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.

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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 the 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

Title	Lecture: Computational Methods in Population Genetics I
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.
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.
Responsible contact	Metzler, Dirk; Pereira, Ricardo

Title	Lecture: Computational Methods in Population Genetics II
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 Marko-Chain Monte Carlo methods (MCMC) and

	different variants of Hidden Markov Models (HMM) as used in programms 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	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.
Responsible contact	Dirk Metzler, Ricardo Pereira

Title	Lecture: Functional morphology and phylogeny of metazoa – Vorlesung: Funktionelle Morphologie und Phylogenie der Metazoa
Content	In this lecture different aspects of functional morphology and phylogeny of Metazoa will be outlined. Especially those animal groups which have not been in the focus in the basic organismic courses will be treated in detail. Different aspects of outer morphology and internal anatomy and their functions will be in the focus of the lecture. These include, among others, locomotion, sensorial functions, feeding, and reproduction and development. In the lecture the evolutionary changes of these morphological characters will be outlined for the different metazoan groups. For this purpose, phylogenetic systematics will be used as basis to explain the evolutionary changes in the context of evolutionary relationships between the groups.
Learning outcomes	The aim of the lecture is to achieve a profound functional morphological understanding in a phylogenetic context within Metazoa. The students should be able to explain character evolution along a phylogram and to state which characters evolved at

	which time for the first time. Furthermore, they should be able to explain morphological transformations in a functional context. Basic zoological knowledge (as provided, e.g., by the basic organismic module in the first two bachelor semesters) is required before this lecture can be attended. This lecture provides a profound basis for all organismically interested students who plan to attend advanced zoological, ecological or evolutionary biological courses. Furthermore, the lecture provides a profound basis for the zoological part of the Staatsexamensprüfung (state examination).
Responsible contact	Matthias Starck, Joachim Haug

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	Wolfgang Enard, Ines Hellmann

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	Gompel, Nicolas

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

Title	Lecture: Phylogenetics I
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 evoltion, application of software packages

	such as PHYLIP and RAxML. The lecture is accompanied with practical sessions.
Learning outcomes	After taking this course, 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
Responsible contact	Metzler, Dirk; Höhna, Sebastian

Title	Lecture: Phylogenetics II
Content	Contents are computational methods for the reconstruction of phylogenetic trees as well as the underlying probabilistic evolution models and statistical principles, in particular maximum likelihood and 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, including RAxML and BEAST. They perform simulation studies for various scenarios to assess whether and, if so, 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	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.
Responsible contact	Metzler, Dirk; Höhna, Sebastian

Title	Lecture: Transcriptional regulation from DNA to diversity
Content	This lecture describes how embryonic development, particularly in animals, is controlled at the transcriptional level. It is rooted in a historical perspective on research in genetics, embryology and the birth of molecular biology. It reviews the basic molecular mechanisms of Eukaryotic transcription of DNA into RNA, as well as the different levels of regulation of this process. The lecture has a strong emphasis on cis-regulatory elements, and much less emphasis on epigenetic regulation. Finally, the lecture examines the consequences of the molecular processes on cell specification and differentiation, tissue patterning and morphogenesis, as well as species evolution.
Learning outcomes	The students will have an overview on the transcriptional control of embryonic development. In particular the lecture highlights the relationships between different levels of biological complexity, from molecules, to cells, to organs and to the entire organism. In addition, the lecture provides a solid refresher on the basic mechanisms of gene transcriptional regulation.
Responsible contact	Stephane Rolland, Nicolas Gompel

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 Malacology
Content	Die Vorlesung vermittelt Anatomie, Phylogenie und Diversität der Großgruppen.
Learning outcomes	Die Studierenden beherrschen die Inhalte der Vorlesung.

Responsible contact	Haszprunar, Gerhard; Schrödl, Michael; Nützel, Alexander; Brenzinger, Bastian

Title	Vorlesung und Praktikum Osteologie und funktionelle Anatomie der Hominiden
Content	Vorlesung: Aufgaben der Prähistorischen Anthropologie, Erstellung von Individual- und Kollektivbefunden an menschlichen Skelettfunden, naturwissenschaftliche und soziologische Interpretation. Funktionelle Anatomie des Primatenskelettes und fossiler Homininenfunde, evolutive Merkmalsänderung, Form und Funktion ausgewählter Merkmale des aktiven und passiven Bewegungsapparates. Praktikum: Morphologie des menschlichen Skelettes unter funktionell-anatomischen Gesichtspunkten, Identifikation basisbiologischer Parameter incl. Pathologie und Todesursache bei unterschiedlichen Überlieferungsformen (Körperbestattungen und Leichenbrand), Bevölkerungsrekonstruktion, funktionelle Anatomie des Primatenskelettes und von Funden fossiler Hominiden am Beispiel des Mastikations- und Lokomotionsapparates unter evolutionsbiologischen Gesichtspunkten.
Learning outcomes	Vorlesung; Determinanten menschlicher Bevölkerungsentwicklung in Zeit und Raum, Differentialdiagnose von Primatenskeletten i.wS. Praktikum: Die Studierenden lernen, menschliche Skelettfunde verschiedenen Überlieferungsgrades zu identifizieren, die biologischen Basisdaten zu erheben, und Implikationen für ehemalige Bevölkerungen abzuleiten. Die Kenntnisse sind sowohl im anthropologischen als auch im forensischen Kontext relevant. Merkmalsevolution wird anhand der funktionellen Anatomie von Primatenskeletten und jener früher Homininen erlernt mit Schwerpunkt auf den funktionellen Anpassungen des aktiven und passiven Bewegungsapparates für die obligatorische Bipedie.
Responsible contact	Göhring, Andrea; Grupe, Gisela

Title	Vorlesung: Anthropologie, Biologische Spurenkunde

Content	Methods of forensic and legal science introduced by members of the Institute of Legal Medicine and anthropologists.
Learning outcomes	The students are introduced to the archaeometry of mineralized vertebrate tissues. Besides the communication of methods, students are trained in hypothesis building, choice of adequate methods, and interdisciplinary discussion of scientific questions arising both from the natural and social sciences. Students will be equipped with advanced knowledge prerequisite to scientific research in this topic, including forensic anthropology.
Responsible contact	Gruppe, Gisela

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, Prian) nachdrücklich empfohlen.
Responsible contact	Schrödl, Michael; Melzer, Roland; Heß, Martin; Jörger, Katharina; Neusser, Timea; Straube, Nicolas

Lectures summer term

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, isochors, 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

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

Title	Lecture: Archaeometry
Content	Archaeometry is a scientific field where the methods of physical, chemical, and biological sciences are applied to answer both anthropological and archaeological questions. Current research focuses on palaeoecology, subsistence economies, population admixture, and culture transfer. At the Faculty of Biology, research substrate is made up of the bodily relics of human individuals from the Holocene. The lecture introduces the field of archaeometry and the most frequent analytical approaches (laboratory and mathematic) towards archaeological skeletal remains. Archaeological human skeletons belong to the movable objects of the cultural heritage. The lecture is mandatory for the Archaeometry practical course.
Learning outcomes	Choice of the appropriate method for answering a specific question including hypothesis building, decision making between invasive and non-invasive methods, and the expected outcome. Isotopic sourcing by the application of mixing models. Physiological pathways of marker isotopes.
Responsible contact	Göhring, Andrea; Grupe, Gisela

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	Martin Heß

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: Contemporary Behavioral Ecology
Content	Students will be thoroughly introduced to behavioral ecology. They will learn in depth about the history of the field, the role of evolution in behavioral ecology, mechanisms of behavior, communication, predator-prey and parasite-host interactions, foraging and optimality, sexual selection, mating systems, parental care, life history theory, altruism and cooperation, and group living.
Learning outcomes	Students acquire a firm knowledge about basic principles and different research fields in behavioral ecology. They obtain the fundamental knowledge required to participate in further specialized courses, such as "Experimental Behavioral Ecology"
Responsible contact	Dingemanse, Niels; Tuni, Cristina

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

Learning outcomes	The evolution of flowers --and of flowering plants-- is the result of plant/animal interactions. Practicing ecological field research.
Responsible contact	Renner, Susanne

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

Title	Lecture: Human genomics II
Content	This lecture builds on knowledge obtained in molecular biology and genetics on the Bachelor's level and partly on knowledge from Human Genomics I (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 Genmics, 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: Microscopic anatomy and histology of vertebrates
Content	The lecture covers all aspects of light microscopic histology of vertebrate cells and tissues. A focus is on correct diagnosis of normal, healthy tissues. Technical aspects of light and electron microscopy are covered and explained so that students learn to read microscopic images correctly.
Learning outcomes	General goals for the course are to communicate fundamental knowledge about cells, tissues and microscopic anatomy of organ systems. Knowledge acquired in the class will enable the students to transfer theoretical knowledge to practical applications, in particular recognize and analyze structures of animals on a microscopic level.
Responsible contact	Starck, Matthias

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

	Biology for any further application of land plants using contemporary in vitro methods.
Responsible contact	Gottschling, Marc

Title	Lecture: Morphology, Phylogeny and Evolution of Deuterostomes
Content	The lecture covers all aspects of functional morphology, microscopic anatomy, and phylogeny of the deuterostomes. Goal of the lecture is that the students understand the body plan of the deuterostomes and how it changed during course of evolution. The lecture also covers important aspects of the ecological and economic importance of the animals in that clade. The class is part of a series of morphology and phylogeny classes which all communicate fundamental knowledge about major clades of the animals. Together, all these classes present a concise but complete overview of all animal clades ("Lower Invertebrates", Arthropoda, Mollusca, Deuterostomia, Vertebrates).
Learning outcomes	General goal for the course is to communicate fundamental knowledge about deuterostome biology (anatomy, microscopic anatomy, ecology, and basic physiology). Knowledge acquired in the class will enable the students to transfer theoretical knowledge to practical applications, in particular recognize and analyse structures of deuterostomes.
Responsible contact	Starck, Matthias

Title	Vorlesung: Historische Umweltforschung
Content	Contents are determinants of human population development in space and time as well as cultural aspects of everyday life history with their biologically available results.
Learning outcomes	The students are introduced to the biology of the human population and its development. Students will

	be equipped with advanced knowledge prerequisite to scientific research in this topic, including forensic anthropology.
Responsible contact	Göhring, Andrea; Grupe, Gisela

Seminars winter term

Title	Seminar: Anthropological Seminar: Focus on Africa
Content	Anthropological seminar, each semester with a different topic according to current issues (waste and environment, modern and historic human ecology, evolution, hostility and discrimination, forensic anthropology, new methodological approaches…).
Learning outcomes	The students acquire skills in literature research, presentation and communication skills. The structure of the seminars introduces the students to presentations and discussions on scientific meetings.
Responsible contact	Andrea Göhring, Gisela Grupe

Title	Seminar: Behavioural Ecology meets Quantitative Genetics
Content	In this course, students are trained in modern evolutionary behavioural ecology, which strongly focuses on the integration of classic behavioural ecology with other fields of evolutionary biology such as quantitative genetics. Topics include environmental and genetic underpinning of behaviour, the multivariate nature of behaviour, social behaviour and interacting phenotypes, and behavioural traits as latent variables.
Learning outcomes	Students receive lectures on theory and concepts, are trained in the (statistical) methods necessary for their study, and apply these methods to answer specific questions.
Responsible contact	Dingemanse, Niels

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	Sabine Schultes, Herwig Stibor

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	Maria Stockenreiter

Title	Seminar and Discussion 1: Species Concepts, Adaptation and Speciation
Content	Students will read scientific publications treating the topics adaptation, species concepts and speciation from different angles and will give oral presentations or short summaries on these papers. They will actively discuss the scientific issues raised in each presented publication.
Learning outcomes	After this course, students will know why and how adaptation and speciation play a central role in evolution, ecology and systematics. They will have read important publications on these central topics. They will have gathered experience giving presentations in different formats, asking critical questions about scientific studies and participating in group discussions.
Responsible contact	Renner, Susanne

Title	Seminar: for practical course: Knowledge of selected useful and toxic plants/ Seminar zum Praktikum Kenntnis ausgewählter Nutz- und Giftpflanzen, Systematik, Biologie, Geschichte, Verwendung, Morphologie der genutzten Teile. (Ergänzungsveranstaltung)
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	Ehrentraud Bayer

Title	Seminar: Paleopathology
Content	This seminar will deal with various aspects of anthropological reseach focusing on Early Medieval ages. From a methodological view this includes studies dealing with osteology, palaeopathology, ancient DNA and stable isotopes. We will provide insides into indiciplinary research combing data from skeletal remains and archological findings.
Learning outcomes	The students will get an overview on the field of Paleopathology and will be able to understand, present, discuss and critically judge current literature in the field.
Responsible contact	Harbeck, Michaela; Enard, Wolfgang; Zink, Albert

Title	Seminar: Urban Ecology
Content	We discuss selected literature on ecological patterns and processes in urban areas. The literature seminar is complemented with lectures on current research on the urban ecology of birds and mammals.
Learning outcomes	The goal of the seminar is to better understand anthropogenic drivers of biodiversity in cities and global change in general.
Responsible contact	Henrik Brumm

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	Bart Nieuwenhuis

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	Boshart, Michael; Parniske, Martin; Hann, Dagmar

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; Warmuth, Vera-Maria; Pereira, Ricardo

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: The genetic origin of evolving traits
Content	The seminar will cover important recent literature in the field of evolution and development ("evo-devo"). Research papers will be assigned to each participant. Each student will have to independently read, understand a paper and prepare a presentation. The student is invited to use resources and literature beyond the assigned paper. This is a two-days block seminar during which each student will present a paper and moderate the discussion around another paper presented by another student. Each presentation and will be followed by a group scientific discussion.
Learning outcomes	The students will improve their skills to read a paper, dissect its scientific content, present this content to an audience that has not read the paper. The seminar wil

	also highlight genetic principles underlying morphological evolution in animals and plants.
Responsible contact	Stephane Rolland, Nicolas Gompel

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

Seminars summer term

Title	Seminar: Animal Models for Psychiatric Disorders
Content	In the seminar, the students critically discuss the use and applications for animal models for psychiatric disorders, with a special focus on major depression and anxiety-related disorders. The students learn which approaches for translational psychiatry are state-of-the-art, which model systems are used and which molecular and behavioral readouts are applied to study psychiatric disorders.
Learning outcomes	Using examples from the recent literature, the students learn how to read and judge a scientific paper and how to summarize the key findings in a scientific presentation. The implications of different scientific approaches using animal models are discussed.

	Furthermore, the students learn to collect the diverse information on a specific topic related to the overall theme of the seminar and to compose a written assay about this.
Responsible contact	Wotjak, Carsten; Schmidt, Mathias

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

Title	Seminar: Chemical ecology and neurobiology
Content	Topics of this seminar are lying at the intersection of chemical ecology and neurobiology. The course focuses on recent scientific advances in the understanding of how neurons interact with the environment of an individual animal. This includes for example chemical communication in foraging behavior, host-parasite interactions and mate recognition. Each student will be assigned a research paper from primary literature. Using additional literature and feedback from the instructor, each student will prepare an oral presentation on the paper and present it in front of the group.

Learning outcomes	Students will get an overview on topics of chemical ecology, behavior and neurobiology, and the connected primary literature. They will gain insight into methodology and the practical aspects of various different model organisms. Furthermore, they will learn how to present and structure scientific data, as well as how to critically discuss it with their audience.
Responsible contact	Gompel, Nicolas; Bräcker, Lasse

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: Evolutionary developmental biology of arthropods
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	Haug, Joachim; Zhang, Natascha

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; Tuni, Cristina

Title	Seminar: Forensic Anthropology
Content	Topics: Victim and offender identification, 3D reconstruction, simulation of mass graves, accident reconstruction, excavation and recovery; with practical parts in analyses of patterns of movement, simulation, prints/photos of extremities and 3D modeling
Learning outcomes	The students acquire skills in literature research, presentation and communication skills. The structure of the seminars introduces the students to presentations and discussions on scientific meetings.

Responsible contact	Gisela Grupe

Title	Seminar: From genes to behavior
Content	How do genes define the behavior of humans and animals? Based on this question, we will explore examples that link the function of single genes to the behavior of an organism. These behaviors include mating behavior, individual personality and learning. One research paper from primary literature is assigned to each student. Using additional literature and feedback from the instructor, students prepare an oral presentation on their topic and present it in front of an audience.
Learning outcomes	Students will get an overview of various topics from the field, as well as the basis of genetic and behavioral analysis. They will gain insight into methodology and the practical aspects of various different model organisms. Furthermore, they will learn how to present and structure scientific data, as well as how to critically discuss it with their audience.
Responsible contact	Gompel, Nicolas; Bräcker, Lasse

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: Induced pluripotent stem cell technologies
Content	We discuss selected papers for the past 10 years and understand the biological and medical topics inspired by the discovery of induced pluripotent stem cells. Each student has to introduce a milestone paper and has to participate in the discussion.
Learning outcomes	The students will get an overview on the field of induced pluripotent stem cells and will be able to understand, present, discuss and critically judge current literature in the field.
Responsible contact	Enard, Wolfgang; Geuder, Johanna; Drukker, Micha

Title	Seminar: Marine Biology (Systematics of marine flora and fauna)
Content	Introduction to literature search (including electronic), collecting and conservation protocols, determination work
Learning outcomes	
Responsible contact	Haszprunar, Gerhard; Neusser, Timea; Brenzinger, Bastian

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; Marin, Macarena; Hann, Dagmar

Title	Seminar: Transcription & Development
Content	Research papers about transcriptional regulation in the context of embryonic development are assigned to each participant. Each student will have to independently read, understand the paper and prepare a presentation. The student is invited to use resources and literature beyond the assigned paper, and can expect advice from the instructor.
Learning outcomes	The students will gain a conceptual overview of the tight links that exist between transcriptional regulation, the unfolding development of an organism, and the evolution of these processes. They will also acquire state-of–the-art knowledge on current and widely used methods in genetics, genomics and imaging in the field of Developmental biology.
Responsible contact	Gompel, Nicolas

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; Böttger, Angelika

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	Martin Heß

Practical courses winter term

Title	An Introduction to R
Content	R is a widely used, freely available software and programming language for analysing data. In the lecture students learn the necessary theoretical background for using R. They will become familiar with the basic data structures and control flows of the R programming language. In the tutorial, the students become familiar with R, by first trying simple commands and then learning how to simulate data. Then they learn to perform basic data analyses and to write simple programme scripts.
Learning outcomes	Students will have the theoretical background knowledge needed to use R practically, and will be able to perform basic data analyses with R. They are familiar with a selection of functions of R and will be able to write simple programme scripts.
Responsible contact	Dirk Metzler, Sonja Grath, Noémie Becker

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; Straka, Hans; 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; Resl, Philipp

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	Martin Heß

Title	Practical course: Drosophila genetics and neurogenetics
Content	This course is a hands-on illustration of modern approaches to study the model organism Drosophila melanogaster. The students will be presented with state-of-the-art techniques used to address fundamental questions in developmental biology and neurosciences. The first part of the practical course will concentrate on the formation of gene expression patterns and their relationships to morphological phenotypes. It will focus on Drosophila wing development to illustrate these processes. The second part of the course will explore how the function of nervous system can be studied in a developed organism, and in particular how modern research deciphers the relationship between neuronal circuits and animal behavior. The practical course will cover several techniques including classical fly genetics, the use of transgenic

	lines, microscopy, micro-dissection, immunochemistry, image analysis.
Learning outcomes	The students will have concrete notions of how research with Drosophila is conducted. In particular, they will see the connections between formal genetics, phenotypic analysis, and how this relates to gene expression and function.
Responsible contact	Nicolas Gompel, Lasse Bräcker

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	Ehrentraud Bayer

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: Phylogenetic Analysis of Morphological and Molecular characters / PAMM Kurs
Content	Students learn how to code morphological characters for the construction of phylogenies. They learn to use the main algorithms and software packages for the construction of phylogenetic trees and to use them in systematic classification.
Learning outcomes	Students gain practical experience and knowledge of the use of algorithms and software for the construction of phylogenetic trees and systematic classification.
Responsible contact	Haszprunar, Gerhard; Erpenbeck, Dirk; Voigt, Oliver

Title	Practical course: with excursion for scientific investigations in natural history museum collections
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	Carolin Haug, Joachim Haug

Title	Practical on Computational Methods in Population Genetics
Content	This practical class starts with a lecture, followed by with exercises in which each student will explore a different data set and present the results daily. The course is structured under two major methodologies that are commonly used in current literature on Population Genetics: 1. Determine population structure, 2. Determine gene flow during divergence. Through these methodologies, the students will learn several concepts of population genetics such as: Hardy-Weinberg equilibrium, Linkage disequilibrium, vicariance, hybridization, coalescent, and introgression.
Learning outcomes	In this master-level course, the students will: - Get familiar with working in a computer cluster; - Get familiar with UNIX computational language; - Get familiar with the Bayesian clustering method implemented in the programme STRUCTURE (Pritchard et al. 2000); - Get familiar with the coalescent analysis implemented in the programme IMa2 (Hey and Nielsen 2004); - Learn how to analyze and present results from these methodologies.
Responsible contact	Jochen Wolf, Ricardo Pereira

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	Roland Melzer, Joachim Haug, Matthias Starck

Title	Praktikum Malacology
Content	Der praktische Teil fokussiert auf unterschiedlichste Methoden (Sektion, Histologie, REM, Freilandarbeit, molekular, paläontologisch) der Malakologie. Ggf. in Englisch.
Learning outcomes	Die Studierenden verstehen die theoretischen und praktischen Inhalte des Praktikums. Besonderes Augenmerk wird auf die Anfertigung korrekt beschrifteter und mit Größenmaßstab versehener Zeichnungen von Sektionen und Histologie-Präparaten gelegt.
Responsible contact	Haszprunar, Gerhard; Schrödl, Michael; Nützel, Alexander; Brenzinger, Bastian

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	Wolfgang Enard, Ines Hellmann, Beate Vieth

Practical courses summer term

Title	An Introduction to Remote Satellite Sensing and GIS
Content	The aim of this course is to provide a first insight into the potential of satellite remote sensing and Geographical Information Systems (GIS) in the field of biology and environmental monitoring. The first part of the course introduces to various methods of image processing such as image calibration and enhancement, geo-referencing, image to image registration, filtering and spectral analysis (using ERDAS IMAGINE). The students will learn about the spectral properties of different sensors and how to interpret the information in satellite images. They will explore how to extract relevant information by supervised and unsupervised classification approaches. The students will learn also the basic principles of object based image classification using eCognition. Next they will apply this knowledge to practical examples: they will analyse land cover change and deforestation by comparing time series of satellite images as well as the impacts of fire and storm. The second part will give an introduction into GIS (using ArcGIS) and its basic functions for spatial analysis and digital cartography.
Learning outcomes	Students learn to process, understand and interpret satellite images. They obtain skills to work with satellite images using three different software packages (ERDAS IMAGINE, ArcGIS, and eCognition).
Responsible contact	Siegert, Florian

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
Content	The seminar part is based on the book "Measuring behaviour" by Paul Martin and Patrick Bateson (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, collect background information, and present the results to the

	other members of the course in an oral scientific presentation. After the course, each group will write a report in the form 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	Brumm, Henrik; Goymann, Wolfgang

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; Marin, Macarena; Hann, Dagmar

Title	Practical course: Archaeometry
Content	The students will acquire practical skills in microanatomy and histomorphometry, X-raying, stable isotope analysis of heavy and light elements, and isotopic sourcing.
Learning outcomes	Practical experience in the application and interpretation of methods and, equally important, concepts in physical anthropology.
Responsible contact	Göhring, Andrea; Grupe, Gisela

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; Wiegrebe, Lutz

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

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

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

Title	Practical course: Flowers and pollinators - reproductive biology of higher plants. (Blüten und Bestäuber)
Content	The evolution of flowers --and of flowering plants-- is the result of plant/animal interactions. This course explores all aspects of the function of flowers, integrating findings and approaches from ecology, physiology, and animal behavior. Topics that will be covered are (1) hypotheses about the benefits of sexual reproduction, (2) the origins of insect pollination, (3) the production and ecological role of flower color, scent, and nectar, (4) deceptive pollination systems, (5) pollen-stigma interactions and incompatibility systems, (6) flowering plant mating systems incl. selfing and apomixis, and (7) the main pollination syndromes.

Learning outcomes	The evolution of flowers --and of flowering plants-- is the result of plant/animal interactions. Practicing ecological field research.
Responsible contact	Facher, Eva-Justina; Renner, Susanne

Title	Practical course: Microscopic anatomy and histology of vertebrates
Content	During the practical course the participants are introduced to standard microscopy techniques with bright field, phase contrast and fluorescence light microscopy. The material studied is histological slides that embrace all cell and tissues types that occur in vertebrates. At the end of the class the students should be able to diagnose tissues and cells as well as recognize organ structure by their microscopic anatomy. The class communicates fundamental knowledge of how tissues and organs are built. The lab requires a detailed lab report according to excellent scientific practice.
Learning outcomes	General goals for the course are to communicate fundamental knowledge about cells, tissues, and microscopic anatomy of organ systems. Knowledge acquired in the class will enable the students to transfer theoretical knowledge to practical applications, in particular recognize and analyse structures of animals on a microscopic level. With this, the students obtain skills for future lab work, in particular in preparation for their master's thesis or PhD work. Students learn scientific presentation in written data presentation, including introduction to the topic, documentation, interpretation and discussion of the results. These skills are particularly aimed at preparing students for theses writing and scientific publications.
Responsible contact	Starck, Matthias; Yavorskaya, Margarita

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; Böttger, Angelika

Title	Practical: Morphology, Phylogeny and Evolution of Deuterostomes
Content	During the practical course the participants study preserved material, learn dissection techniques and analyse histological slides of all major clades of deuterostomes.
Learning outcomes	General goal for the course is to communicate fundamental knowledge about deuterostome biology (anatomy, microscopic anatomy, ecology, and basic physiology). Knowledge acquired in the class will enable the students to transfer theoretical knowledge to practical applications, in particular recognize and analyse structures of deuterostomes. With this, the students obtain skills for future lab work, in particular in preparation for their master's thesis or PhD work. Students learn scientific presentation in written data presentation, including introduction to the topic, documentation, interpretation and discussion of the results. These skills are particularly aimed at preparing students for theses writing and scientific publications.
Responsible contact	Starck, Matthias; Baranov, Viktor

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; Resl, Philipp

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	Martin Heß

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	Roland Melzer

Research courses

Title	Research course: Anthropology
Content	Participation in current research, lab work, data interpretation. Possible topics: Hard tissue histology, stable isotope analysis, interpretation of isotope data (mathematics, statistics, isotopic sourcing, data mining), X-raying. The students participate in current research projects. Dependent from the subject, the focus on the research course is on laboratory work or data evaluation, both under supervision. The research course includes independent literature research and scientific documentation of the results. A written documentation (topic, methods, results) is requisite.
Learning outcomes	Students who successfully completed this module are able to - contribute substantially to current research projects, thereby getting insights into project designs - choose the appropriate method for addressing specific scientific questions - learn the responsible handling of human remains - analyze experimental results - deepen their knowledge and experience in the specific topic of the research group
Responsible contact	Göhring, Andrea; Grupe, Gisela

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	Joachim Haug

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

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 or wet-lab/computional projects related to the evolution of molecular circuitry within the AG Enard and AG Hellmann. This includes cancer genomics, single-cell RNA-seq technologies, molecular neurobiology and primate iPS cells.
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; Ohnuki, Mari

Title	Research course: Computational Genomics
Content	Purely computational projects related to the evolution of molecular circuitry within the AG Hellmann. We focus on testing and developing computational methods for the statistical analysis of gene expression networks in evolution. Most of our work is done in with R.
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	Dingemanse, Niels; Schultes, Sabine; 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; Schultes, Sabine; Stibor, Herwig; Stockenreiter, Maria

Title	Research course: From sensory to motor behavior: a look on the gaze stabilization of the vestibulo-ocular reflex
Content	During the course, the student will study gaze stabilization as an example of a sensory-motor transformation driving eye movement behavior and the influence of drugs onto the vestibular system. The gaze stabilization investigated during this course is the vestibular ocular reflex (VOR) in amphibians. The student will learn to elicit the VOR with a motion platform or a galvanic stimulation. The resulting behavior of the eyes in the in-vitro preparation is recorded either with eye tracking or with electrophysiological methods. The influence of

	different drugs onto the VOR is then quantified using Spike2 and Matlab
Learning outcomes	At the end of the course the students will be able to: - Knowledge about electrophysiological recording technics - Analyze electrophysiological data - Use of Spike2 and Matlab - Perform statistical analysis - Interpret and discuss their own data
Responsible contact	Straka, Hans

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	Starck, Matthias; 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	Straka, Hans; Sanchez-Gonzales, Maria del Rosario

Title	Research course: Microscopic anatomy and histology of vertebrates
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	Matthias Starck

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; Enard, Wolfgang; 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	Haszprunar, Gerhard; Heß, Martin; Neusser, Timea; Brenzinger, Bastian

Title	Research course: Statistical Genetics
Content	Pariticipants carry out a small research project in the statistical genetics group. This may be a comptuter simulation study, a theoretical analysis or a statistical-bioinformatic analysis of a complex dataset.
Learning outcomes	Students gain research experience and are able to plan and conduct an independent research project. Students practice to present and discuss their work. They improve their theoretical knowledge in mathematical modeling in evolutionary biology and/or statistical-bioinformatic methods in statistical genetics.
Responsible contact	Dirk Metzler

Title	Research course: Taxonomie und Morphologie ausgewählter Blütenpflanzen
Content	In the course, students are embedded in current research of flowering plants. Methodologically, the work includes taxonomy and nomenclature, herbarium study, biogeography (georeferencing), light and electron microscopy and/or molecular phylogenetics. Emphasis is put on the interpretation and presentation of data. The lab requires a detailed lab report, which can be a part of a future publication.
Learning outcomes	Students obtain skills for biological research including design, web lab work, presentation and scientific writing. Students can apply theoretical and practical knowledge to approach biological questions in independent work. Students are well-trained in good general lab practice, including standard safety procedures, precise handling of chemicals and instruments and consciencious documentation of lab procedures. In working in small lab groups, social skills (teamwork, cooperation, fair play, work delegation, mutual respect), communication skills (rapport with

	instructors and fellow students, presentations, written lab reports) as well as organizational skills (efficient planning, documentation) are refined.
Responsible contact	Gottschling, Marc