

## Core Research at the Faculty of Science

Faculty of Science



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## Research, Relevance, Responsibility

Innovative. Interdisciplinary. International. Since 1477. These have been the University of Tübingen's guiding principles in research and teaching ever since it was founded. With this long tradition, the University of Tübingen is one of the most respected universities in Germany. In 2012 and in 2019, its institutional strategy was successfully selected for funding in the Excellence Initiative sponsored by the German federal and state governments, making Tübingen one of Germany's eleven universities distinguished with that title of excellence.

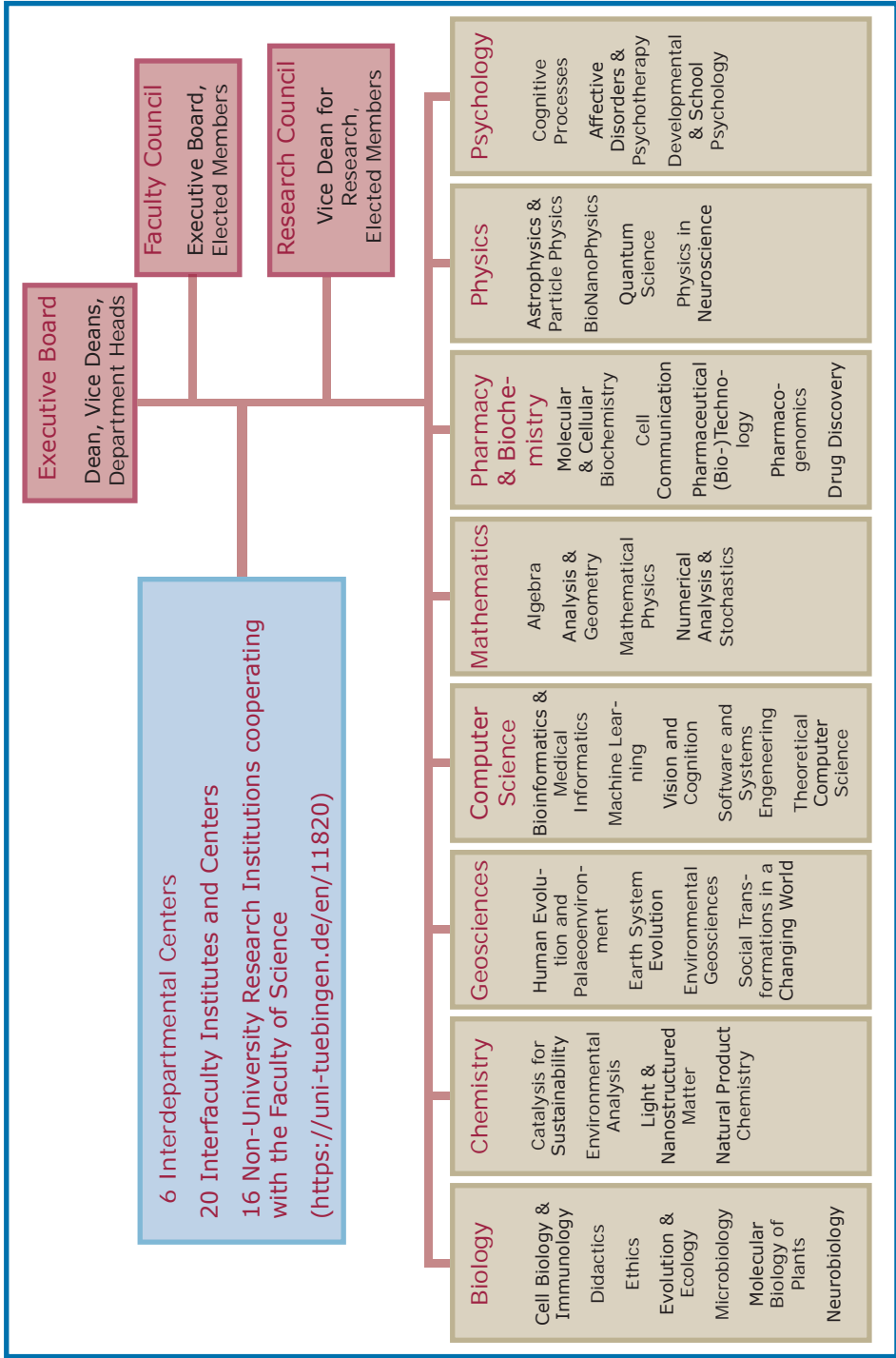
Founded in 2010 as a part of institutional restructuring, the new Faculty of Science has much to offer students and researchers alike. Next to traditional degree programs, we offer an interesting variety of interdisciplinary courses, which attract many students, as well as innovative study programs addressing new technological and societal challenges. The Faculty of Science not only offers traditional degree programs, but also an assortment of interdisciplinary degree programs, for example, Biochemistry, Geocology, Machine Learning, and Mathematical Physics. Special degree programs with a specific, applied focus have also been included, such as Applied Environmental and Geoscience, Media Informatics, Nano-Science, Pharmaceutical Sciences and Technologies, and School Psychology.

At the University of Tübingen, instruction and international research collaborations inform and enrich one another. Within the Faculty of Science, almost 2000 of our scientists and professors are currently working within various research networks. We offer our approx. 9700 students outstanding opportunities for their education in many different areas. This gives our graduates the optimal requirements for finding suitable careers in industry, research and education, whether they graduate with a Bachelor's, Master's or a Doctoral Degree.

The specific research profile of the Faculty of Science is mainly characterized by the areas of Life Sciences and Natural Sciences. Besides the pronounced interdisciplinary networking within the university, our research substantially benefits from tight collaborations with numerous independent research institutions, like the National Bernstein Network, the Max Planck Society, the Helmholtz Association, or the Leibniz Association/Senckenberg Nature Research Society.

Professor Dr. rer. nat. Thilo Stehle

Vice Dean for Research of the Faculty of Science





## Astrophysics and Elementary Particle Physics: From tiny particles to the universe

The Kepler Center combines a rich experimental program with intense theoretical studies in the field of particle physics. It is made up of four groups, focusing on astrophysics, computational astrophysics, general relativity, and particle physics.

Our Astrophysics research includes both the area "UV and Optical Astronomy" (focusing on experimental UV astronomy and quantitative spectral analysis of stars in their late and final stages of evolution), and the area "Experimental High Energy Astrophysics" (encompassing X-ray and gamma astronomy and ultra high energy astrophysics). For spectral analyses we are utilizing ground- and space-based observatories in a wide wavelength range, from the infrared to the X-ray region of the electromagnetic spectrum. The High-Energy Astrophysics group is involved in the exploration of the high-energy universe, from X-rays to very high-energy gamma rays (in the TeV regime) up to ultra high energy cosmic rays ( $10^{20}$  eV). The main research fields are the observation of high energy sources, data analysis, and interpretation of the underlying physical processes, as well as the development of instruments for the observation of high energy sources. Our researchers are involved in international space missions (XMM-Newton, INTEGRAL, eROSITA, ATHENA, JEM-EUSO) and ground based projects (HESS, CTA).

The research conducted in the Computational Physics group is focused on various aspects in the early phases of stellar evolution. This includes the theory of accretion disks, the formation and evolution of planetary systems from dust aggregates to fully grown planets, and the formation and propagation of jets. The researchers use different computational methods such as molecular dynamics simulations, SPH simulations and grid-based Magnetohydrodynamics, and Radiation-Hydrodynamics simulations.

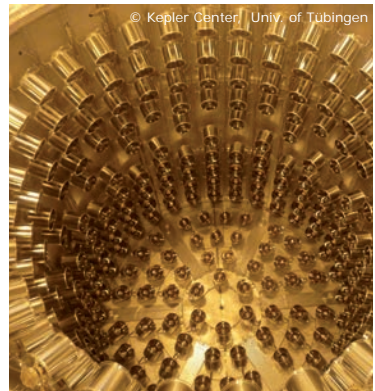
The Theoretical Astrophysics group works on problems related mainly to sources of gravitational waves and also on the processes which generate gamma rays and X-rays from neutron stars and black holes. The group studies the creation and the subsequent oscillations of neutron stars and the instabilities that may be induced via fast rotation. Moreover, the group is working on problems related to black hole perturbations and their relation to gravitational waves as well as to thermodynamics and quantum processes near black holes.

The experimental projects of the Particle Physics section aim to search for physics beyond the standard model and to study the role of elementary particles in cosmology.



They seek to directly detect the particles which form the dark matter in the universe. Novel detection techniques based on superconducting thin films and crystals at very low temperatures are being developed. The determination of the neutrino mixing parameters by measurement of neutrino oscillations will prepare the ground in the search for CP violation in the neutrino sector. The observation of neutrinoless double beta decay would prove the existence of Leptonflavor number violation, which together with CP violation could explain the matter–antimatter asymmetry in the universe. The experimental groups are part of international collaboration (CRESST, DOUBLE CHOOZ, GERDA, LHC-ALICE, FAIR-CBM, JUNO, SOX, ECHO) and are members and coordinators of the Helmholtz Alliance on Astroparticle Physics. Research in Theoretical Particle Physics aims at an improved understanding of the strong and electroweak interactions that govern the dynamics of elementary particles, and on identifying signatures of physics beyond the standard model that require an extension of our current picture of the most fundamental interactions. Another important focus of theoretical particle physics is finding out how quarks and gluons account for the spin of the proton. Physicists at Tübingen are furthermore pursuing research in the theoretical understanding of strongly interacting composite particles called hadrons.

The Kepler Center is part of many collaboration networks in experimental particle physics and in astrophysics, involving a high level of international exchange. To prepare for and carry out space missions for astronomic research purposes, additional relationships exist with the major space agencies, such as ESA, NASA and ROSCOSMOS. Scientific exchange opens up many opportunities for researchers and students to establish contacts worldwide. Similarly, scientists from across Germany and around the world welcome the chance to spend time at the Kepler Center and work on joint projects.

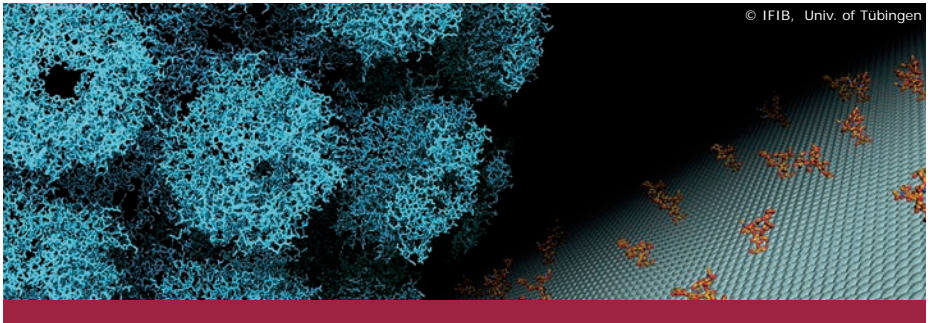


#### Kepler Center for Astro and Particle Physics

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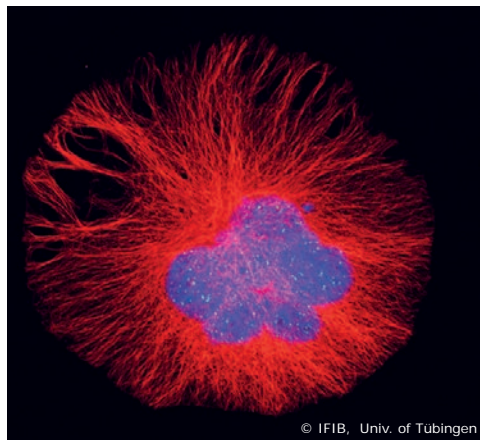


## Cell Biology, Tumor Biology and Immunology

Achieving a comprehensive understanding of basic cellular functions and their roles in both cancer and infectious diseases is a focus of core research at the University of Tübingen. This complex subject combines research in the areas of Biochemistry, Bioinformatics, Cell Biology, Medicine and Pharmaceutical Chemistry. Several national and international research networks, including the CRC 766 "The Bacterial Cell Envelope: Structure, Function, and Infection Interface", and the TRR 34 on the "Pathophysiology of Staphylococci", and the ERC-Grants "Mutation-Driven Immunoediting of Human Cancer?", and "The Quantitative BCL-2 Interactome in Apoptosis: Decoding How Cancer Cells Escape Death" form the basis for highly successful and visible research in this area.

The Interfaculty Institute of Biochemistry (IFIB) and the Interfaculty Institute for Cell Biology (IFIZ) are key players in these research efforts. The IFIB is a vertically integrated research center covering aspects of modern biochemical research ranging from atoms and molecules to cells and organisms. Its research areas include host-pathogen interactions, protein-lipid interactions, tumor biology, immunology and signal transduction. Research at IFIB addresses two fundamental, interdependent questions: "What are the basic molecular mechanisms underlying biological or biochemical processes?" and "How do these processes malfunction in disease?" The aim is to understand how pathogens manage to penetrate a somatic cell, use it as a host and hide themselves from the immune system. Scientists can use this knowledge to develop new medications that directly infiltrate the cells, opening up the prospect of combating previously untreatable infectious diseases. Additionally, understanding these processes will have an impact on the development of new treatments for tumors and degenerative diseases.

Within the Interfaculty Institute for Cell Biology (IFIZ) the research focus Cell Biology and Immunology is oriented towards the complex processes of the immune system and



tumor research. The IFIZ comprises four departments. Researchers in the Department of Animal Genetics are investigating cell migration and organ formation. The Department of Immunology researches mechanisms for stimulating the immune system to respond to substances and cells foreign to the body. The Department of Molecular Biology uses the tools of molecular genetics to investigate how genetic information is expressed and can be activated within cells of the brain, the vascular system, or within tumors. The cellular mechanism of autophagy is actively being investigated here. Autophagy defines the life span of eukaryotic organisms and critically contributes to the development of age-related human diseases. Autophagy assessments are carried out by using an automated image acquisition and analysis platform for high-content and high-throughput approaches. The fourth IFIZ department is the Proteome Center Tübingen (PCT, p 95). The major research area of the PCT is investigation of the structure and evolution of signal transduction networks in prokaryotes and eukaryotes, with an emphasis on phosphoproteomics and identification of kinase substrates.

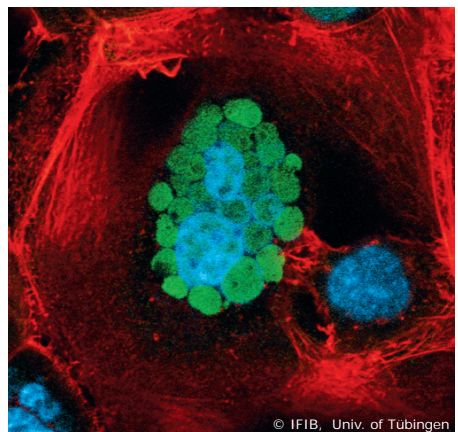
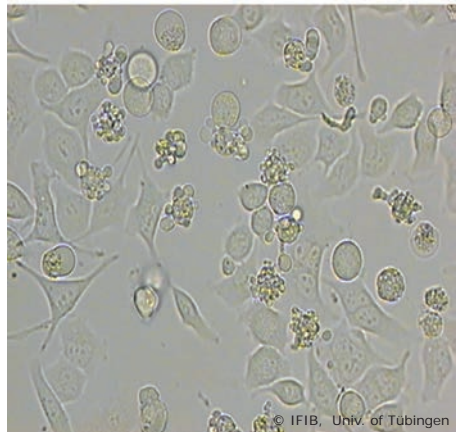
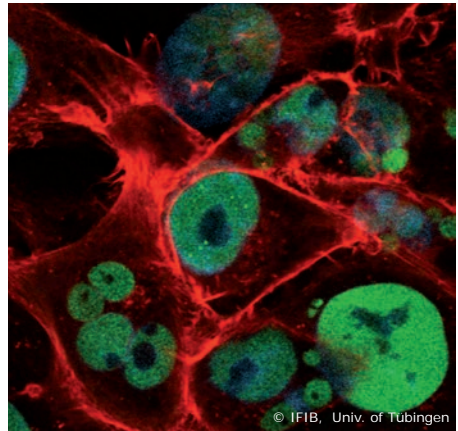
Several new biotechnology companies have been founded by IFIZ members. For instance, Immatic Biotechnologies, CureVac GmbH, ProteoSys AG, Synimmune GmbH, and Bamomab GmbH.

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## Geoscience and Environmental Science

### Geoscientific Aspects

The research area Geoscience and Environmental Science focuses on the topics water, climate, and energy. These foci provide plenty of issues crucial to the future of mankind: the availability of clean water, the pollution of the environment by harmful chemicals, the supply of raw materials, and the changing global climate. We are researching these broad-based diversified questions at the Center for Applied Geosciences (ZAG) and in interdisciplinary groups such as the Evolution and Ecology Forum – EvE (Biology). Our special subjects include Hydrogeochemistry, Environmental Mineralogy and Chemistry, Geomicrobiology, Hydrogeology and Modeling, Geophysics and Sedimentology. The Center’s activities range from basic research to practical application, while individual topics extend from biogeochemical processes to tapping geological resources.

Coordinated large-scale projects include, for example, the CRC 1253 CAMPOS (“Catchments as Reactors: Metabolism of Pollutants on the Catchment Scale”, p 46-47) in cooperation with the Universities of Hohenheim and Stuttgart, the Helmholtz Centers in Leipzig (UFZ) and Munich (HMGU). CAMPOS aims at mechanistic understanding of the fate and behavior of diffuse pollutants on the catchment scale. Additional projects are: The international research training group Integrated Hydrosystem Modelling (RTG 1829, p 61), as well as the German Science Ministry network project YANGTSE-GEO (ecosystem research at the Three Gorges Dam in China). Associated with the Geoscience and Environmental Science research focus are two European Research Council Grants (“From the Origins of Earth’s Volatiles to Atmospheric Oxygenation”, and “Microbial Formation of Minerals by Communities of Fe(II)-oxidizing Bacteria in Modern and Ancient Environments”,) one A.v. Humboldt Professorship (p 71), and one Emmy Noether group. Furthermore, the research area Geoscience and Environmental Science jointly coordinates the DFG Priority Program SPP 1803 EarthShape: Earth Surface Shaping by Biota (p 54-55), which calls the climate-tectonics paradigm into question by closely examining the biologic processes of Earth’s surface.

The research on georesources in Tübingen addresses the formation of geological deposits of ores and fossil raw materials, the geodynamic principles, the numerical modeling of the underlying processes, the exploration of deposits, the use of geomaterials, the recovery of valuable metals from waste, the influence of georesources on human development, as well as the broad geoscientific context of resources in the subsurface.

The central importance of the soil is taken into account in multiple joint projects within research networks (e.g. SPP 1374 “Exploratories for Large-Scale and Long-Term Functional Biodiversity Research”, FOR 1451 “Jena Experiment”, PAK 823 “Tropical Moun-



tain Rainforest”, FOR 891 “Biodiversity and Ecosystem Functioning”, and the German Research Ministry collaborative research project “Central Asia-PERMATRANS”).

On the basis of its outstanding interdisciplinary network and orientation towards ever more complex environmental issues, Geoscience research at the University of Tübingen is to be centralized within a major new Environmental and Geoscience Center (GUZ). There, Applied Geoscience with its core focus on water and the environment will work closely with Biogeology (Evolution), Geodynamics and Mineralogy.

### Biological Aspects

The Plant Ecology group studies climate change impacts in highly vulnerable regions, such as the water-stressed Jordan River region, and is currently involved in several initiatives dealing with the impact of climate change on biodiversity and the functioning of ecosystems. Among these, the DFG priority program „Adaptomics“ is the most prominent, and the research of the Plant Ecology group focuses on the potential of plants to adapt to environmental change. Together with the Evolutionary Plant Ecology group, there is also a special focus on the biology and evolution of invasive species, which is currently best reflected in the EU BiodivERsA project WhoIsNext. Here the latter group studies the potential of newly introduced plant species to become invasive in an era of climate change.



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#### Center for Applied Geoscience (ZAG)

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## Human Evolution and Archaeology

The Tübingen Institute for Archaeological Sciences (INA) applies methods and concepts from the natural sciences to investigate the biological and cultural evolution of humans and their ancestors. The institute offers the complete spectrum of archaeological sciences, which it uses to study the earliest hominins (DFG Research Unit (FOR) 2237 "Words, Bones, Genes, Tools: Tracking Linguistic, Cultural and Biological Trajectories of the Human Past", p 65) through to the development of complex societies, late Antiquity and the Middle Ages (CRC 1070 "ResourceCultures", p 40-42). The Institute conducts long-term field projects around the world, including excavations in Germany, France, Greece, South Africa, the Arabian Peninsula, Iran, Syria, Israel and Armenia, making important contributions to the University of Tübingen's reputation in the field. The Institute for Archaeological Sciences (INA) four work groups are Early Prehistory and Quaternary Ecology (including Zooarchaeology and Archaeobotany), Geoarchaeology, Palaeoanthropology, and Archaeogenetics.

The Early Prehistory and Quaternary Ecology group conducts excavations across much of the Old World and investigates paleolithic archaeology, lithic technology, taphonomy, faunal and botanical assemblages, pleistocene chronostratigraphy, evolution and dispersal of modern humans, past environments, settlement history of western Eurasia and southern Africa, and the origins of agriculture and sedentism.

The Geoarchaeology group investigates archaeological deposits and landscapes using a variety of geoscientific methods, including geophysical survey, GIS, micromorphology, and infrared spectroscopy. The group's research focus includes anthropogenic sedimentation processes, archaeological site formation, the role of fire in human evolution, hunter-gatherer settlement dynamics, pleistocene paleoenvironments and landscape evolution in Europe and Africa.

The research interests of the Paleanthropology group include modern human origins in Africa and Eurasia, Neanderthal evolution and paleobiology, Pleistocene hominin systematics, the relationship of skeletal morphology to environmental adaptation and to population history, and dental development in extant and extinct anthropoids. Under the leadership of Professor Harvati, the Paleanthropology group conducts fieldwork and applies state-of-the-art imaging techniques to solve problems in human evolution.

The main focus of the Archaeogenetics group is the analysis of fossil DNA from hominin remains. Novel techniques of high-throughput DNA sequencing and targeted DNA enrichment are applied to obtain insights into the population history and the evolu-

tion of extinct hominin groups such as Neanderthals and Cro-Magnon. Furthermore, the group focuses on paleopathogen research to obtain insights into the evolution of historical diseases such as the Plague.

### Collaboration and Joint Projects

The Senckenberg Centre for Human Evolution and Palaeoenvironment (SHEP, p 97) is a cooperative network established between researchers from the University of Tübingen's Archaeological Sciences and Paleobiology and researchers from the Senckenberg Research Institute and Natural History Museum in Frankfurt and Weimar. The research areas that HEP cover include archaeology, paleoecology, and paleoanthropology. In 2015, HEP was established as a joint institute of the Senckenberg Nature Research Society and the University of Tübingen.

Moreover, the Institute for Archaeological Sciences (INA) is a member of the Tübingen Interfaculty Centre for Archaeology (TZA), which covers the complete temporal range of human history from the Paleolithic to the Medieval Period.

A major research project that members of the University of Tübingen are participating in is "The Role of Culture in Early Expansions of Humans" (ROCEEH, p 98), which investigates the spatial and temporal patterns of hominin settlement and migration between three million and 20,000 years ago in Africa and Eurasia. This 20-year project aims to understand the reasons behind population expansions in the human past, and to investigate why our species – Homo sapiens – were ultimately the most successful form of human. The project in particular is testing the hypothesis that through time, changing environmental conditions became less influential in the success of hominin populations as cultural and technological innovations increased. An important affiliated institute of the University of Tübingen is the Curt Engelhorn Center for Archaeometry in Mannheim, strengthening the analytical capabilities of the Institute for Archaeological Sciences (INA).

Members of the Institute for Archaeological Sciences (INA) also manage successful museums in Tübingen, Blaubeuren and Niederstotzingen, in part through close cooperation with the Senckenberg Research Institute and Natural History Museum.



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## Microbiology and Infectious Diseases

Research on infections is carried out first and foremost to find more efficient ways of fighting them. Most importantly, real progress can only be made when the disciplines of Medicine, Biology, Biochemistry, Pharmaceutics and Bioinformatics work together. Researchers at the University of Tübingen have been doing just that for more than four decades, giving infection research here an outstanding reputation worldwide.

Within the research focus on Microbiology and Infectious Diseases, scientists of Biochemistry, Bioinformatics, Biology, Medicine and Pharmacy have developed close relationships with the Max Planck Institute for Developmental Biology.

Within the Interfaculty Institute of Microbiology and Infection Medicine Tübingen (IMIT) the research priorities are:

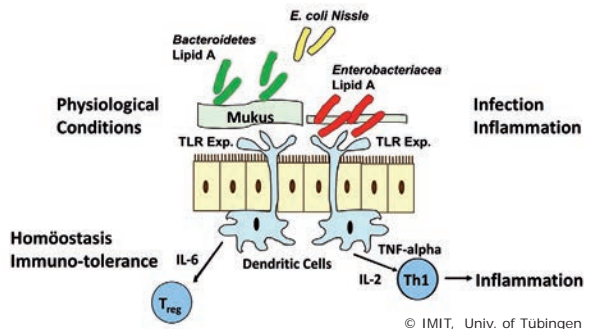
- microbial physiology with the focus on symbiotic interactions and molecular mechanisms of microorganisms,
- antimicrobial agents synthesized by Actinomycetes,
- infection mechanisms (staphylococci and gastrointestinal pathogens), and
- the role intestinal flora play in defense against infection and the development of chronic inflammatory intestinal disorders.

Additionally, we work to improve the diagnosis, prevention and treatment of infectious diseases in order to improve health conditions and to prevent the spread of difficult-to-treat pathogens, such as methicillin-resistant staphylococci (MRSA).

Several research networks have been founded to address the above-mentioned questions using joint, interdisciplinary approaches.

A key starting-point for combating bacterial infection is the bacteria's cell wall (CRC 766 "The Bacterial Cell Envelope: Structure, Function, and Infection Interface").

A second area of investigation in this CRC 766 is the interaction between disease-causing bacteria and their host cells in humans, mice, and plants. In the TRR 34 "Pathophysiology of Staphylococci in the Post-

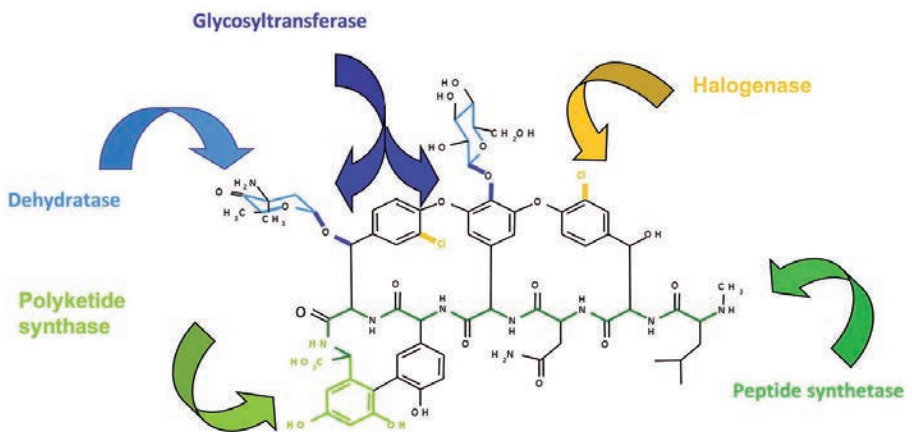




Genomic Era" the spotlight is on the bacterium *Staphylococcus aureus*, which causes a number of severe infections (e.g. blood poisoning, wound infections, pneumonia and endocarditis).

The Research Training Group 1708 "Molecular Principles in Bacterial Survival Strategies" (p 60) focuses on bacterial viability in adverse environments. This topic is of particular relevance in bacterial ecology and physiology for understanding the dispersal of bacterial pathogens and for the development of new antimicrobial drugs.

The link to clinical research and an insight into the potential applications is assured by the newly-founded Comprehensive Infectious Diseases Center (CIDiC) and the German Center for Infection Research (DZIF, p 93). Primarily as a result of its competence network, the CIDiC Tübingen provides a central contact point for all questions regarding the care of patients with infectious diseases, and infection medicine research and teaching. DZIF focuses on improving the diagnosis, prevention and treatment of infectious diseases.



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## Molecular Biology of Plants

Plants have always played a key role in life on earth and form the basis for our human existence. In contrast to almost all animals, plants are sessile and have to cope with a multitude of environmental constraints. Questions of how plants grow and how they adapt to their environment are part of the basic research carried out at the Center for Plant Molecular Biology (ZMBP).

### Why is plant science important?

Plants assure our everyday life by providing energy, nourishment, clothing, medicines, and the oxygen that we breathe. On the one hand, the predicted increase in global temperature is expected to result in a decrease of agricultural yields due to extreme weather events such as droughts and floods. On the other hand, we are faced with the problem of how to feed a growing world population that is expected to reach more than 10 billion by 2050. Scientists at the ZMBP address questions of how plants grow and develop and how they deal with pathogens and hostile conditions such as drought. The majority of ZMBP scientists work with an inconspicuous weed called thale cress (*Arabidopsis thaliana*). *Arabidopsis*, with its short generation cycle of six to eight weeks, produces more than a thousand seeds per individual plant but takes up little space in the greenhouse and hence has become the model species for most plant biologists. Importantly, many findings can be directly related to other plant species – including economically important crops.

### Details about the ZMBP

In May 1999, the University of Tübingen inaugurated the Center for Plant Molecular Biology (ZMBP). Since then, it has established itself as a leading name in the international plant research community. The core of the ZMBP comprises 17 independent research groups from the Departments of Biology and Biochemistry.

### Additional important facts about the ZMBP:

The ZMBP offers junior group leaders the unique opportunity to independently conduct their research. Since 1999, 19 former ZMBP group leaders have been appointed as professors at various universities world-wide.

Central facilities support the research at the ZMBP, offering state-of-the-art light and electron microscopy, analytics, flow-cytometry, plant cultivation and transformation.

The ZMBP is highly successful in attracting third-party funding from various funding

sources, including the German Research Foundation (DFG) or industrial partners. In 2014, a new Collaborative Research Center (CRC 1101, p 42-43) was awarded to the ZMBP which addresses the scientific question how specificity is achieved in plant processes.

The success of the ZMBP depends heavily on the excellent contributions of dedicated graduate students and postdocs. More than 80 PhD students and 30 postdocs supported by 50 technical assistants are currently carrying out research and training at the ZMBP.

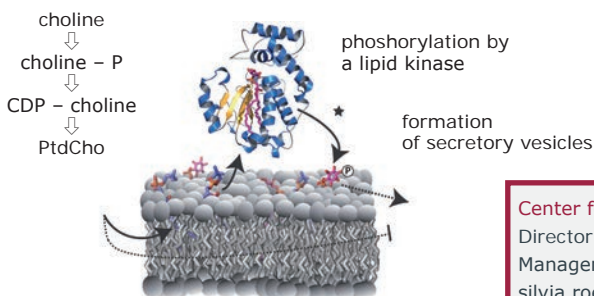
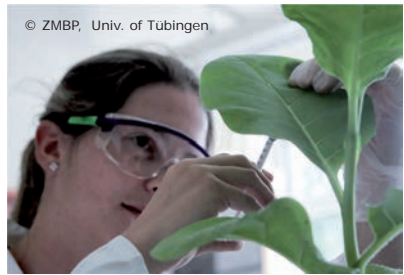
The ZMBP is an integral part of Biology, Biochemistry and Nano-Science training of Bachelor and Master students at the University of Tübingen. The ZMBP organizes the International Master's Degree Program "Cellular and Molecular Plant Biology" to train the next generation of PhD students.

In 2013, the ZMBP introduced a structured PhD Graduate Program, providing individual thesis advisory committees, training in teaching and professional skills, and a Summer School organized by the PhD students once every two years.

The ZMBP and the CRC 1101 run a Plant Seminar Series with distinguished visiting speakers, and organize important conferences, including the 2013 meeting of the German Botanical Society with more than 400 attendees. In addition, the ZMBP co-organizes the regional plant science community in the state of Baden-Württemberg together with the Max Planck Institute for Developmental Biology in Tübingen and the Universities of Hohenheim and Ulm.

ZMBP performance is regularly evaluated by an International Scientific Advisory Board (ISAB), made up of renowned scientific leaders from all over the world.

In 2013, the ZMBP moved into a modern, purpose-built research building with 5200 m<sup>2</sup> of working space and 650 m<sup>2</sup> of plant growth area. The new building, jointly funded by the German federal and state governments, brings together all the ZMBP's research groups under one roof for the first time.



#### Center for Plant Molecular Biology (ZMBP)

Director: Prof. Dr. Eric Kemen

Management: Silvia Röcker

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predictable individualized therapy with patient-directed drugs and dosages. This is of prime importance for the maximum benefit for the patient's health after treatment, but is also important for the economy of the public health system. Facilities available to the scientists for conducting basic research include a comprehensively equipped mouse clinic, where researchers can study special target genes, the way they work, and the extent to which they can be influenced in living organisms. The mechanisms identified are then investigated in more detail in cellular systems, with the results being used as input for developing improved pharmacotherapy for patients.

Ultimately, all this research work is geared towards application in clinical practice. Like any new generation of medical procedures, pharmacogenomics must first demonstrate its efficacy and harmlessness in carefully designed and properly executed trials. Designing and conducting such cohort studies on selected patient groups is all part of the research work at the ICEPHA.

The starting point for this research is identifying genes and individual gene variants, that play a part in the emergence of illness. Based on this knowledge, scientists hope to develop effective analytical methods for practical application in medicine. The target genes and lead structures identified should also make it possible to develop new agents and medications that directly intervene in the pathogenesis process. Another research field is finding anti-inflammatory drugs from natural sources, molecular interactions and cancer pathways and metabolomics and xenobiotic metabolism, biomarker analysis and pharmaceutical analysis. At the forefront of this research is the idea of personalized therapy, which has already shown tremendous promise in a number of areas. Within this research area, scientists at the Institute of Pharmacy work on targeting kinases involved in inflammation and cancer, evaluating the potential of potassium channels as drug target, and the biosynthesis of anti-microbial compounds. The Pharmaceutical Institute is part of ICEPHA, together with the Institute for Pharmacology and Toxicology of the Faculty of Medicine, the Clinical Pharmacology, the Department of Internal Medicine IV of the University Hospital Tübingen, the Robert Bosch Hospital in Stuttgart as well as the Dr. Margarete Fischer-Bosch-Institute of Pharmacology.

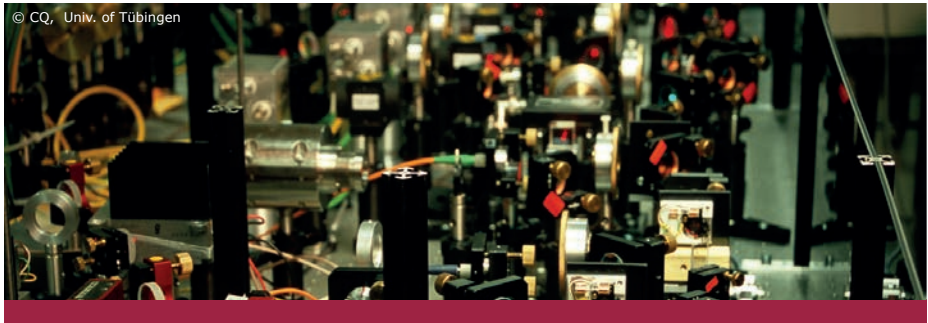
As a major advance towards training the next generation of experts who will tailor pharmacological treatment regimens to the individual genetic makeup, the ICEPHA has established a graduate program focusing on "Membrane-associated Drug Targets in Personalized Cancer Medicine". Since the program's launch in 2014, our young graduates have been working on different aspects of tumor cell biology, on risk and prognosis prediction, and the molecular mechanisms of resistance to cancer therapy. This research is designed to bridge the gap that exists between discovery and translation, allowing a rapid integration of our results into clinical practice in order to improve outcomes for people with cancer, i.e. breast cancer, hepatocellular carcinoma, glioblastoma, and other tumor entities. To achieve these ambitious goals, we take strong advantage of the synergy achieved through the combined expertise from our working groups at the Faculty of Science at the University of Tübingen, the University Hospital, the Faculty of Medicine in Tübingen and the Robert Bosch Hospital in Stuttgart.

Interfaculty Center for Pharmacogenomics and Drug Research (ICEPHA)

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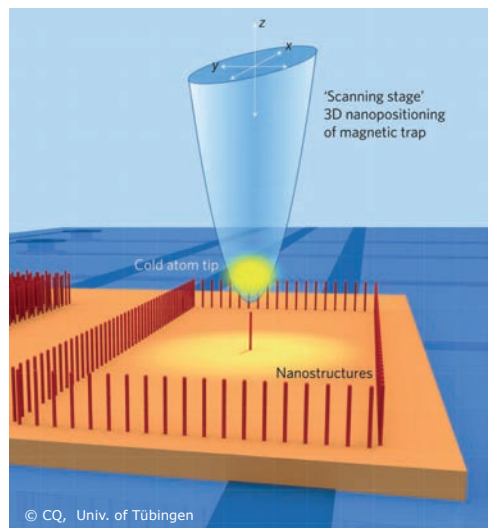


## Quantum Physics and Nanotechnology

Fundamental research in many areas of physics and chemistry is dominated by the phenomena of quantum mechanics. Due to enormous progress in structuring, manipulation and analysis on an atomic level, controllable quantum phenomena for technological applications have also moved to the center of attention. At Tübingen University, many research groups in the fields of physics and chemistry are working in this area. The research focus on quantum physics of atoms, quantum physics of solids, and nanotechnology is hosted at the Center for Quantum Science (CQ), which was established in 2007. At the CQ new features of extremely small objects are studied close to absolute zero temperature, which enables phenomena such as superconductivity and superfluidity. The scientists at our institute are able to produce quantum matter under very well controlled conditions – which see single electrons and atoms lose their independence and act collectively according to the laws of quantum physics. The researchers are also looking into new technical possibilities arising from this, such as new quantum sensors or quantum computers (TRR 21).

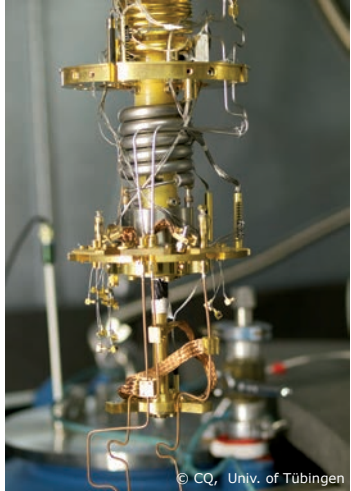
### Research groups involved in the CQ

The Quantum Optics and Laser Physics group focuses on the investigation of the fundamental properties of ultracold atomic Bose and Fermi gases and on the quantum optics on surfaces. The Mesoscopic Physics and Nanostructures group concentrates on aspects of nanotechnology and semiconductor physics. The Nano Atomoptics group develops quantum instruments based on ultracold atoms and solid state nanostructures. The Nanotechnology and Nanostructures group focuses on the creation of application-based structures with micro- and nanometer dimensions, especially from semiconductors, metals and carbon nanotubes. The Solid State Physics group researches superconducting and magnetic layered structures, particularly with respect to Josephson effects, quantum interferometry, manipulation of magnetic flux quanta

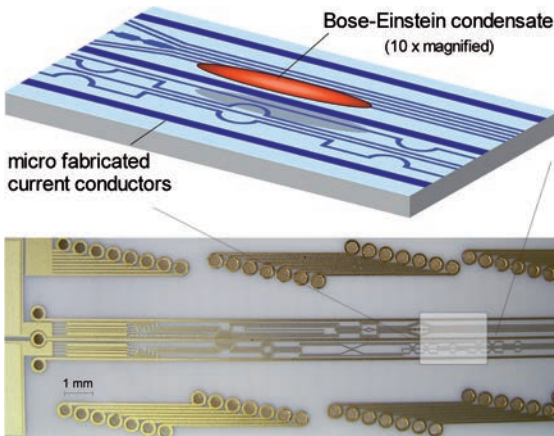


and magnetic tunneling structures. Our Subatomic Physics group concentrates on the search for dark matter (WIMP) by means of superconducting cryodetectors. The Theoretical Physics groups investigate superconductivity, superfluidity, and Josephson physics, quantum optics, and quantum information. The objective of the experimental Emmy Noether junior research group is to understand the structure and the application of the first stable quantum ion interferometer.

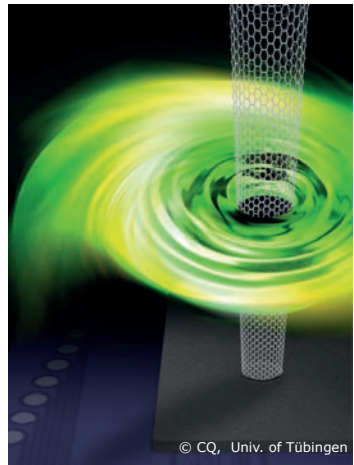
The groups not only profit from synergetic effects concerning their respective methods (nano-structuring, surface sensor technology, quantum optics). They also aim at creating hybrid systems in particular that combine, for example, solid state devices and ultracold atoms. Thus, superconducting quantum systems are coupled with ultracold atoms, firstly to study fundamental questions of basic research and secondly to develop new highly sensitive measuring methods. These measuring methods range from research on dark matter to recent questions of surface physics and the development of sensitive gravimeters and sensors for forces of inertia (rotations, accelerations). Examples are cryodetectors for elementary particles, as well as the matter-wave holography of structured surfaces with Bose-Einstein condensates. This wide range of research gives the CQ Research Center its highly interdisciplinary character in quantum science and technology.



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Center for Quantum Science (CQ)  
 Coordinator: Prof. Dr. József Fortágh  
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<https://uni-tuebingen.de/en/3355>



## EXC 2064: Machine Learning: New Perspectives for Science (ML)

The Cluster of Excellence Machine Learning: New Perspectives for Science is one of the latest additions to the scientific landscape of the University of Tübingen. It is the result of the cooperation between the University of Tübingen, the Max Planck Institute for Intelligent Systems (MPI IS) and the the Leibniz-Institut für Wissensmedien (IWM). The cluster is part of the most influential line of funding

by the German Research Foundation (DFG) with a funding period of 7 years, starting in 2019. The cluster's aim is to enable machine learning to take a central role in all aspects of scientific discovery and to understand how such a transformation will impact the scientific approach as a whole.

The cluster's diverse team of principal investigators consists of researchers in machine learning and its applications in various disciplines, including medicine, neuroscience, bioinformatics, vision, cognitive science, physics, geoscience, linguistics and social science, as well as experts in philosophy and ethics. The cluster is built upon the internationally renowned strength of Tübingen as a hub for machine learning as well as on the established excellence in the contributing scientific fields.



The cluster is targeting the following four research areas:

### Beyond prediction, towards understanding

We are designing algorithms that reveal complex structure and causal relationships from data in order to integrate machine learning into the scientific discovery process.

### Managing uncertainty

We are developing tools to estimate and handle the uncertainty in data-driven scientific models and algorithms, and will exploit this information for experimental design.

## Interface between algorithms and scientists

We are developing techniques to allow scientists to understand and control all stages of the machine learning process in the scientific discovery pipeline.

## Philosophy and ethics of machine learning in science

The fact that machine learning algorithms will play a central role in the process of scientific discovery challenges our traditional understanding of the scientific process and raises fundamental questions about concepts of scientific discovery and the role of the scientists. We are studying these questions from the perspective of philosophy and ethics of science.

The cluster is embedded in an inspiring environment: Tübingen is an international hotspot for machine learning and the most prominent machine learning location in Germany. The high scientific productivity is supported by a clear commitment of many institutions to strengthen all aspects of machine learning in Tübingen, ranging from

basic research to collaboration with corporations. The latter direction becomes most visible in the Cyber Valley Initiative (p 91). In this initiative, the Universities of Tübingen and Stuttgart, the Max Planck Society, the State of Baden-Württemberg and a number of industrial companies agreed on a joint effort, worth at least 50 million Euros, to strengthen the Tübingen-Stuttgart area in the field of intelligent systems.

For PhD candidates, the Tübingen campus offers an excellent environment. It hosts an International Max Planck Research School for Intelligent Systems (IMPRS-IS, p 34-35), run jointly by the Max Planck Institute and the University of Tübingen. All PhD students of the cluster will be associated with the IMPRS-IS. Over the duration of the cluster, we expect to enroll about 70 PhD students of the cluster. In recruiting PhD students, we will benefit directly from the first German Master program in machine learning at the Department of Computer Science of the University of Tübingen.



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### Machine Learning: New Perspectives for Science (ML)

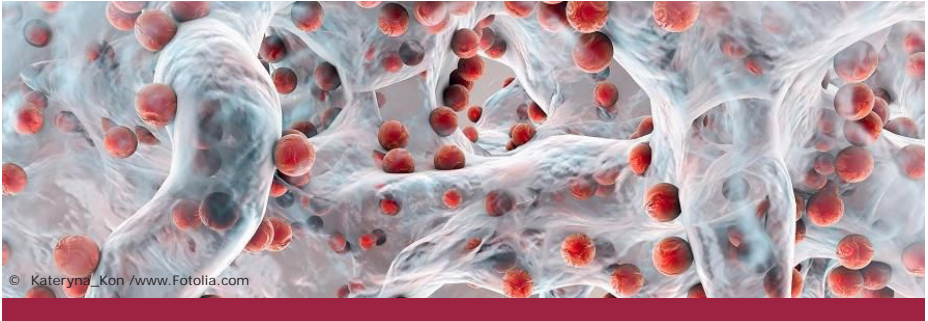
Spokespersons: Prof. Dr. Ulrike von Luxburg | Prof. Dr. Philipp Berens

Coordinator: Dr. Tilman Gocht

[ml-in-science@uni-tuebingen.de](mailto:ml-in-science@uni-tuebingen.de)

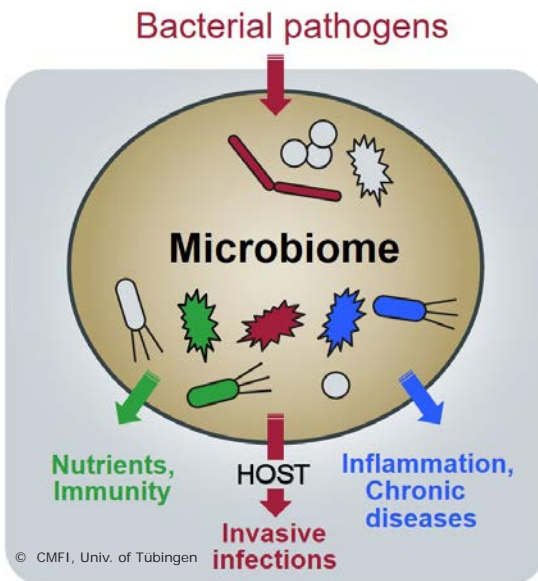
[www.ml-in-science.uni-tuebingen.de](http://www.ml-in-science.uni-tuebingen.de)





## EXC 2124: Controlling Microbes to Fight Infections (CMFI)

Microbial communities (“microbiomes”) that populate human body surfaces impact health in many critical, yet enigmatic ways: They contribute to vital body functions via complex metabolic and immunomodulatory activities but are, at the same time, major reservoirs for facultative pathogens that cause the majority of invasive bacterial infections. A worldwide increase in antibiotic-resistant bacterial pathogens (ARBPs), coupled with declining discoveries of novel classes of antibiotics, raises the specter of a post-antibiotic era. Preventing the spread, human colonization, and subsequent infection by ARBPs is essential in preserving fundamental medical achievements of the 20th century. Broad-spectrum antimicrobials in current use both damage microbiomes and promote rapid ARBP evolution.



A paradigm shift in infection control is needed, putting a hold to the indiscriminate use of antibiotics and enabling the development of targeted anti-infective strategies that promote microbiome integrity. Beneficial ‘commensal’ bacteria can limit the expansion of facultative pathogens in microbiomes but we are far from harnessing these mechanisms for therapeutic interventions. Decoding the complex processes governing microbiome dynamics is a key research challenge requiring a better integration of molecular, computational, and clinical disciplines. Since decades,

scientists at the University of Tübingen, the University Hospital Tübingen, and the Max Planck Institute are at the forefront of research on bacterial interactions with antimicrobial molecules, other microbes, and host organisms.

They made groundbreaking discoveries for instance in the areas of microbiome-derived antibiotics, microbiome-shaping metabolic activities, and epithelial antimicrobial mechanisms. The Cluster of Excellence (CoE) "Controlling Microbes to Fight Infections" (CMFI) elucidates mechanisms governing competition and fitness of beneficial or harmful bacteria as the basis for developing new multi-level interventions against ARBPs and other pathogens.

This will be achieved by developig realistic microbiome model systems of increasing complexity, ranging from continuous in vitro cultivation and gnotobiotic animal models to organoid-based and controlled human colonization studies, to decode major principles of microbiome resilience against invading pathogens. The capacities of novel, microbiome-targeted interventions will be evaluated in preclinical and early clinical trials. Building on its existing strengths, CMFI will close strategic gaps and expand its research capacities by implementing new research groups, cutting-edge technology



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facilities, as well as training, mentoring, and public outreach activities. By integrating functional research on molecular, cellular, community, and microbe-host interaction levels, advanced by omics, imaging, and computational technologies, CMFI will contribute to a new era of comprehensive microbiology, poised to match the challenges of the 21st century.

#### Controlling Microbes to Fight Infections (CMFI)

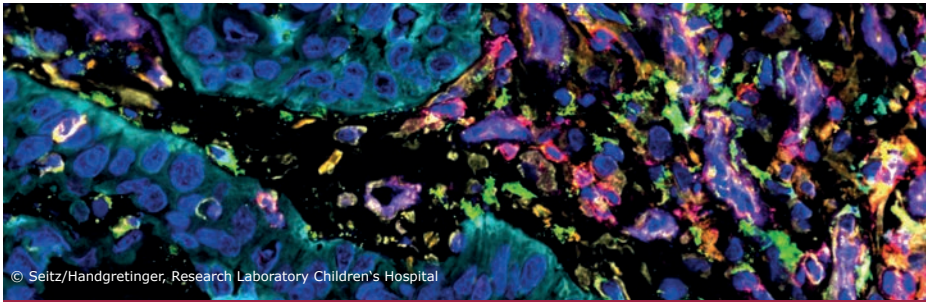
Spokespersons: Prof. Dr. Andreas Peschel | Prof. Dr. Heike Brötz-Oesterhelt | Prof. Dr. Ruth Ley

(MPI for Developmental Biology)

Coordinator: Dr. Dirk Kraus

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<https://uni-tuebingen.de/de/171471>



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## EXC 2180: Image-Guided and Functionally Instructed Tumor Therapies (iFIT)

### Development of improved and individualized cancer therapies

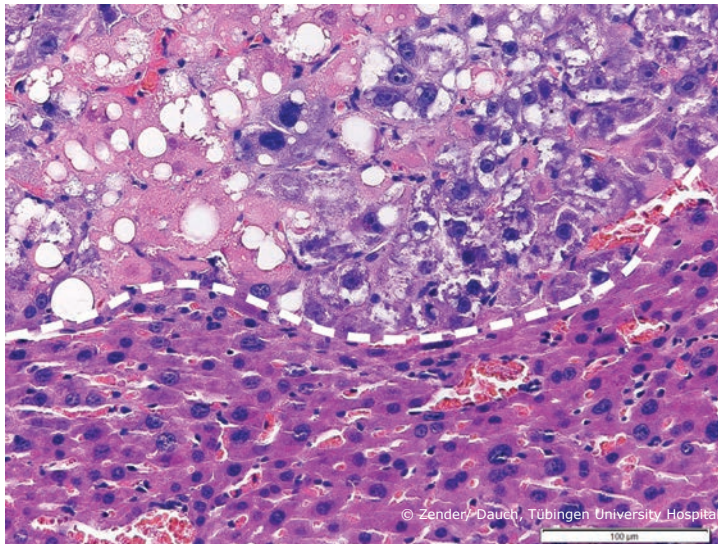
Within the Cluster of Excellence „Image-Guided and Functionally Instructed Tumor Therapies“ (iFIT), in 2020 more than 130 scientists worked on developing innovative and sustainable cancer therapies in the three main research areas of “Functional Target Identification and Molecularly targeted Tumor Therapies”, “Immunotherapies”, and “Molecular and Functional Multiparametric Imaging”. The Cluster will receive a total funding of 47.3 million euros from the Excellence strategy of the German federal and state governments, starting from 2019 to the end of 2025. Special attention is paid to biological processes that allow tumors to survive under stress conditions. Advanced imaging techniques and novel imaging tracers are used to visualize stress states of tumors, so that newly developed cancer therapies in the Cluster can be used in an imaging-guided manner and tailored to the individual patient and his or her disease. Innovative immunotherapies are also designed to activate the patient’s own immune system against tumor cells and to support and supplement targeted drug therapy.

The excellent and internationally visible cancer research conducted in the iFIT Cluster played a major role in Tübingen’s selection as a site of the National Center for Tumor Diseases (NCT) in September 2020. The Comprehensive Cancer Centers Tübingen-Stuttgart and Ulm together form the NCT site „Southwest“. Coordinator of the NCT-SouthWest is Professor Lars Zender, who is also one of the three iFIT spokespersons. The goal of the NCT is to make new therapeutic methods available to patients more quickly and thus improve their prognosis in the long-term. The NCT-SouthWest will work closely with the iFIT Cluster of Excellence and other institutions at the University of Tübingen and the University Hospital.

Novel therapeutic concepts from the cluster’s basic oncology research are being developed into drugs at the TüCAD2 Academic Drug Discovery Center in Tübingen. After extensive preclinical testing, the newly designed therapies then undergo clinical testing within the NCT. With the iFIT Cluster of Excellence, TüCAD2 and NCT-SouthWest, the University of Tübingen thus has a unique infrastructure that will allow developing better cancer therapies and holds the promise to significantly improve prognosis of cancer patients.



In a currently ongoing project, the Department of Preclinical Imaging and Radiopharmacy received manufacturing authorization for an in-house developed senescence tracer. The aim of the study, which is being conducted by the Department of Nuclear Medicine and Clinical Molecular Imaging together with the Department of Medical Oncology and Pneumology (Internal Medicine VIII), is to identify tumors which enter a hibernation state called "cellular senescence" after cancer therapy. As the presence of such senescent cells is believed to result in poor therapeutic outcomes, the researchers hope to apply novel pharmacological therapies to eradicate such cells (so-called senolytic therapies) in an image-guided fashion.



Treated liver tumor under the microscope using a new therapy against liver cancer. The preclinical study focuses on overcoming therapy resistance in hepatocellular carcinoma. While the tumor cells (upper part of the picture) are strongly affected by the lipotoxic therapy (formation of characteristic lipid droplets and cell death), normal liver cells (lower part of the picture) are only barely affected by the therapy.

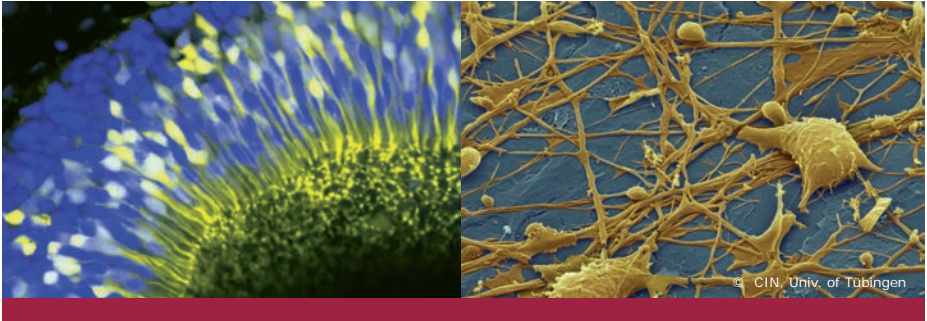
#### Image-Guided and Functionally Instructed Tumor Therapies (iFIT)

Spokesperson: Prof. Dr. Lars Zender (University Hospital Tübingen; Internal Medicine VIII)

Coordinator: Eva Enzinger

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<https://uni-tuebingen.de/en/research/core-research/cluster-of-excellence-ift/>



## Graduate Training Center of Neuroscience

The Graduate Training Center of Neuroscience consists of three neuroscience graduate schools, each comprising a consecutive master's and doctoral degree program with largely complementary scientific foci. Together they provide a broad spectrum of opportunities for neuroscience research and training.

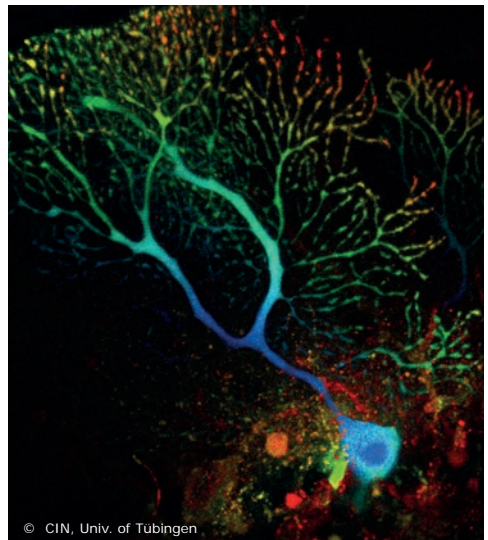
### Graduate School of Cellular & Molecular Neuroscience

The Graduate School of Cellular & Molecular Neuroscience provides research-oriented training with a focus on neurological and psychiatric disorders, and employs genetic, molecular and cellular approaches as well as molecular imaging techniques and transgenic mouse technology. Basic and clinical research on mechanisms leading to neurodegenerative conditions such as Alzheimer's and Parkinson's disease is of particular importance. A second field of core research are pathomechanisms in sensory organs, in particular the eye and the inner ear. Further research topics include neurooncology, development and regeneration.

Major partners of this graduate school are the Werner Reichardt Center for Integrative Neuroscience (p 99), the Hertie Institute for Clinical Brain Research and the German Center for Neurodegenerative Diseases.

### Graduate School of Neural & Behavioral Sciences

The Graduate School of Neural & Behavioral Sciences / International Max Planck Research School for Cognitive and Systems Neuroscience provides research-oriented training in systems, behavioral and cognitive neuroscience. A major aim of the research is to understand the role of higher brain functions that allow humans and animals to operate successfully in natural environments. Topics include the neuronal basis of perception and its top-down control by attention, expectation and



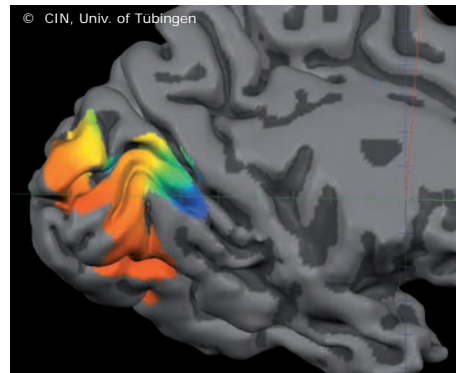
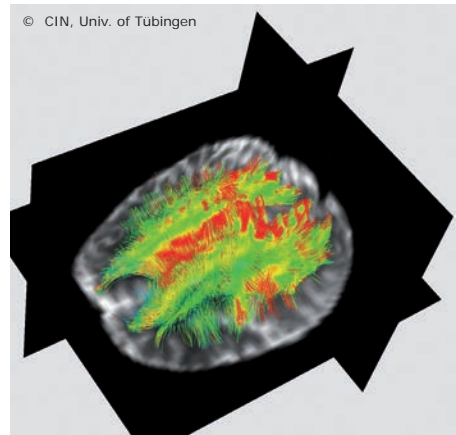
motivation. We are also investigating spatial orientation, the planning and execution of movements, the storage and retrieval of memories, and the processing of language and communication. Our researchers employ a wide spectrum of neuroscientific methods – particularly brain imaging methods and their application in neurology, psychiatry and neurocognition.

The major partners of this graduate school are the Werner Reichardt Center of Integrative Neuroscience, the Hertie Institute for Clinical Brain Research and the Max Planck Institute for Biological Cybernetics.

### Graduate School of Neural Information Processing

The Graduate School of Neural Information Processing / International Max Planck Research School for Cognitive and Systems Neuroscience provides research-oriented training in a range of computational neuroscience topics, such as coding principles in the sensory periphery and their clinical application; population coding in the early sensory cortex; perceptual inference mechanisms; and multi-sensory integration processes. Other fields of research include brain-computer interfaces, neuroprosthetics and rehabilitation robotics. The interdisciplinary combination of neurobiological, psychophysical and theoretical approaches will not only advance understanding of sensory and neural information processing, but also promote the development of technical devices mitigating lost sensory organ or brain function.

The major partners of this graduate school are the Werner Reichardt Center for Integrative Neuroscience, the Tübingen Bernstein Center for Computational Neuroscience (p 86) and the Max Planck Institutes for Biological Cybernetics and for Intelligent Systems.

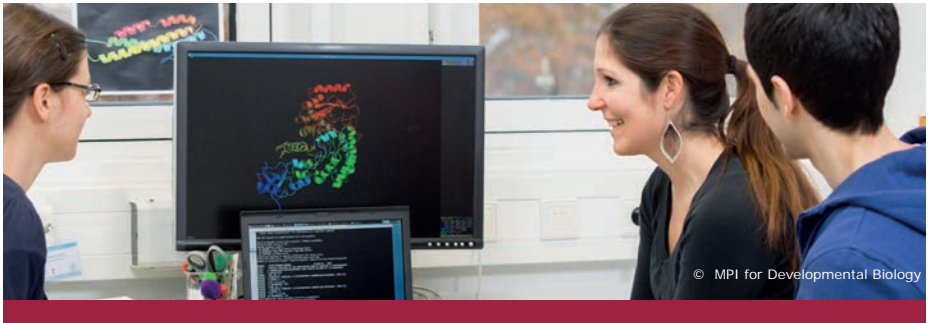


Graduate Training Center of Neuroscience | International Max Planck  
Research School for Cognitive and Systems Neuroscience

Dean of Studies: PD Dr. Marc Himmelfach

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## International Max Planck Research School “From Molecules to Organisms”

The International Max Planck Research School (IMPRS) “From Molecules to Organisms” offers a structured, interdisciplinary program for doctoral candidates working in the Life Sciences. The program is offered jointly by the University of Tübingen, the Max Planck Institute for Developmental Biology and the Friedrich Miescher Laboratory. Participating faculty members from the University of Tübingen are drawn from the Interfaculty Institute of Biochemistry, the Interfaculty Institute of Cell Biology, the Center for Plant Molecular Biology (ZMBP, p 18-19) and the Center for Integrative Bioinformatics (CIBI, p 88).

The school is funded jointly by the Max Planck Society, the University of Tübingen and the participating institutes.

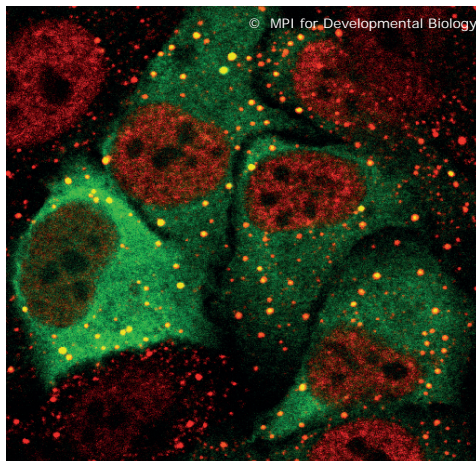
### Research focus

The school aims to endow the participating students with the knowledge and skills to study complex biological processes, which cannot be adequately understood within the limits of single disciplines, in the context of entire organisms. Research fields covered by the program include structural, molecular and cellular biology; biophysics and biochemistry; genetics and developmental biology; genomics and proteomics; bioinformatics and computational biology; microbiome science, ecology and evolution. Thus, the program of the school bridges not only diverse disciplines but also spans several levels of biological organization (from molecules to organisms), which the participating laboratories cover with their broad range of expertise. The IMPRS “From Molecules to Organisms” sets out to go beyond the integration of bioinformatics, biochemistry, and structural biology for the study of cellular and developmental processes in animal and plant models, by beginning to frame both questions and experimental approaches in an evolutionary and eventually ecological context. Questions addressed by the IMPRS include:

- How do molecular structure and dynamics explain function?
- How do molecules interact dynamically in the cellular context?
- How is intracellular organization achieved and maintained?
- How does cellular organization shape organs, whole organisms, and their behavior?
- How is the interaction of an organism with its environment determined at the molecular level?
- How does evolution shape the genome and proteome of organisms and their relationship with the environment?



Our concept is supported by the facilities available at the participating laboratories, including platforms for NMR and X-ray crystallography, the Genome Center at the MPI for Developmental Biology with its next-generation sequencing (NGS) technology, the Proteome Center Tübingen (PCT, p 95) at the Interfaculty Institute of Cell Biology (IFIZ), state of the art plant growth and animal facilities, excellent electron- and light-microscopy imaging resources and large computer clusters offering high-performance computing facilities.



### Program organisation

The principal component of the three-year program is preparation of a doctoral thesis. In addition to ongoing support from the primary advisor, doctoral candidates benefit from regular interaction with their thesis advisory committee (TAC), a panel of at least three IMPRS faculty members.

Alongside this, IMPRS doctoral candidates are supported by a program of in-house professional training. Core activities such as our annual symposium and student retreat help integrate newcomers and allow students and faculty to interact and make cross-connections. The TACs advise on further training options to enhance project progress and career prospects. The language of the school is English.

### Recruitment

The IMPRS "From Molecules to Organisms" admits approximately ten doctoral candidates per year and aims for a strong international feel; two-thirds of participants are from outside Germany. Student participants are recruited through an annual international selection round, with an online application period during January/February and interviews in Tübingen during April/May.

**International Max Planck Research School "From Molecules to Organisms"**  
Spokespersons: Prof. Dr. Andrei Lupas (MPI for Developmental Biology) |  
Prof. Dr. Ralf-Peter Jansen (University of Tübingen)  
Coordinator: Sibylle Patheiger  
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## International Max Planck Research School for Intelligent Systems

Since 2017, the Max Planck Institute for Intelligent Systems and the Universities of Stuttgart and Tübingen have collaborated to offer an interdisciplinary Ph.D. program: the International Max Planck Research School for Intelligent Systems (IMPRS-IS).

This program is a vital part of Baden-Württemberg's Cyber Valley initiative (p 91) to advance basic research and technology transfer in the field of Artificial Intelligence (AI). IMPRS-IS seeks young scientists who want to earn a doctorate while contributing to world-leading research in areas such as Computational Cognitive Science, Computer Graphics, Computer Vision, Control Systems, Haptics, Human-Computer Interaction, Machine Learning, Micro- and Nano-Robotics, Perceptual Inference, and Robotics.

### Aim

IMPRS-IS's main objective is to investigate and understand the organizing principles of artificially intelligent systems that can successfully interact with complex environments. The IMPRS-IS deals with fundamental problems of intelligence: perception, action and learning. In a highly multidisciplinary environment, the doctoral program is training a new generation of young scientists, enabling them to tackle the fundamental challenge of intelligent systems.



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## Setting a New Standard for Graduate Schools

IMPRS-IS is the first graduate school to combine leading researchers in mechanical engineering, control theory, computer science, cognitive science, neuroscience, mathematics, and materials science with the field of intelligent systems. Education and research at IMPRS-IS have great potential for practical applications in a number of areas, among them robotics, autonomous vehicles, and medical devices.



## Graduate Recruitment

IMPRS-IS admits new students once a year, with the call for applications generally opening in July and closing in November. The third cohort began in October 2019.

Key aspects of the program:

- the PhD program of IMPRS-IS is in English
- the next cohort: Fall 2020
- PhD candidates are mentored by IMPRS-IS's internationally renowned faculty
- PhD students register as university graduate students and conduct research for approximately three years
- Participation in a wide variety of scientific seminars, advanced training workshops, and social activities is encouraged
- The doctoral degree is conferred once the PhD students successfully complete their PhD projects



### International Max Planck Research School (IMPRS-IS)

Founding Partners: Max Planck Institute for Intelligent Systems (MPI-IS) | University of Stuttgart | University of Tübingen

Spokesperson: Dr. Katherine J. Kuchenbecker (MPI-IS)

Coordinator: Dr. Leila Masri

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Funding Period: July 2017 - June 2023



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## LEAD Graduate School & Research Network

The LEAD Graduate School & Research Network features an integrated research and training program for doctoral candidates and postdocs on Learning, Educational Achievement, and Life Course Development (LEAD). It is funded within the framework of the Excellence Initiative via the German Research Foundation.

The LEAD mission is to achieve cutting-edge research in an interdisciplinary context, to contribute to the evidence-based approach in educational policy by securing empirical data on “what works” in education, to train highly qualified experts for research and practice, and to find answers to some of the most challenging questions in education.

- Which factors are associated with high and low achievement, and how can achievement levels in reading, mathematics, and science be improved, especially in high risk groups?
- How important are motivation and self-regulation for (academic) success in the short term and across the life course, and how can they be enhanced?
- How can schools best deal with the increased number of students with mental health problems?
- How can teaching quality be improved?
- What are the characteristics of the most effective learning environments and how can such effective environments be made available to all students?
- How can the potential of modern media environments be fully exploited for learning?
- What are the origins of social disparities in education and how can these disparities be reduced?

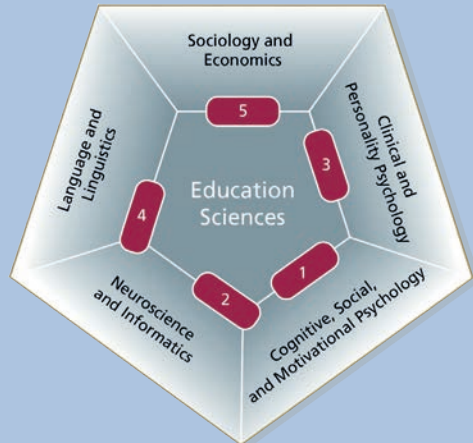
In order to find the best answers to these questions, Education Sciences collaborates with five core research fields and thereby builds on and substantially extends typical research programs in education. These research fields comprise Cognitive, Social, and Motivational Psychology, Neuroscience and Informatics, Clinical and Personality Psychology, Language and Linguistics, as well as Sociology and Economics. Five interface areas of high scientific priority are being investigated within an innovative interdisciplinary approach.

An integral part of the program is the establishment of the LEADing Research Center as a central research facility which assists researchers in applying new research methods and enhanced study designs, in securing access to the field, and in disseminating research results to public, practice and administration.



## Research at LEAD

1. Cognitive, Social, and Motivational Psychology at the Interface of Education Sciences – Learning Processes and Outcomes: This intersection focuses on the psychological foundations of learning, thereby describing causes and consequences of learning from a process-oriented perspective to better understand the origins of educational outcomes which are in the focus of Education Sciences.
2. Educational Neuroscience: The emerging field of „Educational Neuroscience“ or „Neuroeducation“ aims at studying neural correlates and determinants of cognitive and motivational processes relevant to learning and knowledge acquisition.
3. Clinical and Personality Psychology and Education Sciences – Mental Disorders, Learning, and School: This intersection focuses on the understanding, the risk factors, the modification, and the prevention of most relevant psychological problems in school.
4. Language and Learning – Interfacing Research in Education with Linguistic and Cognitive Modeling: Combining expertise from various research fields, this intersection focuses on a greater integration of theoretical and practical perspectives, especially at the interface of linguistic modeling, cognitive modeling, and the teaching and learning context.
5. Sociology and Economics at the Interface of Education Sciences – Education, Life Course Development, and Social Disparities: In this intersection, mutual links between learning, education and their social contexts are analysed in a life-course perspective.



### LEAD Graduate School & Research Network

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## CRC 833 The Construction of Meaning: The Dynamics and Adaptivity of Linguistic Structures

How does context inform our understanding of language? How does meaning arise during the processing of language? How does meaning emerge in different languages?

These are some of the main questions the CRC "The Construction of Meaning: the Dynamics and Adaptivity of Linguistic Structures" is concerned with. In particular, the emergence of meaning is investigated. Common interests are focused on investigating the development of speech and its comprehension under the influence of context factors. Thus, the research center explores how meaning arises (a) in context, (b) during linguistic processing and, (c) in the specific circumstances of an individual language (e.g. English, Russian, Samoan). Our team includes linguists (general linguists, computational linguists, specialists in individual languages) and psychologists.

### Context Awareness and Variability of Meaning

The meaning of linguistic entities features a high degree of variability and openness. In language usage, this uncertainty of meaning is resolved by context-sensitive interpretations. Especially for the domain of sentences, it is not yet clear how this identification of specific meaning takes place. What linguistic mechanisms are responsible for these context-sensitive interpretations? How do combinatory principles of sentence meaning interact with pragmatic strategies in the evaluation of meaning?

### Process Dependence and Cognitive Processing

A considerable amount is known in syntax about the characteristics of cognitive processes that are triggered by linguistic structures: The sub-processes of online interpretation – the composition of meaning in particular – are not as well understood. One central question is how the supposed incrementality of cognitive processes can be related to theories of compositional processing. Frege's principle of compositionality is based on the sentence as a whole and ignores the temporal dimension of semantic processing. The size and nature of sub-sentential units to which the various aspects of an incremental computation of meaning refer and the processes that control the actual composition of meaning in time are therefore unresolved issues.

## Variation and Universals from a Crosslinguistic Perspective

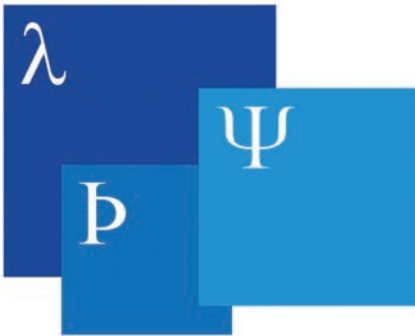
Research in crosslinguistic variation has traditionally focused on morphology and syntax. Mechanisms of interpretation have commonly been regarded as universal. However, linguistic structures describing the same state of affairs often seem to differ substantially in individual languages. It is therefore reasonable to also expect variation within the semantic component of grammar. What are the possibilities and limitations of such semantic variation? Where and how is semantic variation located in a given grammar? How did it develop, and what possibilities are there for language change? To what extent does language change obey universal laws or tendencies?

## The Linguistic Evidence Conference

The Linguistic Evidence Conference was founded by the initial CRC 411 "Linguistic Data Structures: On the Relation between Data and Theory in Linguistics," upon which the current CRC 833 was built. This meeting developed into an established conference that attracts national and international experts in the field of experimental linguistics. It provides a crucial forum for the synthesis of data driven research and theory.

## Promotion of young scientists

The next generation of scientists brings innovative input to the CRC's endeavor. The CRC is, in turn, determined to provide an inspiring and supportive environment for its young scientists. For example, its own "milestone program" supports PhD students with the writing of their theses and a colloquium offers them the opportunity to exchange ideas.



### THEORETICAL LINGUISTICS (LAMBDA)

**SYSTEM-INTERNAL DYNAMICS**

Parameters and limits of meaning variation

- sensitivity to context
- sentence meaning vs pragmatics
- interpretation in literary texts
- automatic meaning comparison

**PSYCHOLOGY, NEUROSCIENCE (PSI)**

**DYNAMICS OF COGNITION**

On-line processing of interpretation

- increments of on-line interpretation
- compositionality and incrementality
- non-linguistic cognition and language
- neurological aspects of representation

### HISTORICAL AND COMPARATIVE LINGUISTICS (THORN)

**SYSTEM CHANGING DYNAMICS**

Variation and universals crosslinguistically

- contrasts in interpretational mechanisms
- variation in the semantic component
- language change: restrictions, processes
- ambiguity phenomena

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Funding period: July 2009 – June 2021



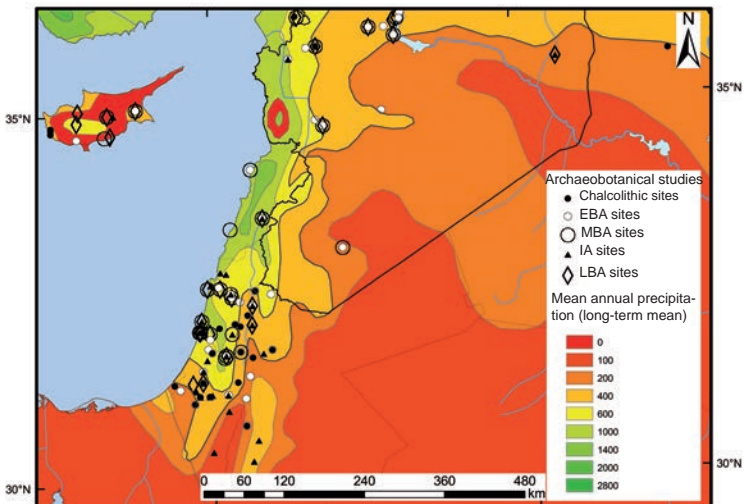
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## CRC 1070 ResourceCultures

The CRC "ResourceCultures" focuses on the socio-cultural dynamics deriving from the use of resources. Resources are defined as the tangible and intangible means by which social relations, units and identities are created, sustained and altered. This definition abolishes the opposition between "natural" and "cultural" resources because even raw materials extracted from nature are subject to cultural constructs. It is further assumed that resources are not normally used as individual elements, but as part of resource complexes which are often combinations of things, persons, knowledge and practices. Based on this approach, "resource use" here refers to the opening up and exploitation as well as the processing, distribution, and utilization of socially relevant resource complexes. It leads to certain dynamics, i.e. multidimensional processes of change, which may affect parts or even the whole of a society.

Three socio-cultural dynamics are the focus of this CRC: Developments, Movements and Valuations. Resources, the use of resources, and the resulting dynamics strongly depend on cultural ideas and practices.

These cultural preconditions are variable and define what resources are and how they are used. Therefore, from a comparative perspective, we can identify different ResourceCultures. The main aims of the CRC are the reconceptualization of the notion of



resources in cultural studies, the identification of diachronic socio-cultural and political developments, the comprehension of the formation of identities in relation to human migrations, and a better understanding of the symbolic dimension of resources. These aims are to be achieved through close cooperation between a broad range of disciplines: Prehistoric, Mediaeval, Scientific, Classical, Near Eastern and Biblical Archaeology (p 14-15); Social and Cultural Anthropology; Classical and Ancient Near Eastern Studies; Ancient, Medieval, and Economic History; Classical Philology & Protestant Theology; Human and Physical Geography, Soil Science and Pedology.

### Developments and Movements's individual projects

The "Land of milk and honey" project looks at the development and significance of agricultural resources in Bronze and Iron Age Palestine. It investigates changes in the use of agricultural resources between 3,600 – 332 BC as an important basis for the emergence and change of socio-political units in ancient Palestine. More generally, the interrelationship of human factors, environmental conditions and the changing use of resources are studied with archaeological, archaeobotanical and archaeozoological methods. The project is representative of the section Developments and contributes to our understanding of structural change in societies. The "Variability of resource use – Occupation dynamics of late Neanderthals and early anatomically modern humans in Europe" project belongs to the section Movements and investigates demographic and socio-cultural change in Europe between 50,000 – 30,000 years ago using archaeological and archaeometric methods. The evaluation of factors and dynamic processes during a period of strong climate fluctuations and the role of landscape morphology in long-distance contacts is expected to help in developing answers on questions such as whether anatomically modern humans were spatially more flexible than Neanderthals and how the Neanderthals were superseded. "Favor - Disfavor? Development of Resources in Marginal Areas" investigates soils and archaeological aspects within the context of processes of spatial development and settlement. The main question is, whether and to which extent such resources are preconditions and causes for spatial and socio-cultural developments. To get a better understanding of the socio-cultural dynamics from the use of resources, processes of soil erosion, resource-development and resulting movements into otherwise unfavourable or marginal areas are analyzed. This will be done against the background of specific cultural and historical needs for resources in the eastern Black Forest, the western Swabian Jura, the Baar and Hegau regions and Upper Swabia.



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**Faculty of Humanities: Institute for Prehistoric and Medieval Archaeology**

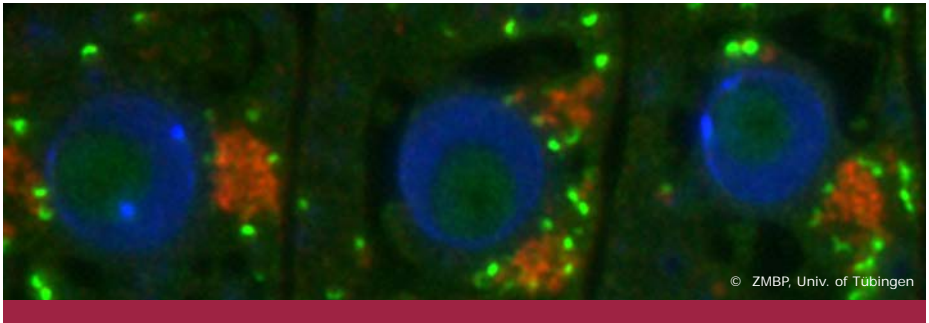
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Funding period: October 2013 - June 2021





## CRC 1101 Molecular Encoding of Specificity in Plant Processes

In recent years many key player proteins have been identified in plant organisms. These play a crucial role in plant physiology, growth and development and adaptation to environmental cues. The next step in plant molecular biology has to be the determination of the molecular-mechanistic function of these key players. A very important but often unsolved scientific question is "How do these key players exert their specific activity inside the nucleus, the cytoplasm, in the membrane and the endomembrane system and by cell-cell communication?".

That is why the CRC "Molecular Encoding of Specificity in Plant Processes" is focused on how specificity of biological processes is achieved on molecular-mechanistic level. The encoding of specificity can be achieved in different ways, from structural changes of single molecules and proteins, via the specific and dynamic interaction of molecules, to higher order complexes and the intracellular trafficking and sorting of molecules up to the systemic distribution of specificity-mediating factors across cell borders.

To succeed, the CRC 1101 must take a multi-disciplinary research approach, based on the broad scientific knowledge and the diverse methodical portfolios of the contributing institutes. This is guaranteed by the scientific and technological strength and synergistic interaction of the Center for Plant Molecular Biology (ZMBP, p 18-19) at Tübingen University, the participating institutes of the Max Planck Society (MPG) in Tübingen, and three associated research groups of the Center for Organismal Studies (COS) at the University of Heidelberg.

The CRC 1101 is made up of four interlocking research areas: (A) Specificity by Subcellular Sorting, (B) Specificity through Regulators of Growth and Development, (C) RNA-Mediated Specificity and (D) Receptor-Mediated Specificity, in which the encoding of specificity of diverse processes will be studied.



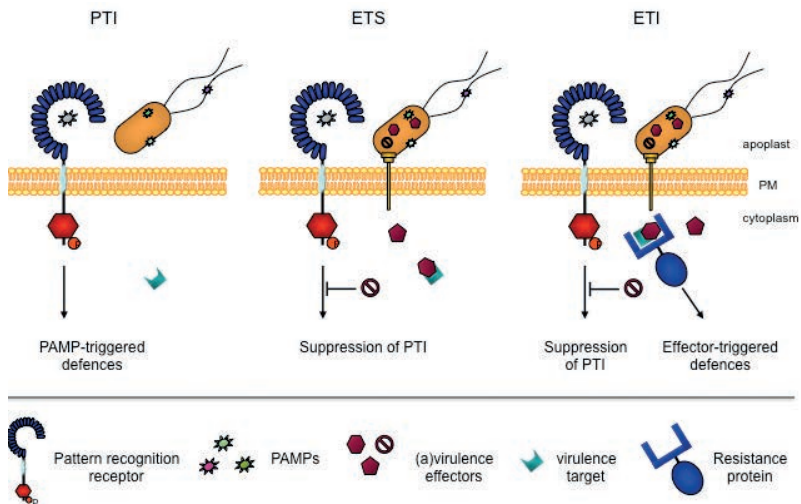
The CRC 1101 will focus in particular on the following issues:

- What are the mechanistic, functional principles of biological molecules which are responsible for growth, development, and adaptation to the environment?
- How is the interaction of these molecules regulated, and which role do processes such as intra- and sub-cellular localization play there?
- How do selected plant molecules function during encoding of specificity at nano-meter and atomic scale?

To address these issues, we are developing spectroscopic, light and electron microscopic and force microscopic tools and techniques. These techniques will ease the recording of quantitative data useful for the mathematical modeling and simulation of processes which are responsible for the encoding of specificity – especially at subcellular and cellular level.

In the medium term, we aim to be able to make predictions about the dynamics of specificity-mediating processes in plant growth and development and adaptation to the environment. In the long term, this should open the door to the creation of amended or novel cell properties in plants using a synthetic biological approach.

Based on the existing international graduate program „Cellular and Molecular Biology of Plants“ (GP-ZMBP) the CRC 1101 offers a structured, multi-disciplinary program, which brings together graduate students of nano-biophysics, biochemistry, structural biology, molecular biology, cell biology, developmental biology, physiology and mathematical modeling.



A schematic representation of the plant immune system (Nürnberg & Kemmerling, Annual Plant Reviews, Wiley Blackwell, 2008, 34: 16-47)

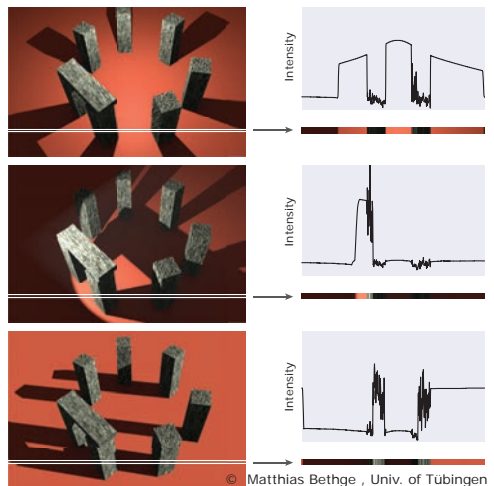
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 Funding period: April 2014 - December 2021



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## CRC 1233 Robust Vision: Inference Principles and Neural Mechanisms

The Collaborative Research Centre “Robust Vision” is a close collaboration between scientists from the University of Tübingen and the Max Planck Institute for Intelligent Systems. It brings together leading researchers in machine learning, computer vision and systems neuroscience to uncover the computational principles underlying robust vision. Vision plays a key role for animals and humans to achieve a reliable correspondence between the brain’s internal model of the world and the external surroundings. It relies on the sensation and interpretation of meaningful patterns implicit in the luminance signals distributed across the entire image. Understanding the principles and algorithms that facilitate robust vision of these patterns plays a fundamental role in understanding biological vision — just as knowledge of aerodynamics is crucial for reasoning about biological flight. Big strides have been made in computer vision over recent years with algorithms being tested on increasingly challenging problems, including real-world applications such as autonomous car driving. However, human vision still clearly excels in robustness and the ability to build internal models of the world. The CRC leverages the successes in computer vision and seeks to advance our understanding of the robustness of biological vision, which in turn can help to increase this capacity in machines again. In close collaborations between computational researchers and neuroscientists, our goal is to uncover the principles of robust vision and to identify its neural basis in the mammalian brain.



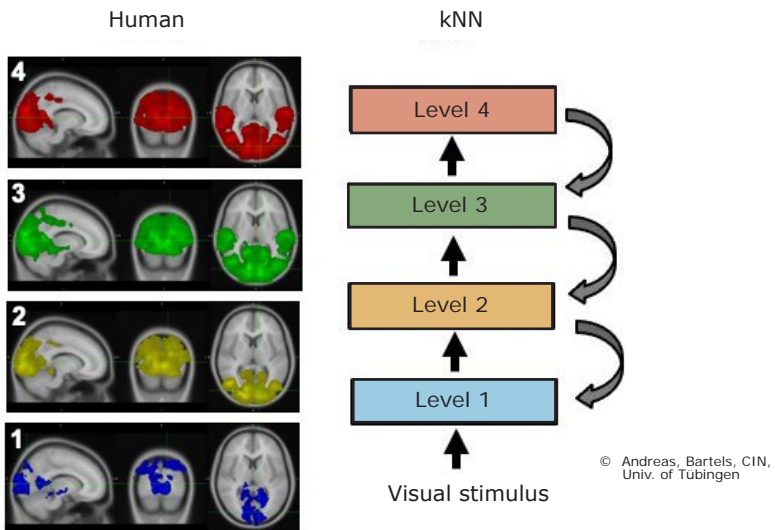
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Images of the same scene under different illumination conditions (left panel) give rise to completely different visual input. To make this most obvious, the intensities taken from the same row of pixels in the three different images are shown in the right panel. Despite the huge variation in the visual input our visual system has no difficulty in recognizing the same scene in all three images. About hundred-fifty years ago, Hermann von Helmholtz was among the first to point out the computational challenge underlying this problem and posed the question of how these unconscious computations are carried out so efficiently in the brain.

In particular, the CRC focuses on areas where the neurobiology of vision prominently diverges from current machine vision algorithms and studies.

- the computational use of feedback in the brain and how generative and causal modelling can improve
- the robustness of visual inference algorithms (Aim 1)
- how robust visual inference is affected by the dynamics of natural image acquisition (Aim 2)
- how robust visual inference is affected by pre-cortical transformations as determined from neurobiological measurements (Aim 3).

In the first funding period the focus was on prominent discrepancies between biological and current artificial vision systems on single tasks. In the second funding period the projects further converged through a common shift towards studying more realistic and dynamic vision problems and stimuli as well as through a joint interest in studying task flexibility as a key signature of robust vision. Building on their progress of the first funding period, both the computer vision and neuroscience projects are now in a position to probe visual systems with more challenging stimuli, such as sequences of naturalistic, time-varying movies instead of static images, in order to gain an understanding of inference algorithms and neural circuits under more complex and realistic conditions and under different task demands.



Similar to the visual brain, artificial neural networks (KNNs) respond to more abstract features in higher layers than in lower layers. The image shows the result of a study from the group of Prof. Bartels in which human brain activity is related to the activations of recurrent artificial neural networks (kNN). Brain slices from 1-4 show brain activity correlated with the four hierarchical levels (ascending from 1-4) of a recurrent neural network. Brain activity was measured by functional magnetic resonance imaging in twelve subjects while they watched a motion picture. The kNN was trained to predict the next frame of any movie sequence.

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Funding Period: January 2021 - December 2024



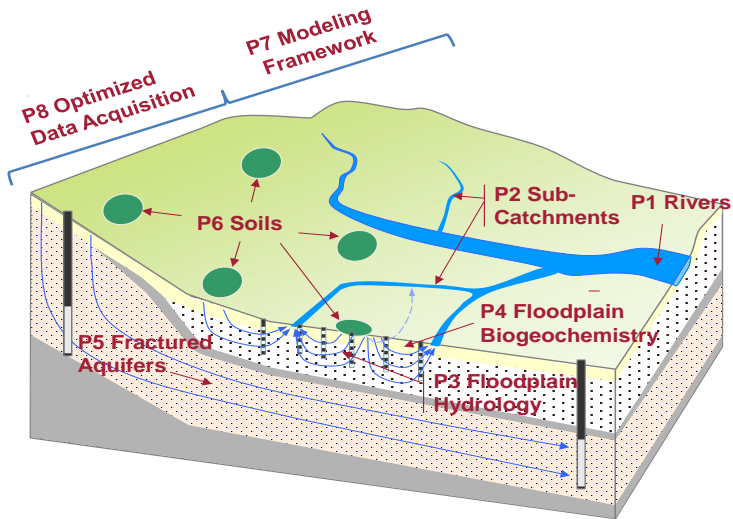
## CRC 1253 Catchments as Reactors: Metabolism of Pollutants on the Landscape Scale (CAMPOS)

The CRC "Catchments as Reactors: Metabolism of Pollutants on the Landscape Scale (CAMPOS)", starting in January 2017, addresses diffuse pollution of soils, surface waters, and groundwater by anthropogenic organic and inorganic compounds. CAMPOS is funded by the German Research Foundation (DFG) for four years and may be extended to twelve years in total upon positive evaluation.

The aims of CAMPOS are to identify landscape elements controlling storage, biogeochemical transformation, or elimination of pollutants, to identify the respective processes and their dynamics responsible for relevant pollutant transformations in the environment, and to develop a new modeling framework to simulate and predict reactive transport and pollutant behavior on the landscape scale.

Researchers from the Universities of Tübingen, Hohenheim, and Stuttgart, as well as from the Helmholtz Centers for Environmental Research in Leipzig (UFZ) and for Environment & Health in Munich (HMGU) will work together in eight collaborative projects to close the gap between relevant processes identified in the laboratory and mechanisms of mass transfer and metabolic transformations on the landscape scale. The CAMPOS research addresses pollutant turnover and reactive zones within the most relevant landscape elements and compartments aligned along the reversed water flow from rivers as integrators of pollutant fluxes in landscapes (project P1), nested and contrasting low-order sub-catchments including the groundwater/surface-water interface (P2), hillslopes and floodplains (P3-P4), the underlying fractured/karstic aquifer system (P5), and finally, soils (P6). Within these compartments, we will identify and quantify the most relevant transport and transformation processes, i.e. biodegradation in biofilms (P1), turnover at steep redox gradients (P2-P4), diffusion-controlled slow turnover in the rock matrix (P5), and limitations of pollutant turnover in soil compartments (P6).





We develop a stochastic modeling framework (P7-P8) addressing the conceptual and parametric uncertainty of reactive transport on the catchment scale and in the interpretation of the monitoring data, in predicting the development of water quality, and in designing experiments to reduce uncertainty. Supporting projects of CAMPOS provide laboratory analysis and maintenance of field sites (S1), central modeling support (S2), and data infrastructure (INF). Research focusses on shared study sites in the catchment of River Ammer, a tributary of River Neckar in SW-Germany, in close vicinity to the City of Tübingen. In a first phase a set of lead substances such as nitrate, persistent organic pollutants (POPs), herbicides, pharmaceuticals, personal care products and their respective metabolites have been selected.

Research in CAMPOS builds upon a well-structured collaboration of scientists from diverse backgrounds such as environmental microbiology and chemistry, soil science, and (stochastic) hydrogeology, as developed, for instance, in the former research cluster WESS ("Water & Earth System Science"). Founded in 2009, WESS focused on the long-term development of water quality at the catchment scale as a function of changes in land use, climate, and water management. Apart from that, CAMPOS is also closely linked to the International Research Training Group 1829 "Integrated Hydro-system Modelling" (p 61), a cooperation of the Universities of Tübingen, Stuttgart, and Hohenheim with Canadian partner universities.

Center for Applied Geosciences (ZAG)

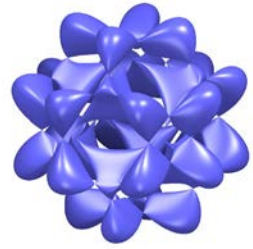
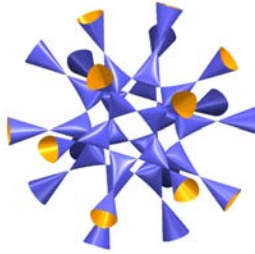
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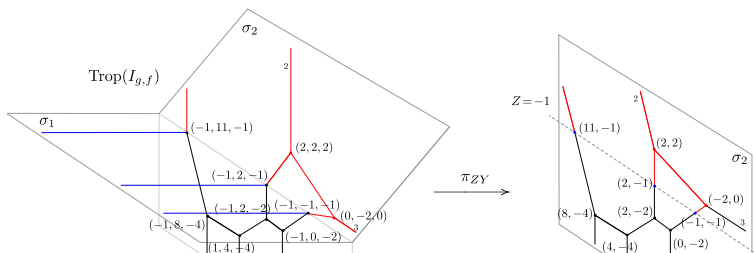
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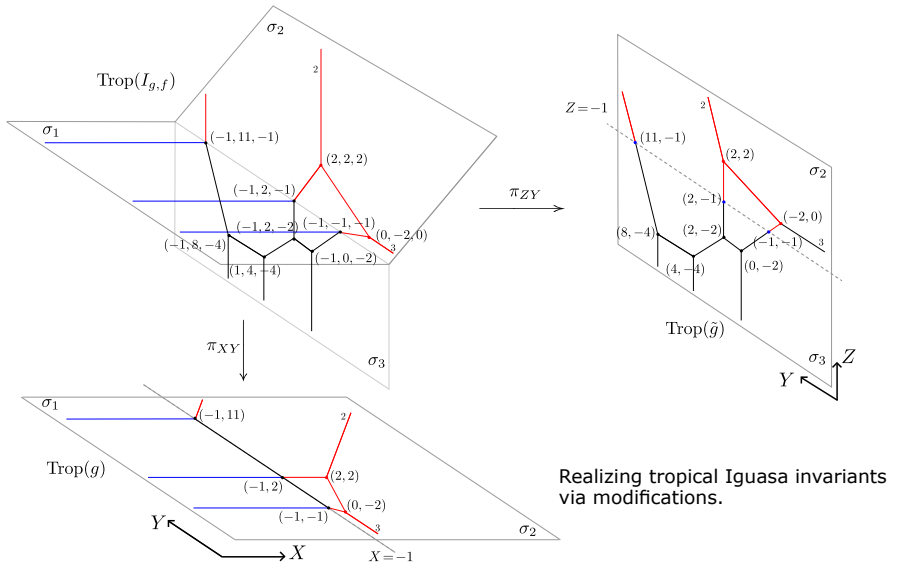
## CRC/Transregio 195 Symbolic Tools in Mathematics and their Application

Experiments based on calculating examples have always played a key role in mathematical research. Modern computers paired with sophisticated mathematical software tools allow for far reaching experiments which were previously unimaginable. They enable mathematicians to test working hypotheses or conjectures in a large number of instances; to find counterexamples or enough mathematical evidence to sharpen a conjecture; to arrive at new conjectures in the first place; to verify theorems whose proofs have been reduced to handling a finite number of special cases.

In the realm of algebra and its applications, where exact calculations are inevitable, the desired software tools are provided by computer algebra systems. These systems are large, complex pieces of software, containing and relying on a vast amount of mathematical reasoning. Driven by intended applications, they are created by collaborative efforts requiring specialists in many different fields. It is an important aspect that through these systems a large treasure of mathematical knowledge becomes accessible to and can also be applied by non-experts.

A decisive feature of current developments is that more and more of the abstract concepts of pure mathematics are made constructive, with interdisciplinary methods playing a significant role. The TRR 195 aims at taking a leading role in driving these developments: In its five mathematical core areas (group and representation theory, algebraic geometry, commutative and non-commutative algebra, tropical and polyhedral geometry, number theory, random matrix theory and free probability), it will provide the computational open source infrastructure for years to come; it will create vast amounts of data important to the mathematical community; and it will exploit the infrastructure and data to solve fundamental mathematical problems.





The principal contributions of the TRR 195 will be:

- to open up fundamental mathematical concepts to constructive treatment and design corresponding low- and high-level algorithms
- to attack and solve difficult mathematical problems, using algorithmic and experimental methods as key tools
- to support theoretical progress by constructing mathematical objects and generating databases and making them accessible to the mathematical community
- to integrate the systems, libraries and packages developed within the TRR 195 into a unified computer algebra system which supports interdisciplinary research in the areas of the TRR 195, implementing the new algorithms and integrating the databases there
- to enhance the performance of all components of the unified system, in particular by designing and implementing parallel algorithms for the efficient use of multicore computers and high-performance clusters.

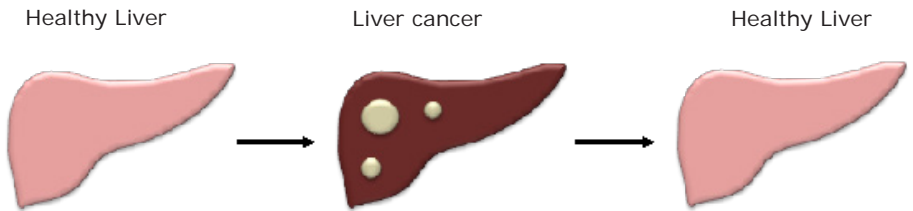
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Funding period: January 2017 - December 2021



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## CRC/Transregio 209 Liver Cancer: New Mechanistic and Therapeutic Concepts in a Solid Tumor Model

Liver cancer (hepatocellular carcinoma (HCC) and intrahepatic cholangiocarcinoma (ICC)) is the second leading cause of cancer-related death with rising incidence, poor prognosis and limited therapeutic options.

The three partner sites founding this consortium, Eberhard Karls University and University Clinic Tübingen, Medical Faculty Heidelberg and Hannover Medical School, have a longstanding biomedical liver cancer research collaboration along with translational and clinical infrastructures. Researchers of the CRC/Transregio 209 have made seminal contributions to the current mechanistic understanding of liver cancer and developed important new model systems for studying liver cancer in molecular detail.

In order to develop novel treatments that effectively combat liver cancer, the complexity and interconnection of key biological mechanisms controlling HCC and ICC development urgently need to be understood.

Based on this demand research of the 18 projects of the newly funded CRC/Transregio 209 will focus on three key biological areas to gain fundamental insight into the complex development of HCC and ICC. Research area A will address protumorigenic mechanisms with regard to chronic Hepatitis C Virus infection or steatohepatitis. In research area B higher-order molecular alterations specific to the tumor cell and its interactions with the hepatic environment will be studied in pivotal cellular and animal model systems. Area C will work on the development of new "bench-to bedside" therapy concepts, in particular viro-immune based concepts and treatment opportunities targeting epigenetic alterations in liver cancer.

Focusing on revealing the regulatory complexity of interconnecting biological mechanisms leading to the development of HCC and ICC, the following projects of the CRC/Transregio 209 will be conducted by members of the MNF:

Prof. Dr. Alfred Nordheim and Prof. Dr. Tassula Proikas-Cezanne from the Interfaculty Institute of Cell Biology (IFIZ, p 6-7) will gain insight into "Metabolic reprogramming and control of autophagy in HCC progression" (project B02),

Prof. Dr. Klaus Schulze-Osthoff and Dr. Stephan Hailfinger from the Interfaculty Institute of Biochemistry (IFIB, p 6-7) will address the "Role of atypical I $\kappa$ B protein I $\kappa$ B $\zeta$  in HCC formation" (project A06),

Dr. Sven Nahnsen from the Quantitative Biology Center (QBIC, p 96), along with Prof. Dr. Peter Schirmacher (Heidelberg) and Prof. Dr. Thomas Illig (Hannover) will organize the central service project with regard to the infrastructure for standardized biobanking, human probe and model system evaluation, database and bioinformatics (project INF).

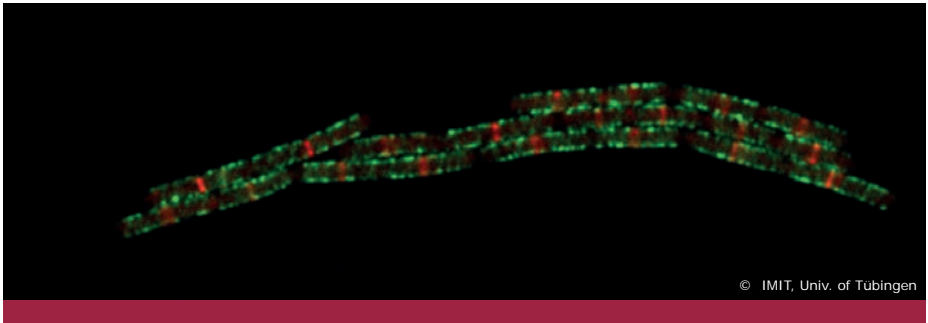


Interfaculty Institute of Biochemistry (IFIB) | Interfaculty Institute of Cell Biology (IFIZ) |  
Quantative Biology Center (QBIC)

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Funding period: July 2017 - June 2021



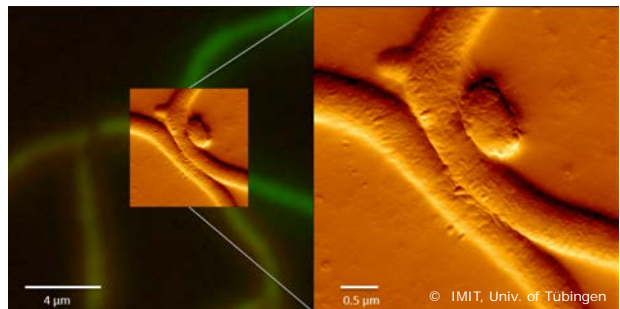


## CRC/Transregio 261 ANTIBIOTIC CELLMAP: Cellular MEchanisms of Antibiotic Action and Production

The transregional collaborative research centre TRR 261 'Cellular Mechanisms of Antibiotic Action and Production' (acronym 'ANTIBIOTIC CellMAP') funded by the German Research Foundation (DFG) has operated since July 2019 under Tübingen's leadership. Researchers from the Faculties of Science and Medical Faculties of the Universities of Tübingen and Bonn study growth-inhibitory mechanisms and biosynthetic pathways of antibiotics from the perspective of bacterial cell biology and, at the same time, at the molecular level.

Although antibiotic resistance is rising to alarming levels and novel antibiotics are urgently needed, new antibiotic classes with unique structural scaffolds and antibacterial mechanisms are scarce in development pipelines. Discovery strategies in the past decades have relied on high-throughput screening campaigns that showed meagre success rates in the antibacterial field. A better understanding of the effects and function of antibiotics is needed to improve future outcomes. Knowledge gaps regarding the biology of bacterial cells exposed to antibiotics (the 'target cells') and bacterial cells that synthesise antibiotics (the 'producer cells') must be closed.

It is often not understood what cascade of events occur within the target cells upon antibiotic exposure and which specific incident causes cell death. Many successful antibiotics attack multiple areas of cellular metabolism. Antibiotic modes of action are the focus of project area A of the TRR261. Here, the aim is to learn from the cellular mechanisms of potent antibiotics so that promising compounds can be rationally selected and developed in the future.

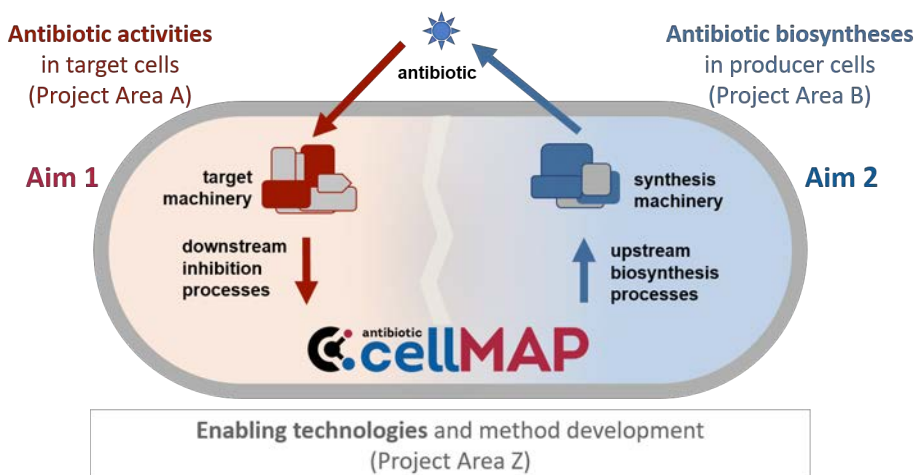


Fluorescence (left) and atomic force (right) microscopy of two *Streptomyces* hyphae. Streptomycetes are the origin of most antibiotic drugs.

About two-thirds of all antibiotic classes applied in therapy are natural products or derivatives thereof. Most of these compounds are synthesised by bacteria using the same molecular machinery in their cellular metabolism as the bacteria against which these compounds are directed. In project area B, researchers investigate antibiotic biosynthesis in such producing bacteria. The aim is to understand how producer cells manage to adapt their metabolism to synthesise the often highly complex agents and how they cope with the toxic compounds. Greater knowledge about antibiotic biosynthesis will later allow the production of agents that currently cannot be produced in the laboratory.

Recent advances in bacterial cell biology have revealed an astounding degree of functional organisation in bacterial cells, where vital processes require elaborate spatiotemporal control. Both antibiotic action and production must be studied in this context, and cutting-edge methodology for cellular analyses will be developed in project area Z, including high-resolution chemical analytics, complex natural product syntheses, super-resolution live-cell microscopy, multi-OMICs technologies and data management according to FAIR principles.

The dedication to study antibiotic action and production in growing bacteria, and to do so with a molecular resolution, is a hallmark of this collaborative research centre. Interdisciplinary researchers from microbiology, chemistry, pharmaceutical sciences, bioinformatics and medicine have joined forces to explore the cellular mechanisms of antibiotic action and production in space and time, thereby contributing to an 'antibiotic CellMAP'. The TRR261 team strives to simultaneously lay a foundation for more rational approaches in antibiotic drug discovery in the future and improve our understanding of the fundamental principles of the cellular organisation of prokaryotic life.



TRR 261: Project areas and aims:  
Improve present concepts in antibiotic discovery - Improve knowledge on bacterial cell biology

Interfaculty Institute of Microbiology and Infection Medicine

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Funding period: July 2019 - June 2023

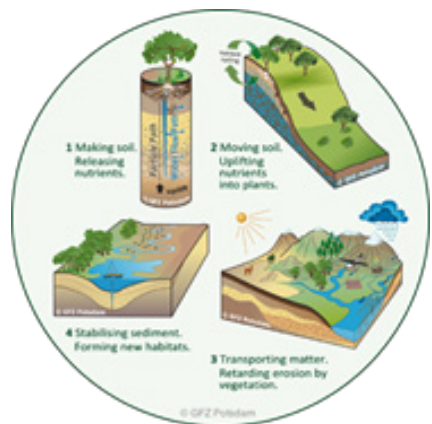


## Priority Program (SPP) 1803 EarthShape: Terrestrial Geosphere-Biosphere Interactions

A common Geoscience paradigm holds that the Earth surface is shaped mainly by climate (eroding soil) and tectonics (building mountains). The EarthShape project challenges this paradigm to explore how in addition biologic processes form soil, influence topography, and thereby shape the Earth surface and modulate the impact of climate change on the Earth surface. The influence of microorganisms, plants, and animals on the formation of soils and the shape of topography is still poorly understood, but new scientific technology now allows identification of their role. Research into biologic controls on topography is particularly important for understanding how future climate and biologic changes will impact the Earth's surface.

The overarching research question of this project is how microorganisms, animals, and plants influence the shape and development of the Earth's surface over time scales from the present-day to the distant geologic past over millions of years.

EarthShape bridges between scientific disciplines and includes geoscientists and biologists to study this complex question from different viewpoints. Approximately 60 German (including 10 from Tübingen) and 20 Chilean researchers are involved in a diverse range of projects in this priority program.



## Interdisciplinary Approach & Research Themes



The EarthShape study sites are located in the north-to-south trending Coastal Cordillera mountains of Chile, South America. These sites span from the Atacama Desert in the north to temperate rain forests approximately 1300 km to the south. The site selection contains a large ecological and climate gradient ranging from very dry to humid climate conditions. The sites were selected to avoid other complicating factors such as differences in rock type, and glacial, and volcanic impacts.



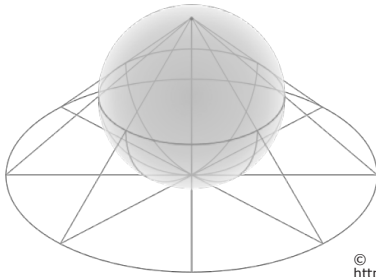
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Funding period: January 2016 - December 2022



Projektive Geometrie :  
This image illustrates in 3D a stereographic projection from the north pole onto a plane below the sphere

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[https://de.wikiversity.org/wiki/Datei:Stereographic\\_projection\\_in\\_3D.png](https://de.wikiversity.org/wiki/Datei:Stereographic_projection_in_3D.png)

## Priority Program (SPP) 2026 Geometry at Infinity

The DFG Priority Programme Geometry at Infinity started in 2017 and entered its second funding phase in 2020. It is led by Christian Bär (Potsdam), Bernhard Hanke (Augsburg), Anna Wienhard (Heidelberg), and Burkhard Wilking (Münster). The University of Tübingen is currently involved with two projects, led by Dr. Armando Cabrera Pacheco and by Prof. Dr. Carla Cederbaum in collaboration with Prof. Dr. Jan Metzger (Potsdam), respectively, both in the Differential Geometry and Mathematical Relativity research group in the Mathematics Department.

Geometry at Infinity is dedicated to the study of asymptotics, a topic considered in almost all fields of mathematics. We may distinguish two different manifestations of this fundamental concept:

- Convergent sequences are used to approach mathematical objects whose precise properties are either not known or difficult to describe.
- Non-convergent or divergent sequences enable us to define new objects as “ideal” (artificial) limit points.

An illustrative example for the second aspect is projective geometry, originating in the development of perspective art in the Renaissance period. It is based on the addition of infinitely distant points to Euclidean space, which serve as virtual limit points of sequences that move to infinity on straight lines. In both cases many essential, sometimes drastic, features such as collapse, explosion of geometric quantities, or rigidity phenomena become apparent only if families and limits of geometric objects are taken into account or if these objects are considered in the large. These features are the subject of Geometry at infinity.

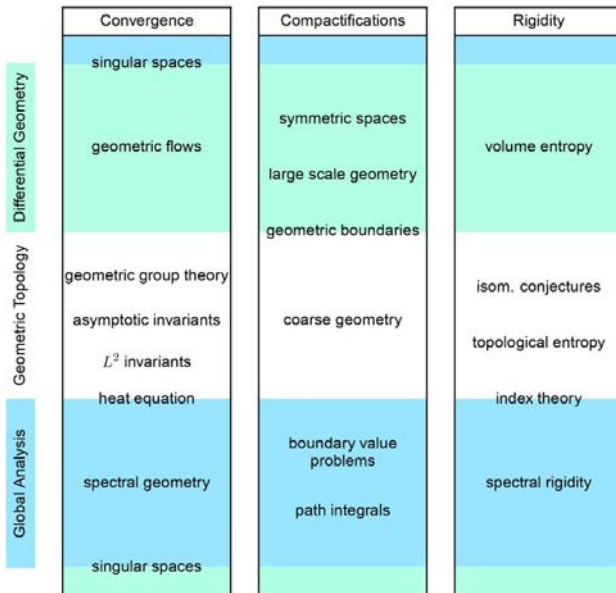


Bernhard Riemann (1826-1866)  
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Recent developments of the last decades have shown that methods dealing with “finite” geometric objects like compact Riemannian or topological manifolds, finite groups and cell complexes, simplicial homology or index theory on compact manifolds are challenged and lead to completely new problems, concepts and theories when “infinite” structures come into play. Examples are asymptotic properties of Riemannian manifolds and their ideal boundaries, convergence of Riemannian manifolds, rigidity phenomena, homology based on infinite chains, K-theory of operator algebras and Brownian motion on non-compact manifolds, just to mention a few. Problems, concepts and results in these different fields bear many similarities that have not yet been explored to a full extent, partly due to the historic formation of different research communities, their regional separation and differences in scientific language. Furthermore, the study of limits and asymptotic properties often involve methods from geometry, analysis, and topology at the same time. In order to improve our understanding of geometry at infinity, it is necessary to investigate problems jointly and to combine different perspectives, mathematical descriptions and solution strategies from all of these areas.

We take the perspective “Geometry at infinity” as the guiding principle to address several key research problems. Taking this perspective we cross and transcend the frontiers of classical disciplines



such as Riemannian geometry, global analysis, and algebraic topology, and bring together researchers from these disciplines to create an interdisciplinary research community. We expect that this more comprehensive approach will lead to important and significant scientific progress in this emerging field, create a new research community in Germany, with international radiance, and provide the structural framework to train the next generation of researchers in an interdisciplinary environment.

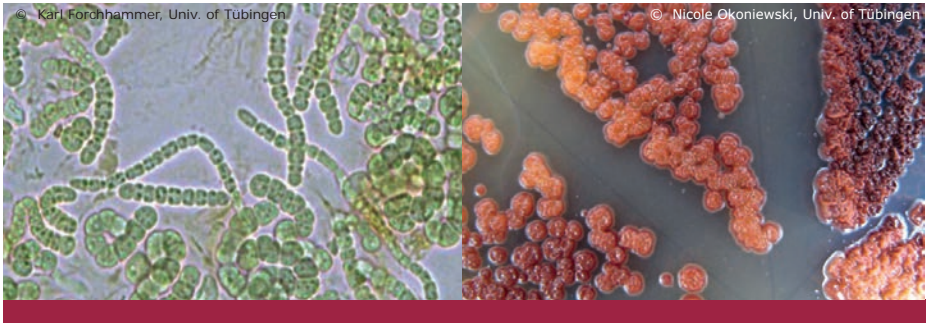
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Funding period: September 2017 - September 2023



## RTG 1708 Molecular Principles of Bacterial Survival Strategies

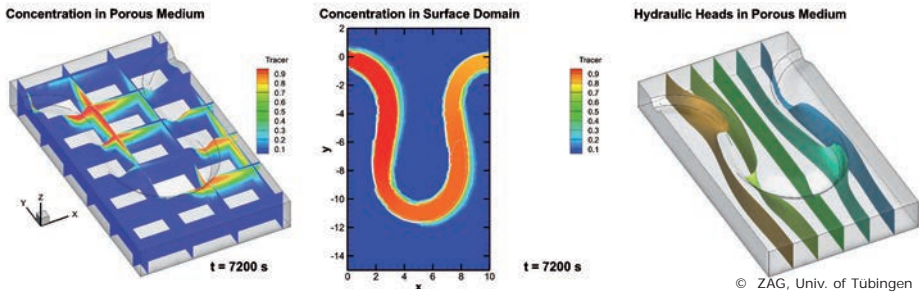
The Research Training Group “Molecular principles of bacterial survival strategies” combines research groups from diverse areas of microbiological sub-disciplinary fields (p 16-17) and related areas to address the question of how bacteria maintain viability in adverse environments. This topic is of general significance for a broad range of microbiological problems, such as infection research, diagnostics, bacterial ecology, and the periodic appearance of toxic cyanobacterial blooms. To be able to evaluate and predict bacterial viability, a large gap in our knowledge has to be filled in basic microbiological research.

We investigate molecular principles of bacterial survival strategies using selected examples. The summing up of the results of different bacterial systems is expected to produce valuable insight into the spectrum of survival strategies. We focus particularly on maintenance metabolism, detoxification, repair pathways, and protective substances and structures. These survival strategies are tightly regulated, may act in concert, and mutually influence each other. Therefore, we do not regard them as singular and isolated processes, but rather consider them as part of the repertoire of a higher-level survival program.

The scientists aim at a synopsis of molecular processes involved in bacterial survival in theory and practice. Such an intense and interdisciplinary effort provides all members of the graduate team with expert knowledge in this highly relevant area of study. An accompanying study program will provide practical knowledge and foster professional skills. Since the various groups are trained in the different sub-disciplines of microbiology and related fields and have different experimental backgrounds, the entire graduate team benefits from a positive environment of complementary experiences. To achieve this, we are developing an expert knowledge pool, a methodical platform and gateways to external technologies. In addition to acquiring expert knowledge, the qualification concept of our RTG aims at developing professional skills as well as general and social abilities. The goals of the program will be achieved by encouraging and requiring teaching, whereby the professors act as mentors to promote individual initiative, creativity, and the ability to solve problems independently.

### Interfaculty Institute of Microbiology and Infection Medicine Tübingen

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Funding period: October 2012 - June 2021



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## RTG 1829 Integrated Hydrosystem Modelling (Hydromod)

Groundwater is the most important source of drinking water worldwide. Its quantity and quality is threatened by many factors, such as unsustainable use, diffuse input of anthropogenic pollutants, and anthropogenic changes of biogeochemical conditions. It is now well accepted that groundwater protection requires examination of the coupled terrestrial hydrosystem at catchment scale, including atmospheric and land-surface processes, surface-water bodies, and processes in the unsaturated soil zone and in the aquifer. It is not exactly clear how these processes are related; they are affected by heterogeneity and undergo change. Sustainable management of groundwater resources under climate and land-use change requires predictive models simulating all relevant hydrological and (biogeo)chemical processes as coupled systems, explicitly accounting for feedback mechanisms. Such physics-based coupled modeling platforms have now reached a stage in which they can be applied in quantitative water resources management. Extensions to water quality, however, are still in their infancy and face particular challenges on the conceptual level and in upscaling to the catchment scale.

The key objectives of the Research Training Group Integrated Hydrosystem Modelling are to (a) bring together specialists from all relevant sub-disciplines for integrated assessment and modeling of coupled hydrosystems, located at the Universities of Tübingen, Hohenheim, Stuttgart, and Canadian partner universities, (b) collaboratively train graduate students in the underlying hydrological and (biogeo)chemical processes and their modeling on the regional scale, and (c) to advance modeling tools to be used for an improved understanding of processes controlling water quality on the catchment scale, accounting for internal heterogeneity and changes in external forces. The research is organized into four topics: A: Flux balances at the land surface, B: Biogeochemical reactions in catchments, C: Model legitimacy and uncertainty assessment of large-scale models, and D: Evolution of catchments.

Doctoral candidates within the RTG are co-supervised by a senior advisor (professor), a junior advisor (junior researcher), and a Canadian advisor; they stay about 6 months at the partner institution, and participate in five spring and fall schools.

### Center for Applied Geosciences

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Funding period: May 2012 - December 2021

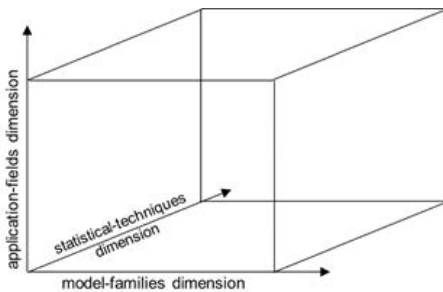


Figure 1. Cuboid model: A framework for the SMiP research agenda

© SMiP group / „Proposal, Nov 2016

## RTG 2277 Statistical Modeling in Psychology (SMiP)

This Research Training Group aims to overcome a persistent and growing challenge in behavioral research, namely, the gap between substantive research in basic and applied fields of psychology and latest developments in statistical modeling and psychometrics. To counteract the segregation of psychology into substantive science and statistical methodology, the RTG conceives statistical models as frameworks for formalizing psychological theories and research questions. Theoretical predictions can thus be phrased in terms of model parameters, and state-of-the-art statistical techniques can be used both to measure psychological constructs via parameter estimation. Up-to-date methods of model selection and model testing will be employed to test these predictions.

The SMiP research agenda is based on a cuboid model involving three dimensions: model types, application fields, and statistical techniques (Figure 1). The main goal is to link at least two dimensions in any research activity of the RTG. Prototypical research of the RTG is thus intended to integrate substantive psychological research with psychologically appropriate statistical models and to up-to-date techniques of model-based data analyses.

The research program covers applications of existing statistical model families (e.g., structural equation models, generalized hierarchical models, multinomial models, and Wiener processes) to novel research questions in cognitive and social psychology and also in applied fields (e.g., organizational psychology). One particular goal is to extend statistical model families and modeling principles to new application fields in which they have not been utilized before. At the same time, we also aim at developing new model classes and statistical techniques to address innovative psychological research questions; for example, hybrid models including continuous and categorical data with both continuous and discrete latent variables. In cognitive psychometrics, in particular, models based on basic cognitive theories will be developed that enable the

analysis of experimental and group effects conjointly with effects of individual differences. In areas of psychology that focus on complex field data, multilevel models with group-, person-, and situation-level effects will be refined.

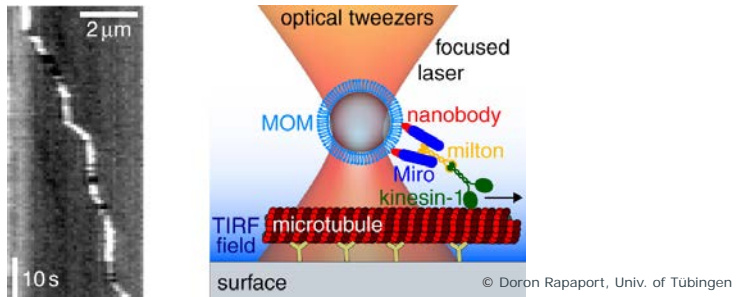
Univ. of Mannheim, Univ. of Freiburg, Univ. of Heidelberg,  
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Funding period: October 2017 - September 2022



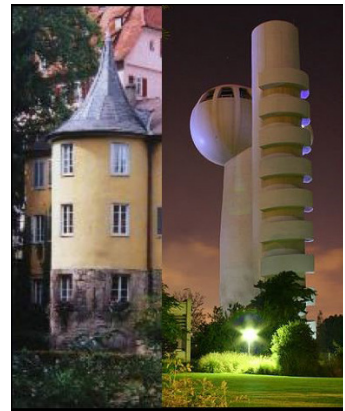
## RTG 2364 The multifaceted functions and dynamics of the mitochondrial outer membrane (MOMbrane)

The mitochondrial outer membrane (MOM) mediates numerous interactions between mitochondria and the rest of the cell. It plays a central role in: mitophagy, apoptosis, motility and morphology of the organelle, transfer of proteins and lipids to and from other compartments, immune response, and exchange of metabolites with the cytosol. Despite its obvious importance, the MOM is currently understudied, making this RTG highly relevant and unique. All the ten included projects are tightly interconnected and deal with various aspects of the same biological question: How are mitochondrial diversity, dynamics and functions coordinated and regulated at the level of the MOM? Our aim is to achieve comprehensive understanding of the structure, function, regulation, and biogenesis of the MOM.

The principal investigators of our program reside in five institutes in Tübingen and represent a broad spectrum of disciplines and approaches. Many close collaborations exist among the groups in Tübingen and partner groups in the Weizmann Institute of Science (WIS, Israel).

To achieve our goals, we use an interdisciplinary approach. On the one end of the spectrum, we will use yeast cells to study basic mitochondrial mechanisms, and on the other, we utilize induced pluripotent stem cells and mouse models to investigate MOM-related pathomechanisms of human diseases. Our RTG brings together different disciplines such as protein analytics, structural biology, biophysics, cell biology, and modern imaging.

All fellows participating in this RTG benefit from an intense program of training measures. Each fellow in our RTG has a dual mentoring team including a co-supervisor from the WIS. In addition, each fellow will spend an internship in the partner group at the WIS.



Tight collaboration of the IFIB with the Weizmann Institute of Science, Israel

### Interfaculty Institute of Biochemistry (IFIB)

Coordinator: Prof. Doron Rapaport, PhD

Administrative Coordinator: Regina Grupp

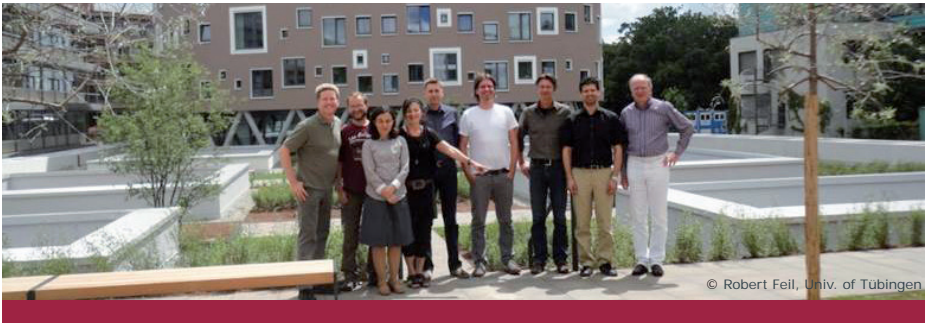
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Funding period: April 2018 - September 2022



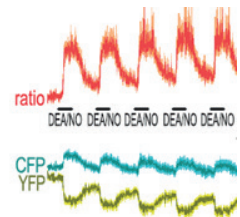
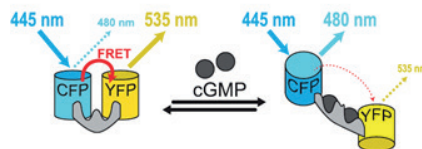




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## FOR 2060 Signaling in Cell Growth and Survival (cGMP)

The cyclic nucleotide cGMP is an intracellular messenger molecule involved in the regulation of diverse physiological functions, for example in blood vessels, the heart, neurons, and sensory cells. The Research Unit "cGMP Signaling in Cell Growth and Survival" investigates how a dysfunction of the cGMP signaling system contributes to the development of degenerative diseases of the cardiovascular and nervous system. Scientists at the Interfaculty Institute of Biochemistry (IFIB, p 12-13) are collaborating with research groups from the Medical and Science Faculties of the University of Tübingen and with further groups in Frankfurt, Hamburg and Würzburg. They use mice as a model system combined with analyses at the cellular and molecular level to get a comprehensive picture of cGMP's multiple roles in the control of cell growth and survival in mammals, particularly in the context of tissue degeneration and regeneration. Amongst other techniques, the researchers use fluorescence-based sensor proteins to monitor changes of the messenger molecule in living cells in real time. The goal is a better understanding of the (patho-)physiological roles and therapeutic potential of cGMP. Because cGMP regulates important body functions - from ion transport in the kidney to muscle contraction and vision - the research is of great relevance for medical applications. Drugs that modulate the intracellular cGMP level have the potential to provide new options for treating degenerative diseases.



### Interfaculty Institute of Biochemistry

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Funding period: March 2013 - June 2021

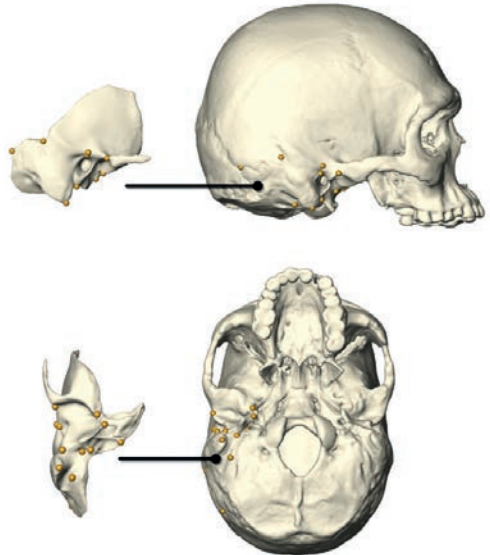


## FOR 2237 Words, Bones, Genes, Tools: Tracking Linguistic, Cultural and Biological Trajectories of the Human Past

The study of human pre-history relies on several independent lines of evidence: excavated artifacts, human skeletal remains, human DNA, records of animal and plant remains, and reconstructed dispersal histories of human languages. As these are the domains of different fields from the humanities and the natural

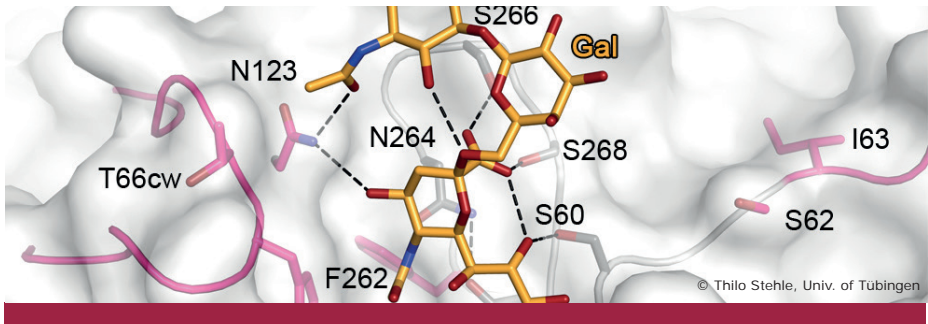
sciences (archeology, paleoanthropology, genetics and linguistics, respectively, p 14-15), our understanding of human prehistory can only be furthered with transdisciplinary research. The Research Unit "Words, Bones, Genes, Tools: Tracking Linguistic, Cultural and Biological Trajectories of the Human Past", directed by Prof. Gerhard Jäger (Linguistics) and Prof. Katerina Harvati (Paleoanthropology), aims to help establish the theoretical foundations of the new cross-disciplinary field of Bio-Cultural Coevolution by pushing the limits of transdisciplinary cooperation. The Center therefore constitutes a forum for interdisciplinary exchange, which will bring together scholars from the relevant fields to exchange ideas and develop common research questions and common methodological approaches.

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### Department of Geosciences

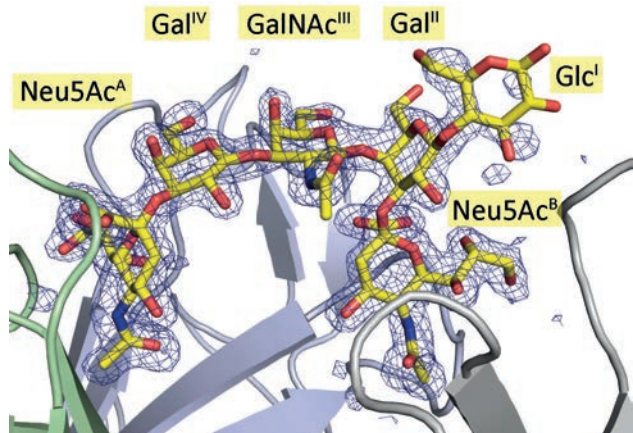
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Funding period: January 2015 - December 2023



## FOR 2327 Glycans Controlling Non-Enveloped Virus Infections (ViroCarb)

The overall goal of the new Research Unit "ViroCarb" is to define the role of glycans in viral infections. Glycans help to mediate diverse biological processes, including cell-cell recognition, cell growth and differentiation, neoplastic transformation, and cell death. The function of glycans in many of these processes is poorly understood, in part due to the limited availability of biologically relevant synthetic glycans and technical challenges in their analysis, including interactions with proteins. ViroCarb focuses on studying the functions of specific glycan structures in establishing virus infections. The focus is on Caliciviruses, Polyomaviruses, and Papillomaviruses. The goals are to first define the parameters that, at the atomic level, guide glycan-binding for members of each of these virus families, and, subsequently, use this knowledge to develop novel compounds with inhibitory and thus antiviral activities.

The multidisciplinary research unit is coordinated at the IFIB in Tübingen (p 10-11). The consortium links experts from different areas of glycovirology that are currently distributed throughout Germany and have expertise in structural biology, cell biology, infection models as well as chemical synthesis and mass spectrometry.



Interfaculty Institute of Biochemistry

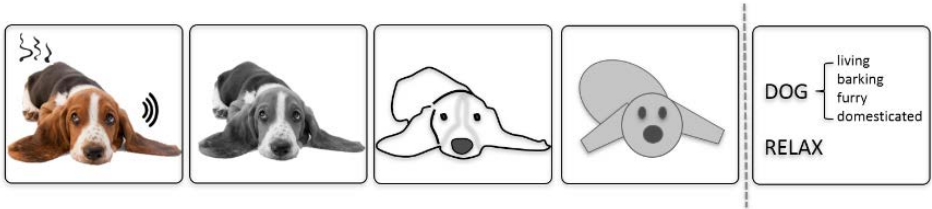
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Funding period: March 2016 - April 2022





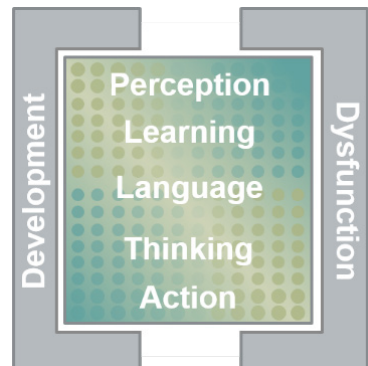
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## FOR 2718 Modal and Amodal Cognition: Functions and Interactions

The question of how the human mind represents the internal and external world plays a crucial role in theories of human cognition. Central to this question is the distinction between modal vs. amodal representational formats. Modal representations are experiential in nature and are therefore rather concrete. The structure of these representations preserves structural aspects of how we experience the world. Amodal representations in contrast resemble an abstract description of the state of affairs they represent. Their structure is different from the structure of their referents. It has often been assumed that one or the other of these two types of representations underlies cognitive processing in a certain domain of cognition. For instance, in research on thinking, memory, and language processing, the traditional assumption is that properties, objects, situations, and events are captured by means of amodal representations.

These representations typically abstract from the detailed aspects of the specific state of affairs that is being represented. For instance, the meaning representation of a word such as “dog” will include symbols for typical features of dogs whereas in research on perception, it is often assumed that the relevant representations are modal in nature. When perceiving, for instance, a dog, it is assumed that humans create a rather specific representation that preserves many properties of this dog.

The present research group proceeds from the notion that both formats play a major role in all cognitive domains. Specifically, we believe that a comprehensive theory of cognition requires a solid understanding of the different representational formats and their functional roles for cognition.



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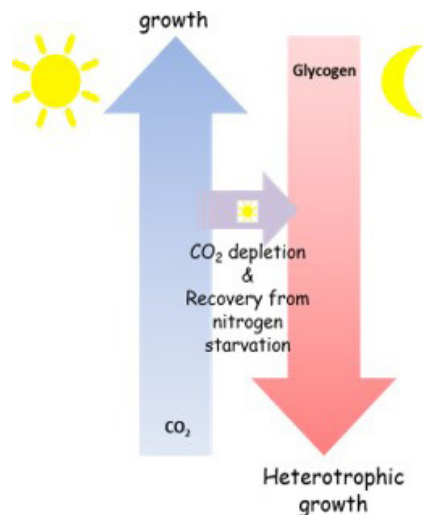
Funding period: 2019 - 2021





## FOR 2816 The Autotrophy-Heterotrophy Switch in Cyanobacteria (SCyCode)

Cyanobacteria are the primordial photosynthetic organisms on earth. They convert carbon dioxide ( $\text{CO}_2$ ) and water ( $\text{H}_2\text{O}$ ) into organic material and thereby release oxygen. Further to their ecological importance, they are explored as green cell factories for a future sustainable economy. The metabolism of fixed carbon in cyanobacteria is far more complex than only recently anticipated. They switch between photoautotrophic ( $\text{CO}_2$  fixing) and multiple heterotrophic ( $\text{CO}_2$  generating) modes of metabolism during day/night or other changing environmental conditions, with the enzymatic features for the antagonistic pathways being present in one cell. That a single cell can operate such a metabolic plasticity, it needs coherent decisions at multiple layers of cellular functions in response to specific external and internal signals. The research unit FOR 2816 aims at elucidating the corresponding signal transduction processes and how the coherent cellular responses are generated. Therefore, an interdisciplinary team that covers all relevant expertise joined forces. The research unit consists of teams from the Interfaculty Institute of Microbiology and Infection Medicine (with the speaker of the unit Prof. Karl Forchhammer), the Proteome Center Tübingen (p 95, Prof. Boris Macek) and six teams from other German universities (Freiburg, Duisburg-Essen, Kiel, Rostock) and the MPI Potsdam-Golm.



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Funding period: January 2019 - December 2021



## MOPGA-GRI – Genomics and Epigenomics of Plant Invasion

The overall goal of the new Research Unit “Genomics and epigenomics of Plant Invasion” is to characterize the molecular level mechanisms of invasion of one of the world’s most invasive plant species: Japanese knotweed. Although the field of invasion genetics was established more than 50 years ago, we have only a limited understanding of how genomic level processes translate into phenotypic diversity across different taxa in response to complex environmental conditions. The “Genomics and epigenomics of Plant Invasion” combines genomics approaches in field surveys of 150 natural populations along the east of the USA, throughout the EU and China and experimental studies of response of plants to herbivores



The project is partly funded by a joint DFG/NSF-China grant and the German-French program „Make Our Planet Great Again”, which was created by the governments of both countries following the Paris Agreement. This global research project is coordinated at the Institute for Evolution and Ecology. The consortium links experts from different areas of invasion ecology, ecological genomics and biocontrol that are distributed throughout the EU, USA and China.

### Institute for Evolution and Ecology

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Funding period: January 2019 - December 2022



## Environmental Biotechnology to Recover Carbon and Store Electric Power

Prof. Dr. Lars Angenent builds bridges in two different ways. On the one hand, he creates a connection between environmental and medical microbiology. On the other hand, he links up basic research with a problem-oriented, applications-based approach.

He has worked on microbiome characterization in air, bioreactors, and lungs. For example, he developed a method with which all microbes in the air of a building could be monitored – for instance, to track down the source of airborne disease in a hospital. In the area of environmental technology he was one of the first scientists to work on storing energy from renewables with the help of microbes.

Prof. Dr. Angenent is also interested in the production of soluble biochemicals from waste materials and the recovery of carbon from gaseous streams produced by industry. Yet he is also involved in basic research, which helps us to better understand the biochemistry and energetics of microbial metabolic pathways.

Prof. Dr. Lars Angenent has joined the Center of Applied Geosciences (ZAG, p 12-13) at the University of Tübingen at the rank of Full Professor in Environmental Biotechnology. Here, he is a Humboldt Professor and he leads a research group that will optimize carbon recovery from industrial waste gases and organic wastes. In addition, he starts a new research direction in his group on renewable electric power storage. His interdisciplinary team is focusing on engineered systems with microbial catalysts and uses scientific tools from bioprocess engineering, anaerobic microbiology/biotechnology, electrochemistry, environmental engineering, systems biology, and metabolic engineering. Often his team seeks to use clever bioreactor configurations and operating conditions to perform a conversion route that has not been optimized for industrial application thus far.

His team focuses on carbon because in a future society in which we will no longer utilize nonrenewable fossil fuels (coal, natural gas, or oil) for fuel and chemical production, we will still need carbon-based chemicals. In addition, carbon based products can be stored while this is much harder to do for electricity and heat.



Department of Geosciences

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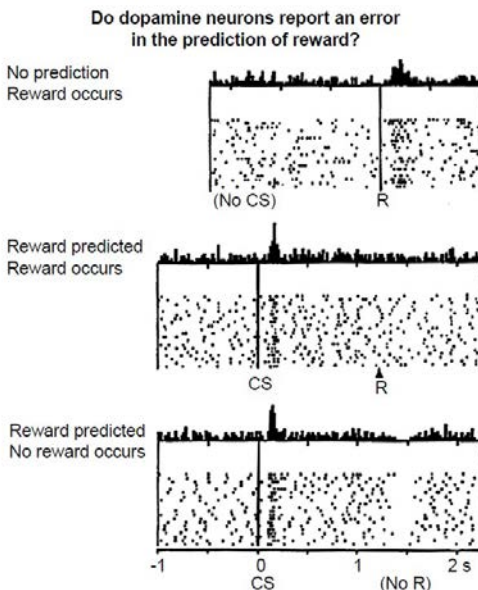
Funding period: April 2017 - March 2022

# Neural Reinforcement Learning

Our brains solve extraordinarily hard information processing problems generally extraordinarily well: recognizing objects from partial and noisy inputs; choosing good actions; and extracting structure in complex inputs. Peter Dayan builds mathematical and computational models of the brain to try and provide a crisp understanding of how these functions are carried out, and to provide insights into some of the modes of failure in neurological and psychiatric disease.

Peter Dayan focuses particularly on neural reinforcement learning - the panoply of methods that normally increase the chance of future rewards and decrease the chance of future losses or danger. The mechanisms involved are evolutionarily extremely ancient, and turn out to offer good solutions to problems that also arise in fields such as artificial intelligence, control theory, operations research and statistics. It is therefore possible to use ideas and methods from these areas to help understand the brain; there turn out to be some surprisingly transparent equivalences.

Many psychiatric diseases are characterized by patients making choices that either they or society wish were otherwise. The analysis of how decisions are made suggests a rich range of modes of potential failure. Peter Dayan also studies these modes, attempting to see how they decompose states of dysfunction, potentially providing alternative, computationally-based, classifications of mental illness, and hopefully ultimately coupled to more accurate prognoses and insights into treatment.



© Schultz, Wolfram, Peter Dayan and P. Read Montague. "A Neural Substrate of Prediction and Reward." *Science*, vol. 275, 14 Mar. 1997, pp. 1593-1599, doi:10.1126/science.275.5306.1593.

Fig. 1. Changes in dopamine neurons' output code for an error in the prediction of appetitive events.

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Funding period: 2020 - 2025

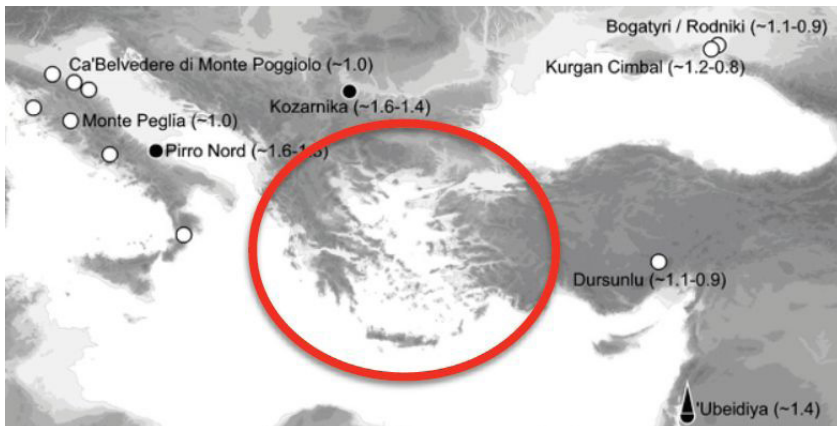
## Human Evolution at the Crossroads (CROSSROADS)

S.E. Europe is generally viewed as the gateway to Europe due to its geographical location at the crossroads of three continents. The region also acted as a refugium for plant, animal and human populations during glacial times. Because of these characteristics, it should yield evidence of both a very old and a continuous human presence since the earliest settlement of Europe more than a million years ago.

However, paleoanthropological research has tended to neglect this region, focusing on more western parts of the continent in the past. With the ERC Consolidator project CROSSROADS Harvati aims to address some of the most important questions in European palaeoanthropology:

- Did early humans arrive in South East Europe as early or even earlier than the findings in Western Europe have suggested so far?
- In which climatic and environmental conditions did they live there?
- And how did these conditions affect their behaviour, evolution and diversity?

The project follows Harvati's former ERC Starting Grant project "Paleoanthropology at the Gates of Europe (PaGE): Human Evolution in the Southern Hemisphere", and will be conducted in collaboration with several partners in Greek Institutions, including the Greek Ministry of Culture, the National and Kapodistrian University of Athens, the Aristotle University in Thessaloniki, and the American School of Classical Studies at Athens.



Map showing early paleolithic sites of Europe. The area within the red circle shows the research gap for this time period in S-E. Europe. Adapted from Jöris 2013

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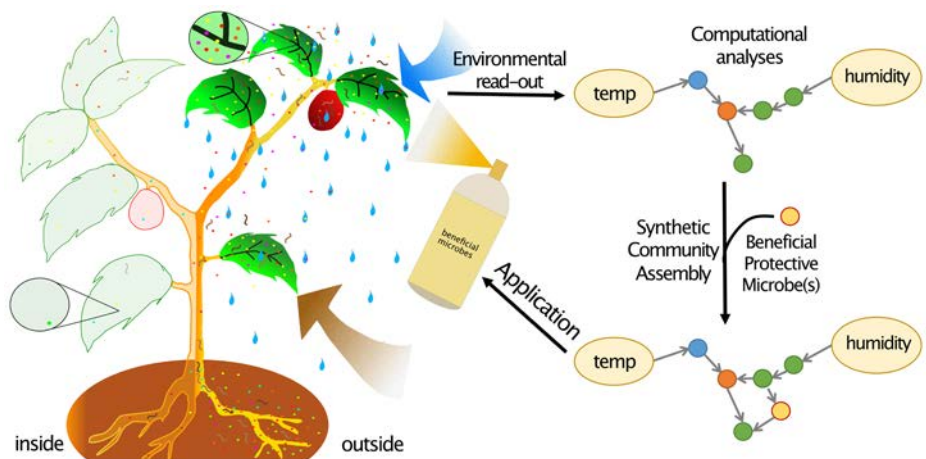
Funding period: April 2017 - March 2022



# Knowledge Based Design of Complex Synthetic Microbial Communities for Plant Protection (DeCoCt)

Many pathogens of important plant crops have developed resistances to main groups of agrochemicals such as fungicides and are therefore a risk to food security. Farmers and industry have tried to overcome this problem by using beneficial microbes. Those microbes, however, disappear very quickly in nature due to the many environmental impacts they are facing and thus most attempts have been unsuccessful.

In this project we are tackling this problem by using high throughput sequencing and computational approaches to model natural microbial communities. In combination with lab based and field experiments we try to unveil general mechanisms that stabilize microbial communities under natural conditions and make them competitive to intruders such as plant pathogens. Our goal is to enable the design of complex microbial communities that are stable to environmental conditions and can protect plants from various pathogens while promoting diversity and beneficial natural microbes.



© Eric Kemen, University of Tübingen

Design of knowledge based synthetic communities for plant protection from environmental sampling.

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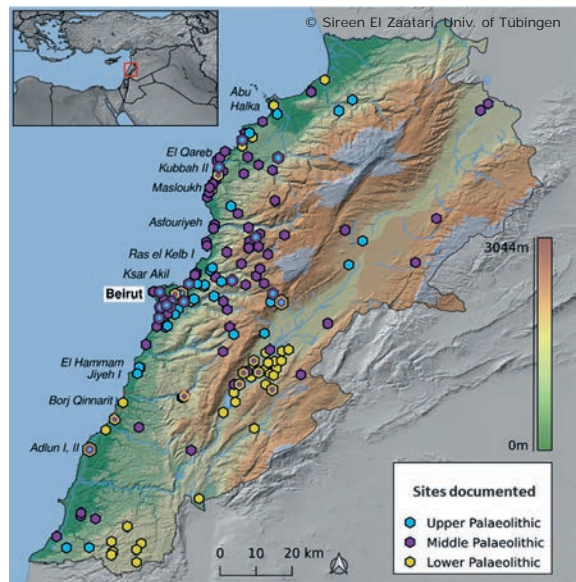
Funding period: March 2019 - February 2024

# Tracing Hominin Occupations of and Migrations through the Levant: Reviving Paleolithic Research in Lebanon

Our species evolutionary success story is intriguing. For over a century, we have been trying to formulate a narrative for the evolutionary and migration steps our ancestors took and made us who we are today. Several decades ago, our narrative for our lineage's dispersals from our place of origin, Africa, across the globe, was based on two separate big waves: one with *Homo erectus* at ca. 1 million years ago and the second with modern humans 60-50 thousand years ago. However, recent archaeological, paleoanthropological, and genetic evidence has forced us to alter this narrative to one which favors more dynamic geographic movements of hominins over several millions of years. Yet, although we seem to have now framed the overall picture of our narrative, its details remain mostly blurred leaving many chapters unfinished and their events highly debated, particularly those related to the number and timing of the dispersal events, the specific hominin taxa involved in each, and the effects of factors like technology, climate, and interactions among hominin populations, in shaping these events.

As the bridge that connects Africa to the rest of the world, the Levant is an ideal place to look for answers. At its heart is Lebanon, a small country exceptionally rich in Paleolithic archaeological material reminiscent of a dense hominin occupation spanning the entirety of this period.

Yet, Lebanon's rich Paleolithic record remains undiscovered and its potential is mostly forgotten since Paleolithic archaeological exploration in the country was forcefully stopped in its early infancy by the outbreak of the civil war (1975). REVIVE, a highly ambitious, groundbreaking project, will form the first ever large-scale and systematic archaeological/paleoanthropological project to be conducted on Lebanon's Paleolithic. It will, finally after 45 years, revive Paleolithic research in the country and use its wealthy record to start filling in the gaps in our ancestors' dispersals narrative.



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Funding period: March 2019 - February 2024

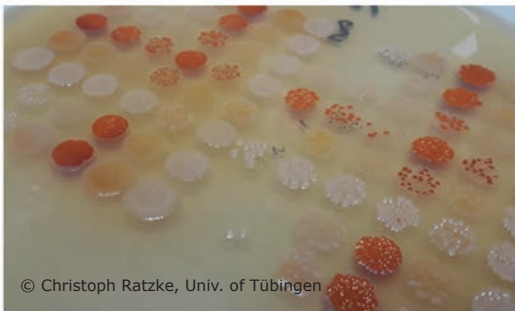
# Bugs as Drugs: Understanding Microbial Interaction Networks to Prevent and Treat Infections

Our body is inhabited by an enormous number of microbes which are crucial for our health. The bacteria in our gut for example help us to digest food but can also make us sick in case of an infection. The overall composition and function of those communities are strongly shaped by the interactions of the microbes within them e.g. how the microbes influence each others growth. These interactions are especially important in the case of microbial infections. Since pathogens have to interact with the microbial communities that already inhabit the host, the native microbes can repel or support the pathogens and thus protect the host from diseases or even facilitate them. Although microbial assemblages are pivotal for our health we have currently no satisfying way to get a mechanistic understanding of them which would be crucial to specifically manipulate these communities e.g. for therapeutic interventions. The aim of this proposal is to develop a microscopy method that allows to obtain interaction networks within complex communities. Since bacteria can only share the same space if they tolerate each other but avoid each other in case of competition, interaction networks of complex communities can be derived from the spatial co-occurrence of the bacteria that form them. With this technology I especially want to investigate how pathogens embed into the native gut microbial community of the model organism *Caenorhabditis elegans*. I want to understand how interactions between pathogens and native gut microbiota can protect a host from infections. Finally, I want to use this technology to identify bacteria in the native gut



*Caenorhabditis elegans*

community that can outcompete pathogens and work as specific probiotic against microbial infections. This approach could revolutionize the usage of probiotics and offer completely new ways to prevent and treat infectious diseases, which are especially valuable in times where we see more and more pathogens become resistant against antibiotics.



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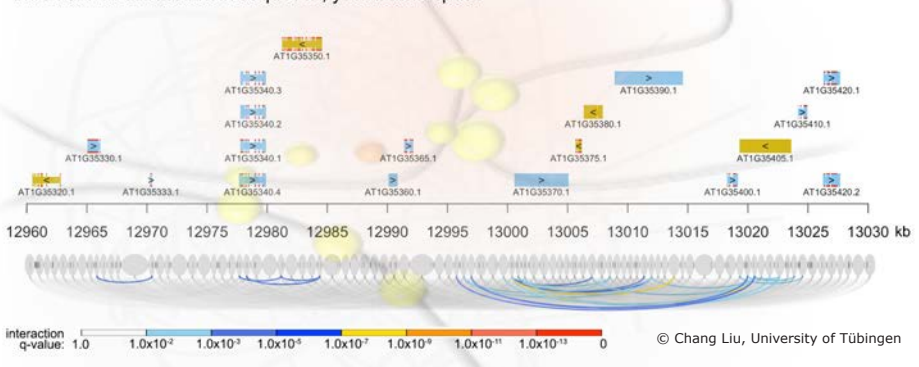
Funding period: January 2021 - December 2025

## Chromatin Packing and Architectural Proteins in Plants (CHROMATADS)

When fully stretched, the genomic DNA of a cell might span meters. In reality, the genomic DNA is organized as chromatin in a nucleus, which is just a few micrometers in diameter. Properly organized chromatin in the three-dimensional space is critical for proper transcription of genes. In a living cell, the transcriptional regulation of genes relies on both local and higher-order chromatin structures. Recently, research in the animal field has greatly advanced our understanding of 3D chromatin structures. In contrast, related work in plants has been much delayed, which is due to the lack of our knowledge of plant-specific factors regulating chromatin folding and organization. By using state-of-the-art methods of both Molecular Biology and Computing, Dr. Liu proposes to solve this puzzle in plant science.

The main aim of this ERC-funded project is to understand molecular mechanisms by which plant genomes adopt a hierarchical organization in 3D. Dr. Liu envisages that this project will achieve a significant advancement in Plant Functional Genomics. It will open many new directions of fundamental research related to chromatin structure and transcriptional regulation in plant science. It will also represent a critical step in structure-informed reverse genetic engineering of crops that aims for generating new varieties with stable agronomic traits through generations.

Chromatin in 3D: distant in sequence, yet close in space



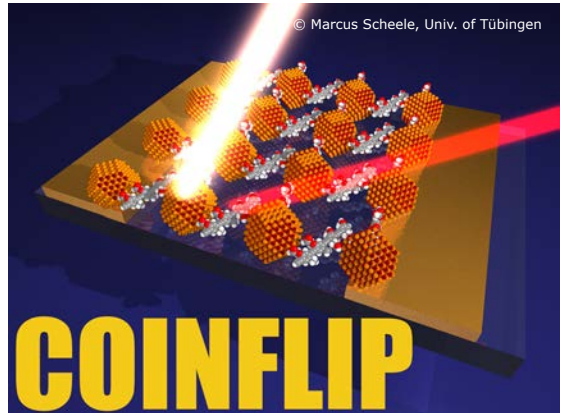
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 Funding period: January 2018 - December 2023

# Coupled Organic Inorganic Nanostructures for Fast, Light-Induced Data Processing (COINFLIP)

The main objective of this project is to design optical switches with a response time  $< 5$  ps, a switching energy  $< 1$  fJ/bit and compatibility with silicon technology to excel in high-speed data processing at low heat dissipation. This will be pursued by combining the chemistry of inorganic, nanocrystalline colloids and organic semiconductor molecules to fabricate thin films of organic-inorganic hybrid nanostructures. Optical switches play a pivotal role in modern data processing based on silicon photonics, where they control the interface between photonic

optical fibers used for data transmission and electronic processing units for computing. Data transfer across this interface is slow compared to that in optical interconnects and high-speed silicon transistors, such that faster optical switching accelerates the overall speed of data processing of the system as a whole. By modifying the surface of the inorganic nanocrystals with conductive molecular linkers and self-assembly into macroscopic solid state materials, new electronic and photonic properties arise due to charge transfer at the organic/inorganic interface. The multiple optical resonances in these hybrid materials result in strong optoelectronic interactions with external light beams, which are exploited for converting photonic into electronic signals at unprecedented speed. A key concept here is an activated absorption mechanism, in which the nanocrystals act as sensitizers with short-lived excited states, which are activated by a first optical pump beam. Efficient charge transfer at the organic/inorganic interface temporarily creates additional resonances in the molecular linkers, which may be probed by a second optical beam for as long as the sensitizer is in its excited state. Utilizing nanocrystals with excited state lifetimes  $< 5$  ps will reward ultrafast response times to pave the way for novel optical switches and high-speed data processing rates for silicon photonics.

While the project is mainly carried out at the Institute of Physical and Theoretical Chemistry, it will also entail collaborations with the Institute of Applied Physics, the Core Facility LISA+ (p 89) and the Natural and Medical Sciences Institute in Reutlingen. This way, the project benefits from the unique combination of chemical synthesis, time-resolved optics, microfabrication and device testing facilities to excel in the search of materials for faster data communication.



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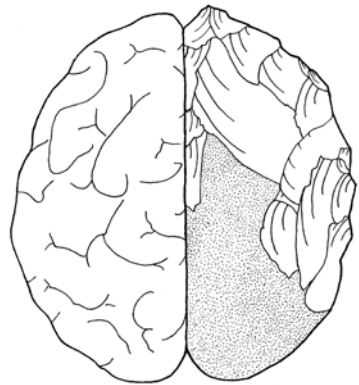
Funding period: February 2019 - January 2024



## Do early stone tools indicate a hominin ability to accumulate? (STONECULT)

Claudio Tennie received the ERC Starting Grant for his research on the cultural status of early stone tools. Humans today have spread and survived across the globe – even with occasional excursions into space. The main underlying skill that allowed this to happen was a so-called cumulative culture – inventions on top of inventions on top of inventions. This requires not only the ability to invent, but it also requires the ability to socially pass on inventions – intact. The underlying mechanism here is high fidelity social learning (including teaching). Tennie’s past work has provided evidence that our closest living relatives, the great apes, fail to spontaneously use such learning mechanisms. Tennie’s ERC project seeks to discover when these learning mechanisms first arose in our lineage.

Cultural – not genetic – adaptations have allowed humans to colonise the planet. While discovering the roots of human culture has been described as one of the 125 most pressing scientific questions of our time (Science, 2005), it remains unclear when such forms of culture first arose in our lineage. Previous research has argued that similar social learning mechanisms underlie modern human as well as early hominin technology. But the latter shows periods of stasis – suggesting the underlying mechanisms were different. A better model for early hominins might be living non-human great apes. Instead of copying the behaviour from others with high fidelity (as modern humans do), ape approaches seem to be based on socially mediated individual reinventions (latent solutions; Tennie et al. 2009). Unlike high fidelity copying, latent solutions do not lead to ‘cumulative cultural change’, in which technological changes accrue over generations. Latent solutions are thus a core candidate to account for early hominin stone tools because, among other things, they provide an explanation for their stasis. Using both a top-down and a bottom-up testing approach, STONECULT will experimentally test whether early stone tools are manifestations of cumulative culture – currently the null hypothesis in the field – or whether they are best accounted for with the latent solutions model. That is, STONECULT will evaluate whether early stone tools were more similar to modern ape or modern human technologies. The outcomes and conclusions of STONECULT will therefore inform several fields at once (e.g. anthropology, archaeology, comparative psychology, ethology and primatology). This proposal is the first to test the new latent solutions account of early stone tools. If its predictions are confirmed, then cumulative culture will have emerged millions of years later in our lineage than is currently assumed. STONECULT will radically transform our understanding of the evolution of human culture.



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<https://sites.google.com/view/stonecult>

Funding period: 2017 - 2022

# Learning Generative 3D Scene Models for Training and Validating Intelligent Systems (LEGO-3D)

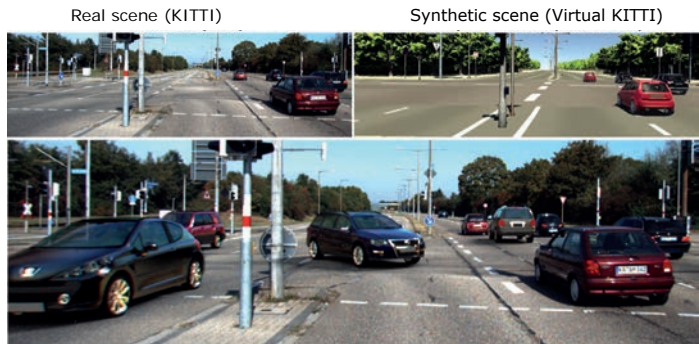
Recently, the field of computer vision has witnessed a major transformation away from expert designed shallow models towards more generic deep representation learning. However, collecting labeled data for training deep models is costly and existing simulators with artist-designed scenes do not provide the required variety and fidelity. Project LEGO-3D will tackle this problem by developing probabilistic models capable of synthesizing 3D scenes jointly with photo-realistic 2D projections from arbitrary viewpoints and with full control over the scene elements. Our key insight is that data augmentation, while hard in 2D, becomes considerably easier in 3D as physical properties such as viewpoint invariances and occlusion relationships are captured by construction. Thus, our goal is to learn the entire 3D-to-2D simulation pipeline. In particular, we will focus on the following problems:

(A) We will devise algorithms for automatic decomposition of real and synthetic scenes into latent 3D primitive representations capturing geometry, material, light and motion.

(B) We will develop novel probabilistic generative models which are able to synthesize large-scale 3D environments based on the primitives extracted in project (A). In particular, we will develop unconditional, conditioned and spatio-temporal scene generation networks.

(C) We will combine differentiable and neural rendering techniques with deep learning based image synthesis, yielding high-fidelity 2D renderings of the 3D representations generated in project (B) while capturing ambiguities and uncertainties.

Project LEGO-3D will significantly impact a large number of application areas. Examples include vision systems which require access to large amounts of annotated data, safety-critical applications such as autonomous cars that rely on efficient ways for training and validation, as well as the entertainment industry which seeks to automate the creation and manipulation of 3D content.



Real scene augmented with synthetic cars (ours)

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Funding period: 2020 - 2025

## Late Pleistocene Hominin Dispersals and Adaptations in Central Asia (PALAEOSILKROAD)

In antiquity and the early Middle Ages, a network of trade routes known as the Silk Road connected east Asia and the Middle East. The Silk Road was not just an economic link, but also the avenue for cultural and even genetic exchanges between these regions. Recent genetic discoveries have hinted that such connections might have begun much earlier, during the Pleistocene. The Pleistocene period is of fundamental importance for human history. It is then that our ancestors evolved and colonised the entire Old World, surviving a suite of major extinction events – and they did so against a dramatic backdrop of ice ages and warmer interglacial phases which substantially altered their habitats. Conquering the extreme environments of arid central Asia to eventually settle the entire Asian mainland and beyond is one of the most impressive feats in this story. Unfortunately, there are too few known Pleistocene archaeological sites in central Asia to allow us to piece together when and how this happened.

PALAEOSILKROAD ([www.palaeosilkroad.eu](http://www.palaeosilkroad.eu)) will resolve this deficit by surveying central Asian mountain foothills as both corridors for human and animal movements and archives of past climate change. The project will discover new sites in the Tian Shan, Dzungar, and southern Altai foothills (Kazakhstan) and use them to examine if and how humans were able to survive in the foothills throughout the last glacial cycle (about 110 - 11500 years ago). Moreover, it will investigate the effect of harsh stadial conditions and of periodic advances of mountain glaciers upon motivating dispersals, population segmentation, and behavioural adaptations in this region. To address these questions, PALAEOSILKROAD will take an ambitious approach rooted in archaeology and contextualised by palaeoenvironmental reconstruction. The results of this project will change the way we understand human dispersals on a global scale and the resilience of early humans in the face of environmental challenges, providing a major missing link to explain how *Homo sapiens* became the only surviving species of our genus.

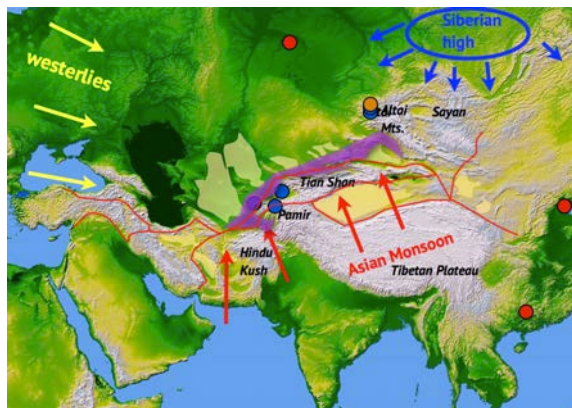


Figure caption: Study area and most important aspects framing the project: high mountain areas flanked by deserts and the three major climatic systems. Dots represent known human fossils (red=modern humans; blue=Neandertals, orange=Denisovans) and the shaded area shows the "Inner Asian Mountain Corridor" (Frachetti, Michael D. (2012) Multi-Regional Emergence of Mobile Pastoralism and Non-Uniform Institutional Complexity Across Eurasia. *Current Anthropology*. 53(1): 2-38. / Map: Radu Iovita & Machalett et al, 2008 Geochemistry, Geophysics, Geosystems

Department of Geosciences

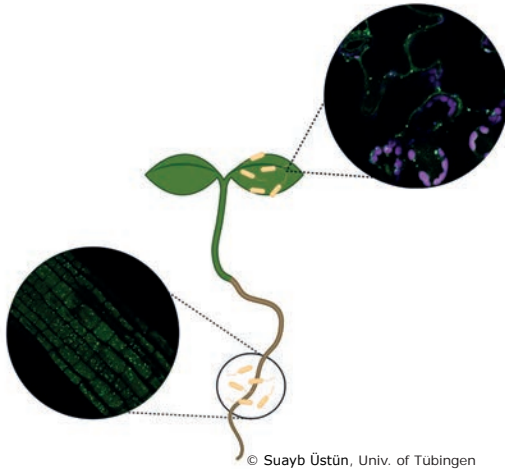
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Funding period: 2017 - 2022

# Utilizing diversity to decipher the role of autophagy in plant-microbe interactions (DIVERSIPHAGY)



During the course of evolution, plants have been exposed to a plethora of beneficial and pathogenic microbes. At the interface of these interactions proteomes at both sides are highly flexible and require regulated protein turnover. In line with this, regulated protein degradation by autophagy has been shown to be an essential player in plant immunity. Consequently, plant pathogens hijack autophagy during binary interactions though in contrasting manners. However, in a more complete scenario, plants are constantly exposed to different microbes and hence it is crucial to include the microbial diversity into this equation to obtain a holistic picture of the role

of autophagy in plant-microbe interactions. The picture is getting even more complex if we look at the cellular diversity on the host side. Thus, DIVERSIPHAGY approaches the role of autophagy through bacterial and cellular diversity on the host side. We aim to address following questions:

- Identifying how the microbiome impacts autophagy and vice versa
- Revealing the autophagy degradome and novel autophagy factors by utilizing autophagy-modulating bacteria
- Identifying tissue and cell-type specific modulation of autophagy by diverse bacteria.

With DIVERSIPHAGY we will reveal the role of autophagy in plant-microbe interactions using a mixture of state-of-the-art approaches including metabolomics, proteomics, single-cell transcriptomics and cell-type specific reverse genetic screens. As such DIVERSIPHAGY is the next generation approach to understand the role of plant autophagy in plant-microbe interactions and by translating our results into crop plants we will be able to develop more durable resistances toward destructive pathogens.

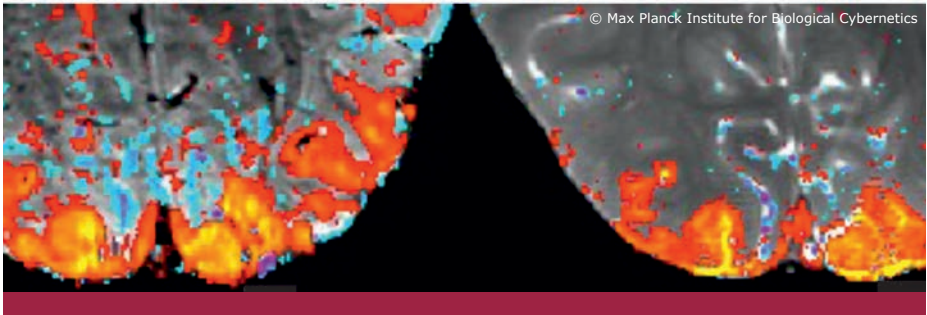
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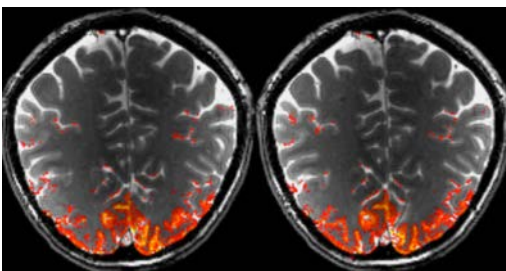
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Funding period: 2020 - 2025



## New Methods in Functional Magnetic Resonance Imaging (fMRI)

Within the scope of the DFG-funded Reinhardt Koselleck Project, Tübingen-based Physicist Professor Klaus Scheffler aims to improve functional magnetic resonance imaging (fMRI) in order to provide detailed information on brain and nerve activity. In current research, only electrophysiology, which requires the placement of a hairy microelectrode on the cerebral cortex or deeper brain structures, is able to record and measure electrical signals of a small number or even a single nerve cell. In contrast to the electrophysiology, the magnetic resonance imaging is a non-invasive method with a very high spatial resolution in the millimeter range and the possibility of detecting the entire brain in humans or animals. Magnetic resonance is often presented as an alternative method to invasive methods, but unlike electrophysiological recordings, it cannot directly measure neuronal activity. Therefore, research is conducted via a methodical detour: Magnetic resonance imaging allows the detection of local changes in the blood oxygen content in the brain, which in turn, is modulated by the neuronal activity. According to Professor Scheffler, the neurovascular coupling is not fully understood at this time and a prediction of the underlying neuronal activity of the brain based on functional MRI data is therefore very difficult if not impossible. Thus, Scheffler's Koselleck



Activation of the visual cortex by presentation of a changing checkerboard pattern in humans measured at 9.4T. The red-labeled activation is based on a new approach (balanced steady state free precession) which allows an improved detection of the vascular response of cortical micro vessels.

project seeks to better understand the relationship between vascular and neural signals. In this project, novel magnetic resonance methods are being investigated with the aim of obtaining more detailed information on the underlying neuronal activities. For this purpose, it is important to know the exact anatomy of the neural vascular system, which is measured by experiments with high-resolution MicroCT. All in all, the Koselleck project intends to provide a more accurate picture of the neuronal interactions of the entire brain as a system.

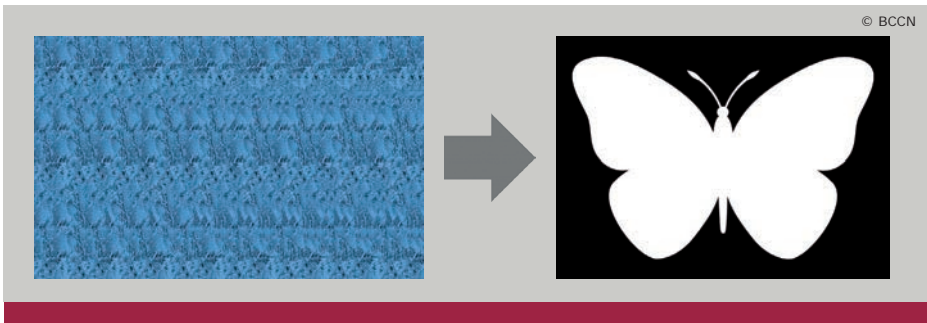
MPI for Biological Cybernetics | Werner Reichardt Center for Integrative Neuroscience (CIN)

Coordinators: Prof. Dr. Klaus Scheffler | klaus.scheffler@tuebingen.mpg.de

[www.kyb.tuebingen.mpg.de/de/forschung/abt/ks.html](http://www.kyb.tuebingen.mpg.de/de/forschung/abt/ks.html)

Funding Period: January 2017 – December 2021





## Bernstein Center for Computational Neuroscience Tübingen (BCCN)

The Bernstein Center for Computational Neuroscience (BCCN) Tübingen is a central research facility at the University Tübingen that was originally established with BMBF funding as part of the national Bernstein initiative for Computational Neuroscience. As integral part of this initiative it coordinates its activities in research and education with the National Bernstein Network for Computational Neuroscience.

A key idea behind the BCCN Tübingen is to build on the existing strength in machine learning and experimental systems neuroscience in Tübingen to foster interdisciplinary Computational Neuroscience research at the interface between the two. The center emphasizes the combination of new neurobiological data and advances in machine learning as the motor of innovation in computational neuroscience, and ultimately aims at reverse-engineering the algorithms of the brain. Human perception is not simply a copy of the sensory stimuli we receive, but relies on complex processing that converts high-dimensional sensory input to meaning. Magic Eye pictures can illustrate this well. From abstract 2D patterns, the brain reconstructs a 3rd dimension which we experience as depth perception. Such artificial examples demonstrate specific inference capacities of the brain that are performed continuously in our everyday life, without us ever noticing. For example, we recognize objects and their properties independently of light conditions or arrangement which is crucial, for example, when we navigate our cars through the traffic. Following up on the BMBF project, the center hosts since 2017 a collaborative research grant by the German Research Foundation (DFG) entitled "Robust Vision – Inference Principles and Neural Mechanisms (CRC 1233, p 44)". The CRC 1233 also plays an important role for Cyber Valley (p 91) to further deepen the interactions between artificial intelligence and neuroscience research in Tübingen. In addition to fostering research across disciplines and institutions such as the Max Planck Institutes, the BCCN further plays an important role in both undergraduate and graduate training in computational neuroscience. In 2011, the BCCN established a Master's and a PhD program for "Neural Information Processing", complementing the existing schools in the Graduate Training Center for Neuroscience on "Neural and Behavioral Neuroscience" and "Cellular and Molecular Neuroscience" (p 30). As of end of 2018,

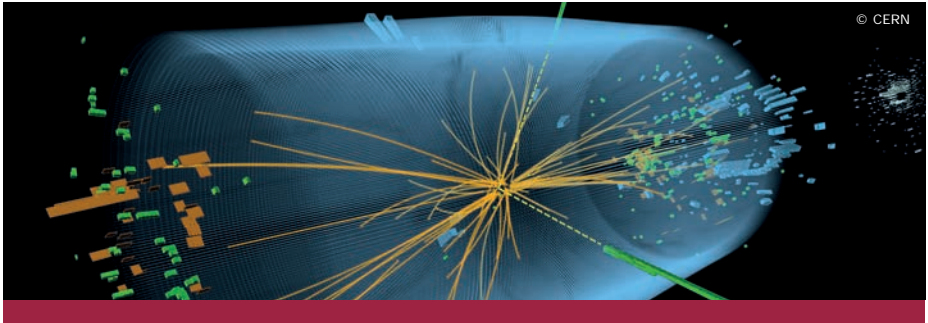
54 graduate students and 16 PhD students have completed their degree in this program, and 43 PhD students are currently enrolled.

### Bernstein Center for Computational Neuroscience Tübingen (BCCN)

Coordinator: Prof. Dr. Matthias Bethge

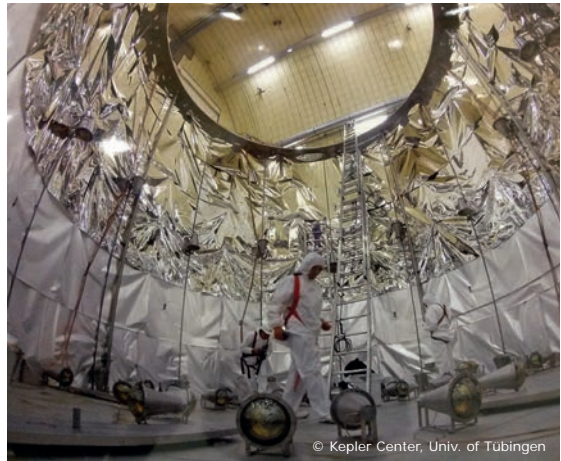
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www.bccn-tuebingen.de



## Carl Zeiss Research Structure: Highly Sensitive Detection Techniques to Explore the Invisible Universe

The two disciplines of astro and particle physics are more and more merging in the last years to find answers to the most intriguing questions on the origin, the composition, and high energetic processes in the Universe. Within the Kepler Center, and building on the existing expertise of the groups in Tübingen, new and innovative ideas are explored to increase the sensitivity of current and future experiments. The Carl Zeiss Research Structure is funded for four years and offered four Kepler Center (p 8-9) Fellowships to experienced researchers, both in theory and experimental physics. The two core topics that are addressed are Dark Matter and Cosmic Rays at the highest energies. Within the Research Structure, promising interdisciplinary ideas at the interfaces between existing groups have been identified and further developed. Improvement of the theoretical understanding and modelling of the detection processes and their background is pursued. Both, the search for hypothetical particles that might constitute the mysterious Dark Matter and the large experiments for measuring ultra high-energetic cosmic rays, often rely on the detection of tiny amounts of light - the realization und application of new techniques and data processing methods for single photon detection, and interpretation of the signals is another important topic addressed within the groups, and might open up a realistic possibility for deploying new instruments in future mission in astro particle physics.

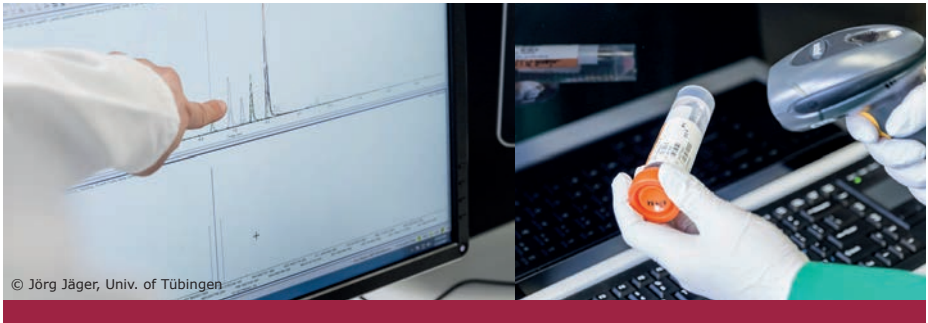


### Carl Zeiss Research Structure

Coordinator: Prof. Dr. Tobias Lachenmaier

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Funding period: October 2015 - September 2019



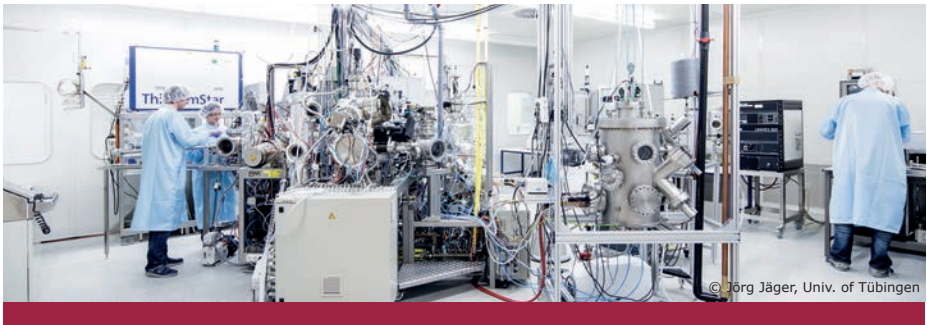
## Center for Integrative Bioinformatics (CIBI)

Since March 2015, Tübingen is part of the BMBF-funded German Network for Bioinformatics Infrastructure (de.NBI). The Center for Integrative Bioinformatics (CIBI) is one of the centers of excellence within de.NBI and is a joint initiative of the University of Tübingen with the University of Konstanz, Freie Universität Berlin, IPB Halle, and the Max Planck Institute for Molecular Cell Biology and Genetics in Dresden. CIBI has been established in March 2015 and will be funded initially for five years. The availability of next-generation sequencing techniques and high-resolution mass spectrometry has caused a paradigm shift in biomedical research. It enabled a cost-effective production of biological high-throughput data (genomics, transcriptomics, proteomics, metabolomics, imaging) at an unprecedented scale. While these methods provide a very comprehensive and deep view of the systems under study, the resulting data sets are very large and complex. More and more several of these techniques are also employed in parallel ("multi-omics"), which results in even more complex data. Innovative and efficient algorithms are required to analyze such data. In most cases, a comprehensive analysis of the data requires the combination of several tools and software packages. Scientific workflows can automate even such complex analysis tasks in a convenient, reliable, and reproducible manner. The Center for Integrative Bioinformatics combines expertise in the development of algorithms and tools for proteomics/metabolomics (Tübingen, software package OpenMS, Prof. Oliver Kohlbacher, IPB Halle, Dr. Steffen Neumann), next-generation sequencing (Berlin, software package SeqAn, Prof. Knut Reinert), image processing (software package FIJI, Prof. Eugene Myers and Dr. Pavel Tomancak, MPI for Cell Biology and Genetics, Dresden), scientific workflows (Konstanz, software package KNIME, Prof. Michael Berthold). The center also provides compute capacity as part of the German Bioinformatics Cloud (de.NBI Cloud). The center is tightly integrated with the other seven centers of excellence within de.NBI and interacts closely with the Center for Bioinformatics Tübingen (ZBIT) and the Quantitative Biology Center (QBiC, p 96).



### Center for Integrative Bioinformatics (CIBI)

Coordinator: Prof. Dr. Oliver Kohlbacher  
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www.denbi.de/index.php/cibi  
Funding period: 2015 - 2020



## Center for Light-Matter Interaction, Sensors & Analytics (LISA<sup>+</sup>)

LISA<sup>+</sup> is a core facility providing unique research and service support in the Sciences at the University of Tübingen. Founded in 2011, LISA<sup>+</sup> includes about 20 scientific research groups from Physics, Chemistry, Geosciences and Biology using the existing multidisciplinary nanostructure laboratory.

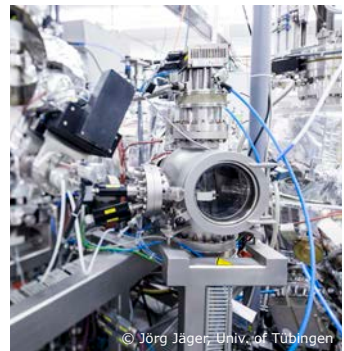
LISA<sup>+</sup> coordinates the human resources, technical facilities and research topics for:

- efficient and professional use of existing resources,
- coherent planning of sustainable development,
- expert training and advice,
- optimizing knowledge transfer between users, collaborators and industry.

With the aim of providing and upgrading key components in the infrastructure needed for excellent research, LISA<sup>+</sup>

- stimulates interaction & knowledge transfer between all users to increase cohesion of research activities,
- professionalizes resource management for efficient use of equipment and develops advanced applications for new measurement techniques,
- coordinates additions to infrastructure to create synergies for access to state-of-the-art equipment,
- stimulates projects and knowledge transfer by opening the core facility to external partners,
- strengthens links with industry to accelerate research to market transfer.

LISA<sup>+</sup> utilizes advances in patterning, manipulation and analysis on the atomic scale for new developments in the areas of quantum instruments, light harvesting, nano systems, and sensor technology. In particular, new measurement techniques are developed based on optical or quantum effects (e.g. in superconductivity, ion interferometry, quantum optics, atomic quantum gases).



### Center for Light-Matter Interaction, Sensors & Analytics (LISA<sup>+</sup>)

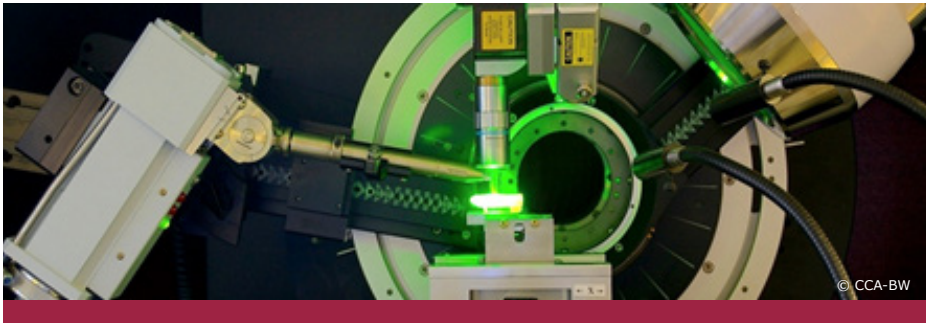
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## Competence Center Archaeometry - Baden-Wuerttemberg (CCA-BW)

Founded in 2016, the Competence Center Archaeometry Baden-Wuerttemberg (CCA-BW) has developed from the archaeometry section of the applied mineralogy work group as an interdisciplinary research center that connects material science with archaeological disciplines.

The CCA-BW is headed by Dr. Christoph Berthold, Professor Klaus G. Nickel and Senior Professor Klaus Bente. It is jointly funded by Baden-Wuerttemberg's Ministry of Science, Research and the Arts, the Helmut Fischer Institut für Elektronik und Messtechnik GmbH and the Excellence Initiative at the University of Tuebingen.

The CCA-BW activities focus on the characterization of archaeological materials with a special emphasis on non-destructive analyses and on the development of flexible and mobile analytical setups with multiple methods. The analyses of the chemical and mineralogical composition of archaeological materials together with study of their microstructure allows the identification of raw materials in order to reconstruct their provenance for a better understanding of manufacturing traditions as well as the deterioration processes of archaeological finds. From these type of analyses, conclusions can be drawn about time and regional dependent cultural and technological developments. In addition, the suitability of conservation and restoration strategies and the authenticity of analysed objects can be tested. The center is interdisciplinary, expanding the role of archaeometry among Tübingen's established archaeological disciplines, while building bridges to natural science disciplines such as mineralogy, physics and chemistry.

In this context, the CCA-BW and its industry partner, Helmut Fischer Institut für Elektronik und Messtechnik GmbH, are going to develop a mobile analytical setup for non-destructive and local highly resolved analyses with multiple methods. With this setup it will be possible to study artefacts directly in museums, perform measurements on immobile cultural monuments or analyse new finds already in the field. However, the newly developed setup is also to be applied to problems of material science, such as the surveillance of industrial processes, engineering of materials, and failure analysis.

### Competence Center Archaeometry - Baden-Wuerttemberg (CCA-BW)

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## Cyber Valley

Situated in the Stuttgart/Tübingen region in southwestern Germany, Cyber Valley is Europe's largest research consortium in the field of artificial intelligence (AI). Initiated by the Max Planck Society and the Max Planck Institute for Intelligent Systems, Cyber Valley has brought together partners from science (Max Planck Institute for Intelligent Systems, University of Stuttgart, University of Tübingen) and industry (Amazon, BMW Group, Daimler AG, IAV GmbH, Porsche AG, Robert Bosch GmbH, ZF Friedrichshafen AG) to advance research and development in the realm of intelligent systems.

Cyber Valley aims:

- to promote and enhance research on artificial intelligence (AI)
- to create an ecosystem for technology transfer
- to offer the ideal environment for start-ups in the field of artificial intelligence (AI)
- to train the world's best young minds at the International Max Planck Research School for Intelligent Systems (IMPRS-IS, p 34-35)

Cyber Valley is funded by the federal state of Baden-Württemberg, its partners, and a consortium of foundations in Baden-Württemberg.

### Cyber Valley's Agenda

Since the initiative was launched at the end of 2016, Cyber Valley has established nine research groups and three professorships in the fields of machine learning, robotics, and computer vision at the University of Stuttgart, the University of Tübingen, and the Max Planck Institute for Intelligent Systems. Several more research groups are being set up and faculty positions are currently in the process of being filled.

#### Cyber Valley

Founding Partners: Amazon | BMW Group | Daimler AG | IAV GmbH | Max Planck Institute for Intelligent Systems (MPI-IS) | Porsche AG | Robert Bosch GmbH | University of Stuttgart | University of Tübingen | ZF Friedrichshafen AG | State of Baden-Württemberg

Executive Board: Dr. Michael J. Black (MPI-IS) | Prof. Dr. Philipp Hennig (Univ. Tübingen) |

Prof. Dr. Thomas Kropf (Robert Bosch GmbH)

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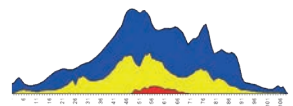
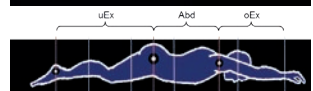


## German Center for Diabetes Research (DZD)

Diabetes mellitus is one of the most prevalent diseases in Germany affecting ~6 million people (~7% of the adult population). A similar number of individuals with “prediabetes” are at high risk to develop diabetes. Thus, the prevalence of diabetes and its complications will continue to rise. Despite recent advances, effective and safe strategies for the prevention and treatment of diabetes and its complications are still lacking.

The DZD was founded by the BMBF in 2009 as a new national institute for translational research in diabetes. Distinguished experts from the Helmholtz Association, the Leibniz Association, and universities have joined forces to develop novel strategies for the early detection, prevention, and treatment of diabetes and its complications, improving patients’ care and quality of life. Research in the DZD aims at understanding the pathogenesis of the disease and its complications in an interdisciplinary effort of experimental and clinical researchers, improving the identification of individuals at risk with novel metabolic, genetic, and environmental variables, and finding targets for novel therapies.

The DZD partner Tübingen contributes to the DZD by establishing and leading the nation-wide multicenter Prediabetes Lifestyle Intervention Study (PLIS) that will prompt personalized diabetes prevention strategies, by developing and applying new non-invasive methods to better assess the individual diabetes risk, by systematically analyzing blood metabolites to identify early markers of impaired glucose metabolism and assessing their potential for clinical diabetes prediction, and by studying the role of the brain in the regulation of appetite, exercise, insulin sensitivity, insulin secretion, and ectopic fat accumulation.



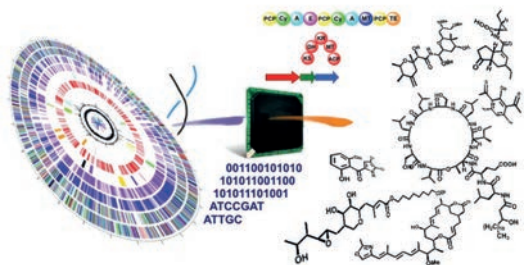
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## German Center for Infection Research (DZIF)

Infections are still responsible for an enormous number of illnesses and deaths around the world. Antibiotics, more than any other medicines, have improved the life expectancy of mankind by combatting infections. But multi-drug resistance has become common in pathogenic bacteria. Currently available drugs are losing efficacy, urging the discovery and development of novel antibiotics. To combat infectious diseases, the German Federal Ministry for Education and Research (BMBF) has established the German Center for Infection Research (Deutsches Zentrum für Infektionsforschung, DZIF). At DZIF's Tübingen partner site, the IMIT (p 16-17) has combined its strength with the University Hospitals and the Max Planck Institute for Developmental Biology with the aim of developing new strategies to treat infectious diseases. In the Faculty of Science, groups from the Department of Biology and from the Department of Pharmacy and Biochemistry are collaborating in the search for novel anti-infective agents. The researchers "mine" bacterial genomes for previously unknown biosynthesis gene clusters and utilize new genetic tools to produce the encoded compounds. A second focus is on utilizing the genetic information on biosynthesis clusters of known and highly effective antibiotic classes, to maximize their production rate and to produce new derivatives through combinatorial biosynthesis. Novel antibacterial agents are characterized with regard to their drug-like potential and their mechanisms of action. Concerning infrastructure, DZIF is currently enabling and supporting two measures, i.e. the junior research group „Synthetic Biology of Anti-Infective Compounds“ and the recently established full professorship (W3) for „Translational Genome Mining for Natural Products“. Furthermore, a natural product chemist was newly recruited to the „NatResouce“ core unit, an infrastructure which supplies the DZIF with natural products from the Tuebingen strain collection.



© DZIF

Interfaculty Institute for Microbiology and  
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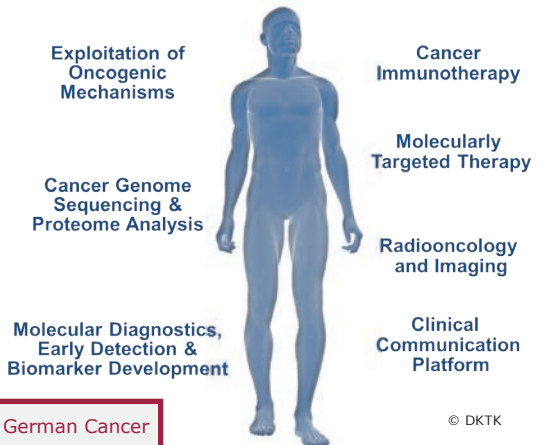
www.dzif.de/en



## German Consortium for Translational Cancer Research (DKTK)

More than 450,000 people in Germany develop cancer annually, and about half that number die of the disease every year. Although recent years have witnessed enormous progress in the understanding of molecular processes governing tumor development, these results have only partially been translated into clinical practice. The German Consortium for Translational Cancer Research is funded by the German Federal Ministry for Education and Research (BMBF) as a long-lasting alliance between the German Cancer Research Center and seven German universities. Its major aim is to transfer research results more swiftly into cancer-patient care by establishing joint translational research units and innovative clinical trials and by implementing personalized treatments for cancer patients.

Tübingen, as one of the seven universities involved, combines the expertise of its Faculties of Medicine and Science, the Comprehensive Cancer Center, and the University Hospital. In the Faculty of Science, groups at the Interfaculty Institutes of Cell Biology (IFIZ) and Biochemistry (IFIB, p 10-11 and the Institute of Pharmaceutical Sciences collaborate on joint approaches (e.g. CRC 685) to pave the way for novel cancer diagnostics and treatments. Most advanced is the development of promising immunotherapies comprising recombinant antibodies, peptide vaccines and cellular treatments produced for clinical studies in Tübingen's unique GMP (Good Manufacturing Practice) Center. There is also promising research underway on oncogenic pathways, molecular diagnosis, cancer stem cells, imaging and radiation therapy, treatment resistance, and cancer prevention.



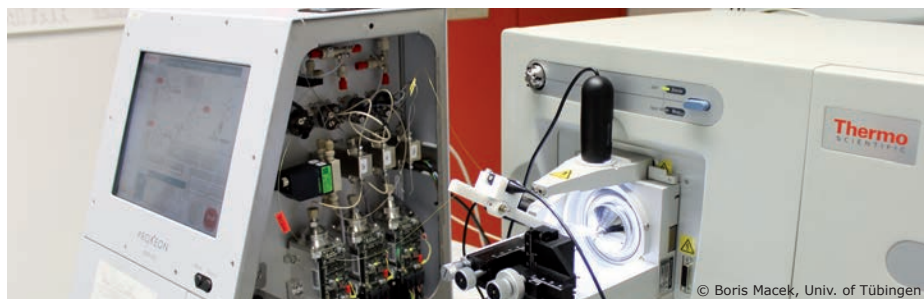
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Interfaculty Institute for Biochemistry | German Cancer Research Center

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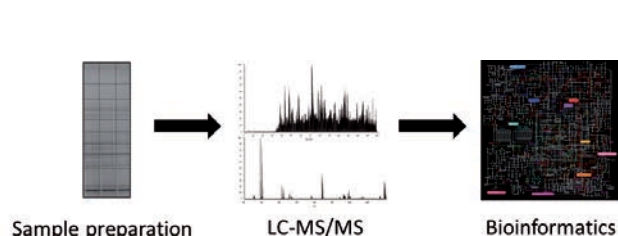


## Proteome Center Tübingen (PCT)

The Proteome Center Tübingen develops and applies state-of-the-art methodologies in quantitative mass spectrometry-based proteomics. The PCT currently employs a staff of 15 scientists and support personnel and operates on approx. 350 m<sup>2</sup> of laboratory and office space. The laboratory is equipped with several LC-MS/MS systems based on the Orbitrap technology, and has elaborate infrastructure for protein biochemistry, tissue culture, molecular biology and bioinformatics.



The major research area of the PCT is investigation of the structure and evolution of signal transduction networks in prokaryotes and eukaryotes, with an emphasis on phosphoproteomics and identification of kinase substrates. Other research areas include clinical proteomics and proteogenomics. Collaboration partners include Prof. Ivan Mijakovic (Chalmers University, Sweden), Prof. Dr. Ivan Dikic (University of Frankfurt), Dr. Iain Hagan (Paterson Institute of Cancer Research, UK) and Prof. Dr. Klaus Pfizenmaier (University of Stuttgart).



A typical „Shot-gun“ proteomics workflow.

As a core facility of the University of Tübingen and a member of Quantitative Biology Center (QBIC, p 96), the PCT provides support in the area of quantitative proteomics to researchers from Tübingen and beyond. Since its establishment in 2003, the PCT has successfully completed more than 720 core facility projects and co-authored 140 research publications.

### Proteome Center Tübingen

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Administrative Coordinator: Ulrike Grammig

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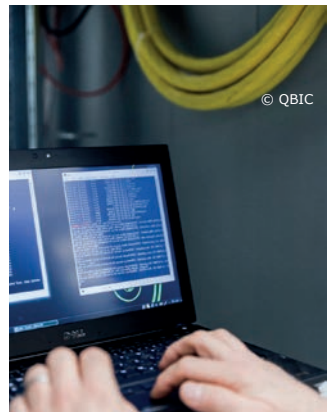




## Quantitative Biology Center (QBIC)

Medicine and the Life Sciences are being revolutionized by major technological developments which have taken place over the past decade. We have moved from analyzing individual genes, transcripts and proteins to whole-genome, -transcriptome and -proteome (OMICS) studies. Quantitative Biology combines these high-throughput methods with computational biology in order to achieve a deeper understanding of complex biological systems. In contrast to more conventional technologies, these high-throughput methods produce large amounts of raw data, which require bioinformatics processing and interpretation. In 2011, we established the Quantitative Biology Center (QBIC) as part of the University of Tübingen and the Max Planck Institute for Developmental Biology. QBIC complements the research activities at Center for Bioinformatics (ZBIT) by providing a bioinformatics service and infrastructure unit that includes OMICS data generation through its member labs. The QBIC member labs are established facilities with long-standing expertise in genome/transcriptome sequencing, protein/metabolite analysis, statistics and computer science. This concept was recognized as highly innovative and is currently funded by the DFG as part of its core facilities initiative as well as through the German government's Excellence Initiative.

The aim of QBIC is to offer coherent bioinformatics solutions for Big Data in the Life Sciences. The major tasks are data processing, analysis, integration and archiving of these data. Through a portal-based interface, QBIC offers secure access to data and enables intuitive user interaction.



### Quantitative Biology Center (QBIC)

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## Senckenberg Center for Human Evolution and Paleoenvironment Tübingen (SHEP)



As of October 2009, the "Senckenberg Centre for Human Evolution and Paleoenvironment" (SHEP) was built and established at the Eberhard Karls University of Tübingen. In May 2017 SHEP became an institute of the Leibniz Association. The close scientific relationship with other areas of the Senckenberg Gesellschaft für Naturforschung is reflected in the cooperation with, for example, the Paleoanthropology section in Frankfurt and the Research Station for Quaternary Paleontology in Weimar. SHEP-Tübingen deals with various aspects of the biological and cultural evolution of humans and apes, as well as with climate and environmental development throughout the Cenozoic. The cooperation between Senckenberg and the University of Tübingen also concerns teaching, as well as the curation of the extensive paleozoological, paleobotanical, archaeobotanical, zooarchaeological, and geoarchaeological collections at the University

of Tübingen by Senckenberg. These internationally renowned collections are a unique feature of SHEP.

The biological and cultural evolution of humans in their environment is a central issue for humanity. The research of SHEP is based on the assumption that biological and early cultural evolution of humans and their ancestors has been significantly influenced by changes in the paleoenvironment and paleoclimate. Cultural evolution gradually played an increasing role starting about 2.5 million years ago. Methods such as genetics, isotope geochemistry, geological and geochronological techniques, climate and environmental reconstructions, and the analysis of archaeological artifacts are used to study the interactions between human biology, culture, and the environment.

The work of SHEP pursues scientifically and socially relevant research topics, which is internationally unique in its approach and coherence, and enjoys considerable societal attention. In 2020, a joint "3D imaging" lab between Senckenberg and the University of Tübingen will be established, which houses a new DFG-funded  $\mu$ CT. In addition to research, the digitalization of the extensive collections will be a priority of the lab.

**Senckenberg Center for Human Evolution and Paleoenvironment (SHEP)**

Director: Prof. Dr. Nicholas Conard

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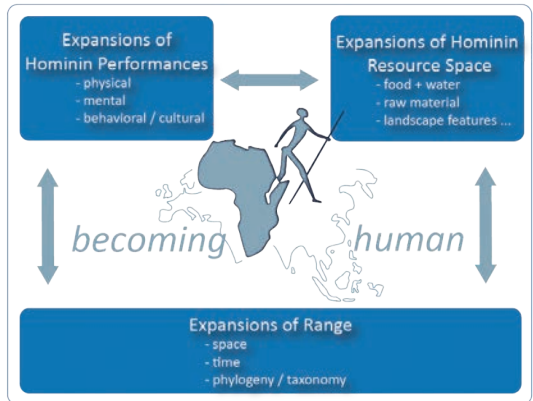
[www.senckenberg.de/de/institute/shep/](http://www.senckenberg.de/de/institute/shep/)



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## The Role of Culture in Early Expansions of Humans (ROCEEH)

Human evolution is a story of expansions: originating in Africa the genus *Homo* spread to and within Eurasia in several waves during the last 2 million years; new taxa evolved, old ones got extinct (range expansions). More than 3 million years ago hominins developed new ways to cope with their specific environment. Stone artefacts manufactured with the help of other tools provided access to new resources leading to physical, mental, and behavioral changes (expansion of performances). The ecospace of the hominins and their resource space for sustenance and development changed due to natural processes, but also due to expansions of range and performance (expansions of resource space).



The project aims to develop a systemic understanding of "becoming human", which integrates the different forms of expansions and the interdependencies between them. The interdisciplinary ROCEEH team with Prof. Dr. Nicholas Conard, Prof. Dr. Volker Hochschild (both University of Tübingen), Prof. Dr. Friedemann Schrenk, and Prof. Dr. Dr. h.c. Volker Mosbrugger (both Senckenberg Research Institute, Frankfurt) includes archaeologists, paleoanthropologists, palaeobiologists, geographers and database specialists. The project focuses on Africa and Eurasia between 3 million and 20,000 years ago. At the core of the project is the web-based georelational database ROAD (ROCEEH Out of Africa Database) with complete GIS functionality. ROAD unifies geographical data about

localities with information about the stratigraphical structure of layers and the archaeology they contain. In addition, ROAD assimilates information on human fossil history, climate, flora and fauna, and uses this information to model early human habitats. The results are integrated into a digital atlas.

ROCEEH, Department of Geosciences and Senckenberg Research Institute, Frankfurt/Main

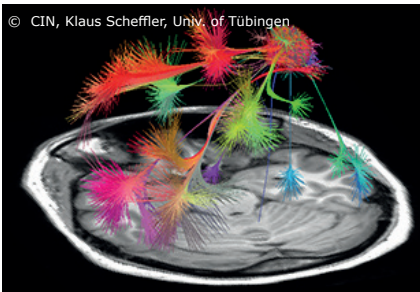
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[www.rocee.net/home](http://www.rocee.net/home)

Funding period: January 2008 - December 2027



## Werner Reichardt Center for Integrative Neuroscience (CIN)



The Werner Reichardt Centre for Integrative Neuroscience (CIN) is the University's cross-faculty centre for systems and cognitive neuroscience. It consists of 27 research groups, belonging to the faculties of life sciences, medicine, and humanities, with associations to the Max Planck Institutes, the Bernstein Centre for Computational Neuroscience, and the Hertie Institute for clinical neuroscience, among others. The CIN was originally founded as a Cluster of Excellence and funded by the German federal and state governments from 2009 until

2019 and remains to be the university's prime cross-faculty centre for systems and cognitive neuroscience. In terms of sustainability, the CIN continues to be funded by the ministry for science, research and the arts of Baden-Wuerttemberg.

The aim of the CIN is to understand how the brain – from the level of synapses up to the level of whole-brain circuits – produces intelligent, adaptive, and robust behaviour. Research combines state-of-the-art measures of behaviour, electrophysiology, and neuroimaging with the latest techniques in machine learning, artificial intelligence, and model-building. Research at the CIN is predominantly basic research, although it counts many application-focused institutions among its many different internal and external collaborating partners. Research is hence also relevant for the development of artificial intelligent systems as well as for gaining insights in clinical syndromes and for development of effective therapies.

Due to the shared interest of both the CIN and the humanities in uncovering the fundamental underpinnings of human behaviour, the CIN also seeks close interaction with the Humanities. The CIN hence organizes a number of well-received summer schools, workshops (e.g. "Games of the Brain" series) and conferences. It is well complemented by the annual CIN "Dialogues between the Neurosciences and the Arts and Humanities", a discussion series on topics of broad interest.

### Werner Reichardt Center for Integrative Neuroscience

Speaker: Prof. Dr. Thomas Euler | Prof. Dr. Andreas Nieder

Coordinator: Dr. Katherina Goris

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- Graduate Program of Infection Biology and Microbiology
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- Graduate School Neural & Behavioural Sciences
- Graduate School Neural Information Processing
- Graduate Training Center of Neuroscience / International Max Planck Research School for Cognitive and Systems Neuroscience
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More information on our Doctoral Programs: <https://uni-tuebingen.de/en/30559>



## International and Multilingual Master Programs

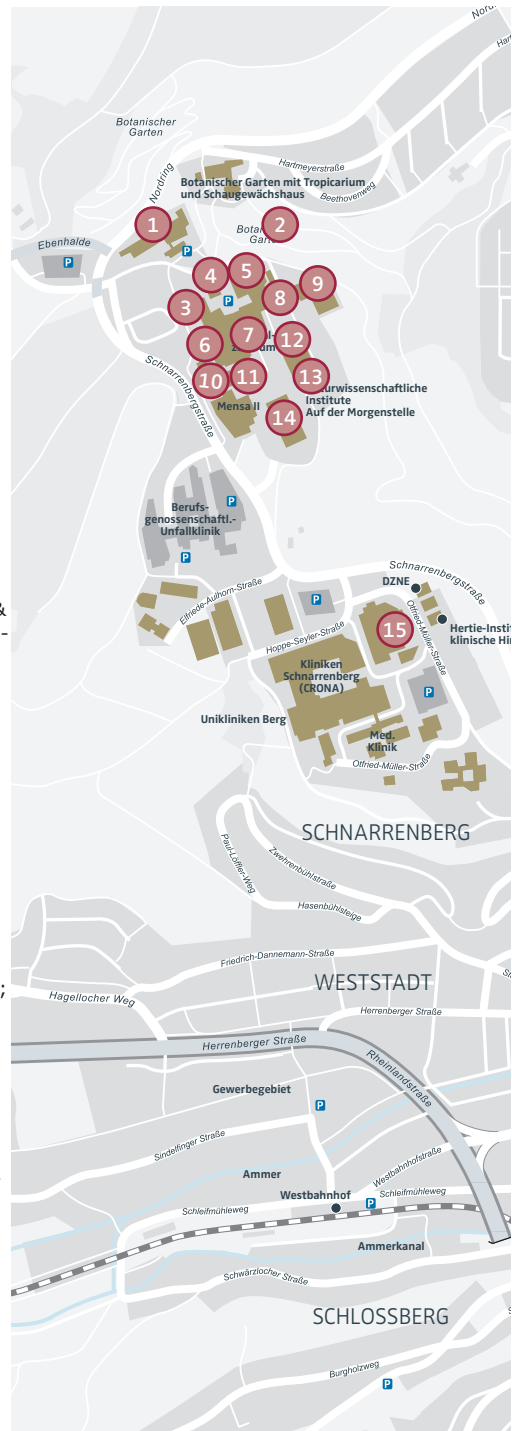


- MSc Advanced Quantum Physics
- MSc Applied and Environmental Geoscience
- MSc Archaeological Sciences and Human Evolution
- MSc Astro and Particle Physics
- MSc Biochemistry
- MSc Bioinformatics
- MSc Cellular and Molecular Biology of Plants
- MSc Cellular and Molecular Neuroscience
- MSc Computer Science
- MSc Evolution and Ecology
- MSc Geoecology
- MSc Geoscience
- MSc Machine Learning
- MSc Mathematical Physics
- MSc Mathematics (Double Master Program with the University of Trento)
- MSc Media Informatics
- MSc Medical Informatics
- MSc Molecular Cell Biology and Immunology
- MSc Nano-Science
- MSc Neural and Behavioral Sciences
- MSc Neural Information Processing
- MSc Neurobiology
- MSc Physics (Double Master Program with the University of Trento)

More information on our Master Programs: <https://uni-tuebingen.de/en/104778>

# Locations

- 1 Dept. of Biology: Inst. of Evolution & Ecology
- 2 Botanical Garden
- 3 Dept. of Pharmacy & Biochemistry: Inst. of Pharmaceutical Sciences; Dean 's Office (B-Building)
- 4 Central Chemistry Institute (H-Building)
- 5 Dept. of Mathematics; QBIC; Dept. of Physics (C-Building)
- 6 Dept. of Chemistry (A-Building)
- 7 Morgenstelle Lecture Hall Center (Hörsaalzentrum)
- 8 Dept. of Physics (D-Building)
- 9 Dept. of Biology: Interfaculty Inst. for Cell Biology (IFIZ); LISA\* (Verfügungsgebäude)
- 10 Isotope Laboratory (F-Building)
- 11 Dept. of Biology: Interfaculty Inst. of Microbiology & Infection Medicine (IMIT), Inst. of Evolution & Ecology, Inst. for Neurobiology (E-Building)
- 12 Center for Plant Molecular Biology (ZMBP)
- 13 Dept. of Pharmacy & Biochemistry: Interfaculty Inst. of Biochemistry (IFIB)
- 14 Dept. of Geosciences: Environmental and Geoscience Center (GUZ)
- 15 Werner Reichardt Center for Integrated Neuroscience (CIN)
- 16 Dept. of Computer Science: Machine Learning
- 17 MPI for Biological Cybernetics; MPI for Developmental Biology; MPI for Intelligent Systems; Friedrich Miescher Laboratory
- 18 Dept. of Computer Science; Dept. of Physics: Astronomy & High Energy Astrophysics
- 19 Dept. of Geosciences: Mineralogy, Geodynamics; Mineralogical Collection
- 20 Dept. of Biology: Ethics in Life Sciences; International Center for Ethics in Life Sciences (IZEW)
- 21 Zoological Collection
- 22 Dept. of Psychology: School Psychology
- 23 Dept. of Psychology; Leibniz-Institut für Wissensmedien (IWM); Leibniz-WissenschaftsCampus
- 24 Dept. of Geosciences: Geography, Prehistory & Archaeological Science
- 25 Dept. of Geosciences: Prehistory & Archaeological Science



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WANNE

NORDSTADT

SAND

Tübingen

ÖSTERBERG

ALT-STADT

für  
rschung

Schloss

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Sportthalle  
WHO

Studentendorf  
Waldhäuser-Ost

Technologiepark  
Tübingen-Reutlingen

Max-Planck-  
Institute

Tropenkl.  
Paul-Lechler Krkh.

Mensa

Unishop

Fernheizwerk

Gericht

Südwest-  
rundfunk

E-Werk

Umland-  
bad

Post

Busbhf.

Hauptbahnhof

Anlagensee

Europa-  
platz

Poststraße

Friedrichstraße

Wohlfahrtsstraße

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