe that the analysis falls in the domain of bioinformaticians. This course aims to set this record straight by enabling students to analyse RNA-seq data by executing and most importantly understanding the following steps: 1. Basic handling skills of NGS data accessing a unix server via the shell commandline. 2. Normalisation and outlier removal of RNA-seq data. 3. Differential expression analysis. 4. Gene-set enrichment analysis. 5. Gene expression network analysis.
Learning outcomes	This course enables students to analyse RNA-seq data starting from raw sequence files ending with expression network analysis.
Responsible contact	Enard,Wolfgang; Hellmann, Ines

Title	Praktikum Arthropoda
Content	Während des Praktikums untersuchen die Teilnehmer außenmorphologisch makro- und mikroskopisch verschiedenstes Material aus allen Großgruppen der Arthropoden (Trocken-, Alkoholmaterial, mikroskopische Dauerpräparate), präparieren verschiedene Vertreter und analysieren histologische Schnitte. Die Dokumentation erfolgt über Zeichnungen und Fotografie. Zusätzlich werden in Gruppenarbeit ausgewählte Fragestellungen mit Transferleistung bearbeitet. Der Kurs ist Teil einer Serie von Kursen zu Morphologie und Phylogenie der Tiere, die alle grundlegende Kenntnisse über die verschiedenen Großgruppen vermitteln. Zusammen bilden diese Kurse einen knappen, aber vollständigen Überblick über alle Metazoen-Gruppen ("Niedere Evertebraten", Arthropoda, Mollusca, Deuterostomia, Vertebrata).
Learning outcomes	Ziel des Kurses ist es die grundlegenden Kenntnisse der Arthropoden-Biologie zu vermitteln (Funktionsmorphologie, mikroskopische Anatomie, Ökologie, Ontogenese, grundlegende Physiologie).

	Das im Kurs erworbene Wissen befähigt die Studierenden dazu ihr Theorie-Wissen praktisch anzuwenden, vor allen Dingen um morphologische Strukturen bei verschiedenen Arthropoden zu erkennen, zu analysieren und in einen phylogenetischen Zusammenhang zu setzen. Damit erwerben die Studierenden Fähigkeiten für zukünftige Laborarbeiten, welche sie insbesondere für die Anfertigung von Abschlussarbeiten oder Promotionen verwenden können. Zusätzlich erwerben die Studierenden Fähigkeiten im Zusammenhang mit Selbst- und Gruppenorganisation.
Responsible contact	Melzer, Roland; Haug, Joachim; Haug, Carolin

Title	**EES laboratory skills course**
Content	The EES laboratory skills course introduces students to common laboratory concepts, techniques and instruments that are essential for laboratory work in Evolution, Ecology and Systematics. It aims to lay a foundation of basic skills on which IRTs can build and is meant for students who either did not acquire these skills during their previous studies, or who feel the need to refresh them.
Learning outcomes	Students gain hands-on experience with laboratory work and best practices. This includes operating instruments such as centrifuges, balances, incubators, or pipettes, and common tasks such as handling samples, making buffers, working with DNA, calculating concentrations and dilutions, and note keeping.
Responsible contact	Muschick, Moritz

Practical courses summer term

Title	Lecture and Practical course: Pretty plots - Visualisierung statistischer Daten
Content	Data Science is not only a buzz word, but it is becoming the key to success in many fields of biology. In this course you will learn basic data science. We will repeat and expand basic statistical concepts and apply them interpret published data and as well as to analyse your own data. Most importantly, the course teaches how to visualize statistical data as beautiful figures generated with R and ggplot2.
Learning outcomes	The students will be able to handle and plot data using the statistical scripting language R. This is a key qualification for modern, quantitative biology and will provide the necessary basics to apply and extend these skills when handling and plotting data in scientific projects.
Responsible contact	Enard, Wolfgang; Hellmann, Ines

Title	Measuring animal behaviour: from an idea to a publication. Combined seminar and zoo practical (6ECTS)
Content	The seminar part is based on the book “Measuring behaviour” by Melissa Bateson and Paul Martin (Cambridge University Press) and introduces the students into scientific methods to study animal behaviour. Briefly, students will learn how to ask a behavioural question, how to describe behaviour, learn recording methods, learn to avoid common methodological pitfalls, and how data should be analyzed and presented. The practical part happens in Tierpark Hellabrunn, where student will be introduced to potential topics that could be studied. However, students are free to pose a question of their interest and choose a project of their choice, which they will work on in small groups of 3 people. Students will use the methods learned during the seminar to scientifically study and answer the question with the appropriate methodology. After collecting data for ca. 1.5 weeks they will statistically analyze the collected behavioural data, gather background information, and present their results to the other members of the course in an oral scientific presentation. After the course, each group will write a report in the format of a scientific paper.

Learning outcomes	The students will be able to pose a scientific question regarding animal behavior, choose the appropriate methods to study behaviour, and to conduct a behavioural project. They will gain a basic understanding of how to analyze behaviour, and will gain experience in presenting their findings in an oral scientific presentation and in a scientific publication.
Responsible contact	Goymann, Wolfgang; Brumm Henrik

Title	Practical course (incl. lectures): Essential skills in the analysis of high-throughput genomic data
Content	The following topics will be covered: - Technologies and application protocols of high-throughput sequencing - Areas of application and study design - Online databases - UNIX like operating systems - Use of remote computer clusters - Bash programming - Bioinformatic principles - Data formats - Data processing
Learning outcomes	Students get familiar with the terminology, technological and algorithmic basis of research using high-throughput sequencing technology. They obtain an understanding of appropriate study design, get familiar with established types of data encoding and acquire hands-on experience with basic components of bioinformatic analyses pipelines.
Responsible contact	Wolf, Jochen

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; Hann, Dagmar

Title	Practical Course: Biology of Bats
Content	Participants are introduced to the systematics, biology and ecology of bats and get acquainted with basic principles of echo orientation. Students get hands-on experience in recording and analyzing sound samples of echolocating bats, obtain practical experience in the usage of bat detectors and observe foraging bats. The course requires an oral presentation summarizing the results of groupwork and providing theoretical background about specific questions, which have been encountered during the course.
Learning outcomes	Students are able to identify bat species and to record and analyze bat calls. They are able to cooperate on specific projects in small groups including designing and conducting data collection in the field, conscientious documentation of field observations and presentation of the results.
Responsible contact	Zahn, Andreas

Title	Practical course: Topics in Evolutionary developmental biology
Content	The course covers developmental biological aspects of different arthropod groups in an evolutionary context (EvoDevo). The students perform own lab experiments as well as literature research to understand the developmental patterns in different arthropod groups. The lab experiments include external morphological documentation, partly with material of the Zoological State Collection Munich (ZSM) where appropriate, as well as staining of developmental gene expression patterns. The results of the own observations are combined with the literature data. All collected data are plotted onto existing phylogenies to reconstruct the evolution of developmental patterns.
Learning outcomes	The students learn how to collect developmental data in different ways, including morphological observations, developmental genetic experiments, as well as literature data. They learn how to deal with heterogeneity of data based, e.g., on different methods or different authors. Furthermore, the students learn that arthropods exhibit very different developmental patterns and how these have evolved. The lab methods, both the morphological and the genetic ones, can be used in future research internships and theses. Also literature research is an important skill for all kinds of future studies.
Responsible contact	Haug, Joachim; Zhang, Natascha

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; Fleischmann, Andreas

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: Wadden sea
Content	Participants are introduced to the ecosystem Wadden Sea at the Northern coast of Germany and get acquainted with basic principles of analysing terrestrial and marine habitats and with the major plant and animal species colonising the Wadden sea. The course focuses on morphological, physiological and behavioural adaptations, predator-prey relationships and the role of xenobionts. Students get hands-on experience in sampling and determination of species living in this ecosystem, (e.g cnidarians, polychaetes, arthropods, echinodermates a.o.), obtain practical experience in collecting plankton and meiofauna and observe larval stages of a number of animals as well as embryonic development of sea urchins. Relevant methods for preparing specimen from field work for light and fluorescence microscopy and analysing smaller cellular or tissue structures are conveyed.
Learning outcomes	Students are able to connect field work with closer analysis of specific biological questions in the lab. They can move and collect in the field, handle living organisms and observe them under laboratory conditions. They are well trained in using microscopes and field glasses routinely and are proficient in photo-documentation and using determination literature. Students are able to cooperate on specific projects in small groups including designing and conducting experiments in the lab, conscientious documentation of day to day field observations and lab procedures.
Responsible contact	Heß, Martin

Title	Übungen Artenvielfalt bei Flechten/ Exercises for species diversity of lichens
Content	The aim of this course is to obtain practical expertise in identifying lichens with the standard identification keys and techniques. During the course we will identify

	lichens from Iceland and Montenegro, but students are also welcome to bring their own course material for identification.
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

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

Title	Hochalpenexkursion/ Excursion to the alpine upland
Content	The „excursion to the alpine upland“ is a five-days hike in the central alps (Obersulzbach Valley, High Tauern National Park). Twelve students plus university teacher walk from mountain lodge to mountain lodge through all north alpine altitudinal belts, from the montane to the nival level – linked to a mandatory seminar. Topics are the genesis of the alps, physical factors of altitudinal belts, geology and glaciology, habitats and communities of alpine plants and animals, biology of selected animal species, use and threat by humans, signs of climatic change, and the significance of national park installations. Depending on the weather the summit of

	Keeskogel (3291 m) can be reached and the National Park Center in Mittersill will be visited.
Learning outcomes	The student is supposed to holistically experience a selected part of the alpine world with its landscape, dimensions, physical conditions, and organisms together with fellow students and supervisor – by walking, looking, thinking and talking. She/he should learn to get an unerring eye for characteristic species, how to name them, their preferred habitats, and ecological interdependencies. Knowledge from detailed facts to global context is obtained by immediate perception and by theoretical involvement. A talk has to be prepared and given, the talks of other students have to be heard and discussed. Realistic scientific research conditions in the field, the responsibility of the scientist for the preservation of pristine nature and biodiversity, the enthusiasm for authentic biological activities and a sense of community play major roles.
Responsible contact	Heß, Martin

Title	Practical course: Marine biological field practical in Piran (Slovenia)
Content	This 2-week course in Mediterranean marine biology has its main focus on biodiversity and biocoenoses in the coastal Northern Adriatic Sea, and is hosted by the Marine Biology Station in Piran (Slovenia, https://www.nib.si/eng/index.php/departments/marine-biology-station-piran). It combines elements of a practical course (at the institute) with those of an excursion, like field trips to the coast. In addition, introductory lectures are given. Samples are collected with various methods (snorkeling at various places, dredge and plankton trawls with research cutter, etc.), and studied and identified in the lab. The students work in teams focusing on the main taxonomic marine groups, give demonstrations and work together on a protocol. An obligatory accompanying seminar is included during which the students give introductions to marine taxa.
Learning outcomes	The course provides basic knowledge in marine zoology and taxonomy and also practical skills about how to undertake a scientific analysis of the marine environment. The students learn how to identify various

	groups of marine organisms using scientific literature and how to present the results to the course during daily demonstrations. Moreover, the students learn how to compare their results with taxonomic and faunistic studies made in the Adriatic, and also correlate them with their ecology and the studied biocoenoses. Technical aspects are (i) the students learn how to use imaging techniques (underwater and in the lab), (ii) sampling techniques (during both snorkel rips) and sample trips with the institute's research boat to get their work material and (iii) curatorial handling of sampled specimens. Simple faunistic and biogeographic skills are also provided.
Responsible contact	Melzer, Roland

Research courses

Title	Research course: Aquatic Ecology
Content	The research course in aquatic ecology introduces students into basic methodology of large scale field experiments. Students will first learn important basics of the design of field mesocosm experiments and will gain a broad understanding of the aquatic ecosystem. Attached to bigger ongoing experiments or working in their own small project, students will be introduced to the common methods of water chemistry analyses where they can apply their basic chemical knowledge from the bachelors. Probe measurements, PAM fluorescence methods, and other modern techniques will be available for the students. A major task in this course is that students will be introduced to sampling strategies. Data will be analysed by applying common statistical methods. Students are required to take minutes in their lab journal and summarize their work in a report and a talk.
Learning outcomes	Students will be able to design experiments and will have knowledge about basic water chemistry analyses, identification of plankton organisms, planning and coordinating own research projects. A major knowledge gain for students will be the introduction into sampling strategies in field experiments. This course is especially recommended for Master students willing to proceed with a Master thesis in aquatic ecology.
Responsible contact	Stibor, Herwig; Stockenreiter, Maria

Title	Research course: Arthropod diversity through time
Content	In the course of the research project, the student will work on current topics of arthropod diversity research, including ontogenetic and fossil data, in the lab of the work group. The research course includes practical studies of arthropod material, including different modern imaging techniques such as macro-photography under different light settings, stereo imaging, or microscopy under fluorescence and white-light conditions. The

	student will learn up-to-date image processing techniques. The images are analysed quantitatively, and the results are compared to literature data and set into an evolutionary and ecological context.
Learning outcomes	The students acquire practical skills of handling arthropod material (extant and fossil). They learn how to properly image the animals in high-quality, including the macro- and micro-photographic skills as well as the subsequent image processing. The image presentation techniques learned in the framework of this course include digital drawing and possibly also 3D modelling. Furthermore, the students acquire quantitative analytical tools and skills for literature research. By comparing the results to literature data, evolutionary and systematic/phylogenetic thinking is trained.
Responsible contact	Haug, Joachim

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

Title	Research course: Biology of the arthropods and molluscs
Content	Students design and carry out their own small research projects about arthropod or mollusc biology and systematics applying suitable techniques and methods. Usually, they combine imaging techniques, such as light microscopy, scanning electron microscopy, and µCT, with histological techniques, such as embedding and sectioning specimens, identifying tissues and 3D-reconstructing organs, or with molecular analyses, using DNA sequences for species delimitation, phylogenetic reconstructions or evolutionary analyses. Students analyse and interpret their data, write a small paper-like scientific study and present it to an auditory.
Learning outcomes	The course provides knowledge on selecting and elaborating research questions, developing and performing a research project, and writing a scientific study also considering relevant literature. Students learn technical skills for imaging, morphological and histological analyses and working with DNA sequences, such as selecting, generating, and aligning markers or using phylogenetic and evolutionary reconstruction programmes. Students obtain practical experience regarding data analyses, interpretation of results, scientific discussions, scientific writing, and oral presentations. They also gain deepened knowledge about either molluscs or arthropod systematics, morphology and evolution.
Responsible contact	Schrödl, Michael; Melzer, Roland

Title	Research course: Comparative Primate Genomics
Content	Wet-lab projects related to the evolution of molecular circuitry within the AG Enard. This includes projects using (single-cell) RNA-seq sequencing, primate iPS cells and molecular biology methodology.

Learning outcomes	Students learn to independently plan and organize research work, perform and troubleshoot experiments, interpret and document results and communicate and discuss findings within the group.
Responsible contact	Enard, Wolfgang

Title	Research course: Computational Genomics
Content	Computational projects related to the evolution of molecular circuitry within the AG Hellmann. This includes projects around (single-cell) RNA-seq sequencing analysis, comparative genomics, functional genomics and population genetics.
Learning outcomes	Students learn to independently plan and organize research work, perform and troubleshoot computational experiments, interpret and document results and communicate and discuss findings within the group.
Responsible contact	Hellmann, Ines

Title	Research course: Ecology / zoology: Aquatic Ecology
Content	Students want to get into basic methodology of performing ecological experiments, ranging from small laboratory to large field scale. Students will first learn important basics experimental design and gain a broad understanding of the aquatic ecosystem. Attached to the study of chemical engineering in the field of chemistry, where they can apply their basic chemical knowledge from the bachelors. Sample measurements, PAM fluorescence methods, and other modern techniques will be available to the students. A major task in this course is to introduce students to sampling strategies. Data will be analyzed by applying common statistical methods.
Learning outcomes	Students Want to Make Experiments and Want to Know on Basic Water Chemistry Analysis, Identification of Plankton Organisms, Planning and Coordinating Own Research Projects. A major knowledge gain for students wants to learn more about the strategies in

	sampling strategies from laboratory to field scale. This course is especially recommended for Master in Aquatic Ecology.
Responsible contact	Stibor, Herwig; Stockenreiter, Maria

Title	Research course: Ecology / zoology: Behavioural Ecology
Content	Students will conduct a research project throughout the semester with the possibility of designing a personalized work schedule (eg, number of hours per day). Insect or spider behavior, with the opportunity of developing their own research question. They will be involved in all aspects of research, from experimental planning to data collection, analyzing data and interpreting results, and presenting their findings either orally or in written form.
Learning outcomes	Students who successfully complete the research course want to learn hypothesis testing, how to design and execute experimental work, animal rearing and handling, and a wide range of experimental skills such as behavioral assays, trait analysis (song structure, sperm quality) and tools in statistics.
Responsible contact	Dingemanse, Niels

Title	Research course: Functional morphology of arthropods
Content	In the course of the research project, the student will work on current topics of body organisation in arthropods in the lab of the work group. The research course includes investigations of body organisation in different ontogenetic stages as well as in fossil representatives. The student will perform practical studies of arthropod material, including different modern imaging techniques such as macro-photography under

	different light settings, stereo imaging, or microscopy under fluorescence and white-light conditions. The student will learn up-to-date image processing techniques. The images are analysed quantitatively, and the results are compared to literature data and set into an evolutionary and ecological context.
Learning outcomes	The students acquire practical skills of handling arthropod material (extant and fossil). They learn how to properly image the animals in high-quality, including the macro- and micro-photographic skills as well as the subsequent image processing. The image presentation techniques learned in the framework of this course include digital drawing and possibly also 3D modelling. Furthermore, the students acquire quantitative analytical tools and skills for literature research. By comparing the results to literature data, evolutionary and systematic/phylogenetic thinking is trained.
Responsible contact	Haug, Carolin

Title	Research course: Functional regeneration in the axolotl brain: The role of glia in inducing plasticity
Content	During this course the students will characterize the wound healing process upon stab wound injury in Axolotl midbrain. In order to identify the cellular and molecular basis of the regenerative process, the activation of oligodendroglia, radial glia (stem cells) and microglia will be analyzed (by in situ hybridization and immunohistochemistry). Changes in morphology and proliferation rate will be quantified in order to determine if axolotl brain recapitulates the scarless regeneration mode observed in skin and spinal cord.
Learning outcomes	At the end of the course the students will be able to: - Design complex experimental protocols (molecular and cellular techniques) - Dissect and section axolotl brains and carry out staining (ISH and immunohistochemistry). - Acquire and analyze confocal pictures - Quantify cell density and perform statistical analysis - Interpret and discuss their own data
Responsible contact	Sanchez-Gonzales, Maria del Rosario

Title	Research course: Osteology and Bioarchaeology
Content	Research projects within the State collection of Anthropology (www.sapm.mwn.de, Michaela Harbeck) and/or the Institute for Mummy Studies (Bozen; http://www.eurac.edu, Albert Zink). They cover methods, research and research design for topics related to anthropological remains as exemplified in the Literature below.
Learning outcomes	Students learn to independently plan and organize research work, perform and troubleshoot experiments, interpret and document results and communicate and discuss findings within the group.
Responsible contact	Harbeck, Michaela; Zink, Albert

Title	Research course: Plant-microbe interactions
Content	- Genetics and evolution of host microbe interactions - The plant-microbe interface - Types of symbiosis between different organisms (mutualism, commensalism, parasitism, …) - Molecular mechanisms of root nodule symbiosis - Molecular mechanisms of arbuscular mycorrhiza - Signaling in tryopanosoma - Allelopathy and chemical molecule crosstalk of plants with other organisms - Bacterial entry during root nodule symbiosis and microbial interactions - RNAs in host microbe interactions - Plant disease and plant immunity
Learning outcomes	Students develop - a basic understanding of current concepts and insights in host-microbe interactions - a basic understanding of the molecular methods employed to study host/microbe interactions

Responsible contact	Parniske, Martin

Title	Research course: Special zoology
Content	Participation in current research, lab work, data interpretation.
Learning outcomes	The practical research course requires independent planning, organization and performance of experiments, including interpretation and documentation of results.
Responsible contact	Heß, Martin; Neusser, Timea; Brenzinger, Bastian

Title	Practical course: Function, Genetics and Evolution of C4 and CAM Photosynthesis
Content	C4 photosynthesis and the crassulacean acid metabolism (CAM) are the most remarkable examples of convergent evolution across the plant tree of life. Being carbon concentrating mechanisms (CCMs), both result in an increased availability of CO2 close to Rubisco. The output might be similar, but there is great diversity in the way C4 and CAM lineages evolved. The goal of this practical is to explore morphological, anatomical, physiological, molecular and evolutionary aspects of C4 and CAM across the many plant lineages present in the Botanical Garden Munich-Nymphenburg. Moreover, students will perform an experiment using Portulaca oleracea, member of one of the few genera able to perform C4 and CAM in the same organism, to understand the plasticity of these CCMs.
Learning outcomes	Previous attendance to the "Seminar Function, Genetics and Evolution of C4 and CAM Photosynthesis" is mandatory for registering for this practical. Evaluation will be performed in the form of protocols to be completed during practicals and a poster preparation at the end of the course. The course is fully in-person and open to MSc students. As specific learning outcomes, students will be able to design and plan experiments, collect and analyse scientific data, discuss and present their findings as posters.

Responsible contact	Callegari Ferrari, Renata

Title	Practical course: Functional Anatomy of Seed Plants with Focus on Crops
Content	Plant anatomy is the study of the structural arrangement of cells, tissues and organs. A good understanding of anatomy is key for succeeding in all other areas of plant science, such as morphology, physiology, evolution, molecular studies, and ecology. This course is a hands-on dive into the fundamentals of plant anatomy, exploring the functionality of anatomical traits in all plant organs. Whenever possible, the evolution of anatomical traits will be investigated in crops under an evolutionary, comparative perspective. During the domestication process many anatomical changes were favored in wild relatives of today's crops according to human needs, which makes them excellent examples

	to illustrate functional consequences of anatomical changes.
Learning outcomes	Classes will consist of an introduction, preparing and analysing the materials each course day, and the evaluation will consist of protocols to be filled each day, together with a final written exam.
Responsible contact	Callegari Ferrari, Renata

Title	Practical course: Plant Adaptation to extreme environments
Content	The course introduces and investigates the biology (morphology, anatomy, physiology, ecology, reproduction) of plants living under extreme growing conditions, such as hydrophytes, halophytes, xerophytes, epiphytes, carnivorous plants, parasitic plants, alpine and arctic plants and lichens.
Responsible contact	Zerdoner Calasan, Anze

Title	Seminar: Current topics in systematic biology
Content	The seminar schedule can be found here: https://docs.google.com/spreadsheets/d/1rjRYFQDVTknkQloSRa5eD8tYYVPk8ccfh7rKcbNm4CM/edit?usp=sharing
Responsible contact	Kadereit, Gudrun

Title	Research course: Taxonomy and morphology of selected flowering plants
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