Scientific Report of the URPP Evolution in Action

Reporting Year 2015

1 Management Summary

2015 was a successful third year for the URPP Evolution in Action. The number of interactions has been steadily growing and existing research collaborations have been further strengthened. We have established new teaching activities, among them a block course involving as lecturers ten members of the URPP Evolution in Action and highlighting thus the success of our community-building efforts.

Significant progress has been made in the scientific projects funded by the URPP Evolution in Action. Fourteen research projects were ongoing within the larger framework of five themes, mostly in form of PhD theses projects. First publications are now appearing as a result of the research projects, some of them in very highly ranked journals. Besides these projects that were defined from the outset in our research plan, six new pilot projects are running that were granted in an open call procedure. This call was open to PhD students and Postdocs, underlining our effort to foster young scientists, and yielded many interesting and innovative research proposals that were reviewed by the Steering Committee of the URPP Evolution in Action. An equally successful second open call was issued in the autumn of 2015; the granted projects of this call will be running in 2016.

The URPP Evolution in Action is highly popular at UZH and we received and granted applications for membership in the URPP Evolution in Action from eleven colleagues. Overall, the research projects bring together scientists from 36 research groups, twelve departments, and three faculties of UZH: the Faculty of Sciences, the Medical Faculty, and the Faculty of Arts.

The Third Retreat of the URPP Evolution in Action took place in September 2015 in Flüeli-Ranft with 65 participants. Progress reports of all current research projects funded by the URPP Evolution in Action provided an overview of our ongoing research activities. Karl Schmid from the University of Hohenheim and Laurent Keller from the University of Lausanne, both members of our Scientific Panel, gave inspiring keynote talks. The retreat was combined with the site visit of our Scientific Panel. The feedback from the Panel Members was very positive.

All preparatory works for the position of an Academic Fellow were performed in 2015 and the Academic Fellow will start his research in Zurich in February 2016. The research of the Academic Fellow will be independent, but linked to the research themes of the URPP Evolution in Action. The hiring process of a non-tenure track Assistant Professor financed through the URPP Evolution in Action was ongoing throughout 2015 and will be continued in 2016.

Our research program is thus evolving on various levels. We look forward to continuing our work in 2016 and thank the Executive Board of the University of Zurich for financing the URPP Evolution in Action.

2 Objectives

2.1 Objectives for the reporting year

- Planning and realization of the **Third Retreat of the URPP Evolution in Action**, with a program featuring progress reports from all projects, input lectures, as well as faculty and PhD student meetings. The retreat 2015 will be combined with the site visit of the Scientific Panel of the URPP Evolution in Action. Thereby we would like to provide a comprehensive overview of our research projects to the members of the Scientific Panel as well as to give them the opportunity to directly meet with all our members and PhD students.
- Continuation and further development of the **Seminar Series** of the URPP Evolution in Action that takes places at various UZH institutes.
- Organization of further **Scientific Minisymposia** and small **Workshops** is specific areas of evolutionary biology, primarily organized by PhD students and postdocs.
- Start of the **Academic Fellow Position** of the URPP Evolution in Action.
- Advertisement and planning for the non-tenure track **Assistant Professor Position**, foreseen to start in 2016.
- Second **Open Call for Research Projects** to promote young scientists by supporting innovative and/or high-risk pilot projects, to be issued in fall 2014.
- Planning and realization of new **Courses for the PhD Program** covering topics such as Next Generation Sequencing, Concepts of Evolutionary Biology, and Introduction to Evolutionary Biology.
- Continuation and consolidation of the highly successful **Bioinformatics Tutorial Program** and the bioinformatics support services.
- Continuation of regular **PhD Students Meetings** to enhance interaction among students, research projects, and institutes of the URPP Evolution in Action.
- Organization of **Social Events** (excursions, informal get-togethers) to further enhance interaction within the URPP Evolution in Action community.
- Continuation of **Public Outreach** initiatives, including the planning of a future exhibition on topics related to the URPP Evolution in Action.
- Further extension and development of the **Website** of the URPP Evolution in Action.

2.2 Achieved objectives in 2015

- The **Third Retreat of the URPP Evolution in Action** was a highly successful event. It took place in Flüeli-Ranft and was well attended. Progress reports of all current research projects funded by the URPP Evolution in Action provided an overview of our ongoing research activities. The retreat was combined with the site visit of our Scientific Panel. The feedback from the Panel Members was very positive.
- The **Seminar Series** of the URPP Evolution in Action were continued in a successful new format. With the support of the coordination office, PhD students of the URPP Evolution in Action invited speakers for reserved slots in the department seminars of our participating departments. Workshops took place in combination with these seminars, with the speakers teaching in their areas of expertise. The organizing students found this a great opportunity and experience and feedback from the audience was very positive.
- PhD students and Postdocs organized a **Scientific Minisymposium** with internationally renowned speakers in October 2015. The topic of the symposium was Evo-Devo, and the speakers (Detlev Arendt from EMBL, Jody Banks from Purdue University, and Armin Moczek from Indiana University) lectured on cutting-edge topics of evolutionary developmental biology in the plant and animal kingdoms.
- Preparatory works for the **Academic Fellow** position of the URPP Evolution in Action, including problem solving of HR, visa and relocation issues. These organizational aspects were concluded by the end of 2015. The Academic Fellow, Matthew Horton, will take up his position in the URPP Evolution in Action as of February 2016.
- Preparatory works for the **Assistant Professorship** position of the URPP Evolution in Action. Due to a last-minute withdrawal of commitment of the candidate, the position has to be readvertised. Readvertisement will take place in the first week of January 2016 and the Professorial Appointment Process will be executed as fast as possible.
- The second **Open Call for Research Projects** was issued in fall 2015. These open calls aim at promoting young scientists by supporting innovative pilot projects. We received numerous interesting and innovative project proposals. The Steering Committee of the URPP Evolution in Action granted five projects, which will start in January 2016.
- The URPP Evolution in Action in 2015 organized several **Courses for the PhD Program** in Evolutionary Biology, both repetitions of successful courses developed in the last two years, as well as entirely new courses. The courses covered topics such as Next Generation Sequencing, Genome-Wide Association Studies, Concepts of Evolutionary Biology, and Introduction to Evolutionary Biology.
- The **Bioinformatics Tutorial Program** and the bioinformatics support services, both highly successful elements of the URPP Evolution in Action, were continued and further consolidated.
- The **PhD Students Peer Group** has by now become well established. The PhD students of the URPP Evolution regularly meet and interact across departments and faculties, both for scientific and social events.

- Several **Social Events** (excursions, informal get-togethers) were organized and created opportunities for interactions within the URPP Evolution in Action community and beyond.
- Preparatory works for future **Public Outreach** initiatives, in particular the planning of a future exhibition at the Zoological Museum of the UZH on topics related to the URPP Evolution in Action.
- The **Website** of the URPP Evolution in Action has been extended and new content developed.

2.3 Objectives for 2016

- Planning and realization of the **Fourth Retreat of the URPP Evolution in Action**, with a program featuring progress reports from all projects, input lectures, as well as faculty and PhD student meetings.
- Continuation of the **Research Projects** run by the URPP Evolution PhD students, and first graduations.
- Start of the research projects of the **Academic Fellow** of the URPP Evolution in Action.
- Advertisement and filling of the non-tenure track **Assistant Professor Position**, including the organization of a scientific symposium with all short-listed candidates.
- Preparatory works for **Starting Up Phase 2 of the URPP Evolution in Action**, with new members, projects and PhD students. Planning and submission of the Developmental and Financial Plan of the URPP Evolution in Action for the 2nd phase. This will be based on an open call for projects and subsequent selection of the applications by the Steering Committee.
- Presentation of the results from the first two rounds of **Open Calls for Research Projects**, and third Open Call for Research Projects to promote young scientists by supporting innovative and/or high-risk pilot projects.
- Planning and realization of new **Courses for the PhD Program** covering topics such as Next Generation Sequencing, Concepts of Evolutionary Biology, and Scientific Writing for Evolutionary Biologists.
- Continuation of the highly successful **Bioinformatics Support Services** as well as of the **Bioinformatics Tutorial Program**, including the planning for a tutorial curriculum for the new PhD students taking up their positions in Phase 2 of the URPP Evolution in Action.
- Continuation of regular **PhD Students Meetings** to enhance interaction among students, research projects, and departments of the URPP Evolution in Action.
- Organization of **Social Events** to further enhance interaction within the URPP Evolution in Action community.
- Development of **Public Outreach** initiatives for the second phase: further planning of a museum exhibition on topics related to the URPP Evolution in Action, and exploring of potential cooperation with the ZHDK and with the Life Science Learning Center.
- Further extension and development of the **Website** of the URPP Evolution in Action.

3 Research

3.1 Research Projects

In 2015, 14 research subprojects were being conducted in the URPP Evolution in Action, embedded in the framework of our five collaborative and interdisciplinary research projects on different themes in evolutionary biology. In line with the overarching goal of the URPP to educate a next generation of scientists with broad competences for combining molecular and computation approaches with evolutionary questions, all URPP-funded researchers are young scientists, i.e. 12 PhD students and two postdocs. The individual projects, including aims, progress, as well as partners and PhD students involved are described in some detail below.

Project 1: Genomic Correlates of Microbial Coevolution
Project lead: Christian von Mering (Institute of Molecular Life Sciences, IMLS)

Historically, microbes have been viewed as mostly independent organisms. Currently, this view is being challenged as new data hint at intricate ecological interdependencies of microbes. The research project "Genomic Correlates of Microbial Co-Evolution" has made significant progress in identifying and characterizing ecological partnerships of microbes, using modern high-throughput molecular techniques.

Subproject 1.1: Microbial Networks in Lake Zurich
PhD student: Michael Baumgartner (Department of Plant and Microbial Biology, IPMB); PhD Committee: Jakob Pernthaler (IPMB), Christian von Mering (IMLS), Leo Eberl (IPMB), Rolf Kümmerli (IPMB)
This project investigates the experimental evolution of a model predator prey system with focus on the variability of defense traits and phenotypic plasticity. It aims at understanding the eco-evolutionary trajectories of predator-prey interactions in environmental conditions that select for or against plastic phenotypes. The project is close to completion, and the graduate student is going to defend his PhD in March 2016. We found that bacteria can circumvent evolutionary trade-offs between growth and defense by genome reduction. Moreover, we experimentally showed that phenotypic plasticity is selected over genotypic trait displacement only in unstable environmental conditions.

Subproject 1.2: Evolutionary Degeneration of an Obligate Symbiont
PhD student: Marta Pinto (IPMB); PhD committee: Leo Eberl (IPMB), Kentaro Shimizu (Department of Evolutionary Biology and Environmental Studies, EBES), Rolf Kümmerli (IPMB), Aurelien Carlier (University of Gent, Belgium)
The second subproject is a study on the genome evolution of obligate *Burkholderia* symbionts of leaf nodulated plants. The goal is to unveil the evolutionary history, causes and consequences of genome reduction in *Burkholderia* leaf nodule symbionts. We have sequenced 6 *Psychotria* and one *Pavetta* symbiont and using these data we are currently quantifying the impact of genetic drift on the observed differences in genome architecture and mutation patterns. Our genomic analysis of leaf nodule symbionts gave new insights into the genome evolution of obligate symbionts in the early stage of their association with plants.

Project 2: Evolution in Action: Environment, Agriculture, and Human Disease
Project lead: Kentaro Shimizu (EBES)

Traditionally, evolutionary biology has been based on phenotypic observations, with genetic change being deduced from statistical patterns. Today, studying complete genomes makes it possible to directly observe evolutionary processes on the genetic level. The project "Evolution in Action: Environment, Agriculture, and Human Disease" focuses on investigating evolution in action using next-generation sequencing (NGS) and detecting the frequencies of sequence changes. It focuses on recent rapid changes in host-pathogen interactions and in the formation of new species.

Subproject 2.1: Virulence Evolution in Past Human Pathogens
PhD student: Giada Ferrari (Institute of Evolutionary Medicine, IEM, Medical Faculty); PhD committee: Kentaro Shimizu (EBES), Frank Rühli (IEM, Medical Faculty), Abigail Bouwman (IEM, Medical Faculty), Christian von Mering (IMLS)
The topic of this project is the evolution of human pathogens using historical soft tissues. The aim is to establish a workflow for the use of fixed specimens for reconstructing and investigating historical pathogen genomes. Sampling has been concluded and the development of methodologies for obtaining DNA suitable for NGS from fixed tissues is about to be concluded. Collaborations for the investigation of specific historic pathogen genomes have been established. The PhD project shall be finalized and defended in 2017. Two MSc students are currently involved in the project. Strong research links have been established with several of the institutes participating in the URPP Evolution in Action.

Subproject 2.2: Understanding Variation in Borrelia Resistance in Swiss Natural Host Populations
Postdoc: Luca Cornetti (EBES); supervised by Barbara Tschirren (EBES), mentors: Kentaro Shimizu (EBES), Beat Keller (IPMB), Peter Deplazes (Vetsuisse Faculty)
The project investigates how resistance against an emerging pathogen evolves in natural vertebrate populations. We aim to identify molecular mechanisms underlying adaptive processes in host-parasite systems. We have used genotyping-by-sequencing (GBS) to identify new molecular regions involved in Borrelia resistance in natural rodent populations. These data complement the candidate genes approach used in the same populations and allow us to perform host genotype – parasite infection associations as well as to test for molecular signatures of selection. One of the new candidate genes identified by GBS has been found to be overexpressed in macrophages stimulated with Borrelia in an in vitro study, and is thus particularly promising.

Subproject 2.3: Adaptation of a Fungal Pathogen to New Host Species
PhD student: Fabrizio Menardo (IPMB); PhD committee: Beat Keller (IPMB), Thomas Wicker (IPMB), Kentaro Shimizu (EBES)
The goal of the project is to investigate the evolution of grass powdery mildew, a fungal pathogen of grasses and cereals (*B. graminis*). In particular we are investigating the emergence of *B. graminis* on the new host triticale, a man made crop species originally immune to this disease. Based on the genome sequences of strains with different host ranges we could show that the new pathogen originated through hybridization of two other preexisting forms specialized on different hosts. This finding is a major progress in our understanding of the evolution of new host specificities in powdery mildew and a well-documented report of the emergence of a new fungal pathogen through hybridization. To have a broader understanding of the evolution of grass powdery mildew we now sequence additional strains infecting wild grasses and cereals previously not included in the project.

Subproject 2.4: Hybrid Speciation and Male Invasion in Action in Switzerland

Postdoc: Hiromi Matsumae (EBES); supervised by Kentaro Shimizu (EBES), mentors: Beat Keller (IPMB), John Pannell (University of Lausanne)

We study the co-existence of males and hermaphrodites in *Cardamine amara* and aim at understanding evolutionary mechanisms and population histories of this plant using genomic information. We reported the clonal propagation rate in *Cardamine amara* and are now studying the genetic structure of 26 individuals using microsatellites and resequencing data. Currently, we are improving assembly of reference genomes for male and hermaphrodite for *Cardamine amara*. In two side-projects, we study other cases of population histories: i) the hybrid speciation of pathogenic fungi of wheat in collaboration with Prof. Beat Keller, and ii) linguistics diversity in Asian indigenous people in collaboration with Prof. Balthasar Bickel.

Subproject 2.5: Speciation through Chromosomal Rearrangements in Wild House Mice in Switzerland

PhD student: Sofia Grize (EBES); PhD committee: Barbara König (EBES), Anna Lindholm (EBES), Ueli Grossniklaus (IPMB), Kentaro Shimizu (EBES), Aldona Pieńkowska-Schelling (University of Bern), Jeremy Searle (Cornell University, US)

This project investigates the influence of chromosomal variation and hybrid sterility on genetic isolation between house mouse populations. The goal is to understand the maintenance of distinct house mouse populations that vary in number and structure of their chromosomes, despite hybrid dysfunction and gene flow between them. Extensive fertility data was collected, cytological methods vital for chromosomal analysis were successfully performed and SNP genotyping was done on samples of wild populations. The analyses are ongoing and manuscript preparation is in progress. The observation of unusual variation in the amount of centromeric heterochromatin in the samples' chromosomes lead to additional questions on their stability and on centromere activity.

Subproject 2.6: Incipient Speciation Due to Thermal Adaptation or Sexual Selection in Sepsid Flies

PhD student: Athene Giesen (EBES); PhD committee: Wolf Blanckenhorn (EBES), Kentaro Shimizu (EBES), Rie Inatsugi-Shimizu (EBES), Heidi Lischer (EBES)

This project investigates the evolution of reproductive isolation between the two hybridizing dung flies *Sepsis cynipsea* and *S. neocynipsea*. We aim at understanding the speciation process in this group of flies in general and for these two species in particular, in terms of gene-phenotype relationships. The empirical assessment of genetic differentiation of European and North American *S. cynipsea* and *S. neocynipsea* populations using microsatellites and CO1 is essentially completed and the hybridizations between the species are finalized. The partly annotated de novo sequences of both species, performed by Beijing Genomics Institute (BGI) in collaboration with two groups in Bonn (D) and Singapore, are now at our disposal.

Project 3: Investigating the Importance of Epigenetics in Adaptation and Coevolution

Project lead: Ueli Grossniklaus (IPMB)

Traditionally, epigenetic variation has not been given much importance in ecological and evolutionary processes despite its potential for rapid change, which could play an important role in adaptation. This research project aims at assessing the significance of epigenetic variation and inheritance for ecological questions and evolutionary processes.

Subproject 3.1: Epigenetic Variation and Selection

PhD student: Klara Kropivsek (IPMB); PhD committee: Ueli Grossniklaus (IPMB), Bernhard Schmid (EBES), Christian Hardtke (University of Lausanne)

We investigate whether the selection of epigenetic variation contributes to phenotypic responses under selection, specifically whether a change in trichome density observed after several generations of aphid herbivory is due to epigenetic variation, providing the basis for adaptation to biotic stress. If

a contribution of epigenetic variation to trichome density can be demonstrated, we will identify candidate genes by whole-genome methylome and transcriptome analyses. Ultimately, we will try to establish causality by altering the DNA-methylation status of selected candidate genes. Plants from populations that were subjected to five generations of selection have been genotyped, grown in a randomized block design, and phenotypic data has been collected. Analysis of this phenotypic data showed that there are differences in how one plant genotype responds to selection by different aphid species. A manuscript describing this analysis is under preparation and we are currently generating the libraries to sequence the methylome of selected plants, which will be analyzed in 2016. The PhD student working on the project, Klara Kropivsek, decided to discontinue her PhD to pursue other interests. The methylome analysis will be performed by Dr. Vimal Rawat, a postdoc trained in bioinformatics, with wet-lab support by Anja Frey, a technician supported by other funds.

Subproject 3.2: Epigenetics in Plant Adaptation
PhD student: Roman Kellenberger (Institute of Systematic Botany, ISB); PhD committee: Florian Schiestl (ISB), Phillip Schlueter (ISB), Kentaro Shimizu (EBES), Ueli Grossniklaus (IPMB)
We study the induction of trans-generational epigenetic effects in plant-insect interactions. Our aim is to determine the role of DNA methylation in phenotypic responses of plants to pollinators and herbivores. The project is in the very last phase of the experimental greenhouse work (last plant generation). The laboratory part will be scheduled according to the results obtained. The greenhouse work has been delayed due to various technical issues. However, maternal effects of herbivory on plant phenotypes have already been detected.

Subproject 3.3: Effects of Epigenetic Variation in Adaptive Processes in Tetrahymena thermophila
PhD student: Vanessa Weber de Melo (EBES); PhD committee: Owen Petchey (EBES), Ueli Grossniklaus (IPMB), Paul Hurd (Queen Mary, University of London, UK), Bernhard Schmid (EBES), Sinead Collins (University of Edinburgh, UK)
We investigate the importance of epigenetic variation in adaptive processes using *Tetrahymena thermophila* as a model system. The project aims at better understanding the importance of histone modifications in gene expression changes that occur when *T. thermophila* adapts to different conditions, such as increasing population densities and temperature variation. The first experiment analyzing how population density influences *T. thermophila* populations was performed at the end of 2015. Laboratory techniques are currently being optimized and samples will be sent for sequencing after that. ChIP-seq data from a pilot experiment presented very low quality. Laboratory techniques such as cell disruption and nuclei separation are being improved in order to obtain better quality data for the next experiments.

Project 5: The Evolution of Language: an Integrative Approach
Project lead: Marta Manser (EBES)
Language is widely seen as one of human's defining features, yet there is considerable disagreement concerning what features of language are unique to humans and which one we share with animals. The aim of this project is to unpack the features thought to be unique to human language by employing synergistic theoretical and empirical techniques, and ultimately to better understand the evolutionary preconditions that promote the emergence of complex vocal communication systems.

Subproject 5.1: Vocal complexity in cooperatively breeding mammals

PhD student: Katie Collier (EBES); PhD committee: Marta Manser (EBES), Carel van Schaik (Department of Anthropology, AIM), Balthasar Bickel (Dept. of Comparative Linguistics, IVS, Faculty of Arts), Simon Townsend (EBES), Hans-Johann Glock (Institute of Philosophy)

This project is about the evolutionary origins and selective conditions promoting the evolution of human language. We aim to take a highly collaborative, integrative and empirical approach to better understanding how language, one of the key stand-out features of human biology, may have evolved. The PhD student has published a conceptual paper outlining the overall approach we are taking throughout this project (Collier et al. 2014, Proc. Roy. Soc. B), and currently has a second paper in review based on her empirical research conducted in the first year. She spent 6 months conducting observational and experimental research in the field on a second mongoose species (Dwarf mongoose) in South Africa and has currently returned for a brief 2 month period to finalize and complete her experiments. Subsequently, the data analysis will be finished and result in at least two further publications. This collaboration, including anthropologists, linguists, philosophers and animal communication biologists has been highly stimulating and through regular meetings over the last year we have continued to generate new and exciting avenues of research in the field of language evolution. These discussions have led to the formulation of a new hypothesis explaining how combinatorial systems in humans may have evolved (Collier et al. 2014) which has in turn helped guide our own empirical research into the topic of animal vocal combinations. It also has resulted in designing a study on the evolution of acoustic innovations, based on a genetic approach.

Project 6: Conservation Genomics: the Role of Functional Genetic Variation in Conservation

Project lead: Lukas Keller (EBES)

Evolutionary adaptation is essential for endangered species to survive global change, yet the role of functionally important genetic variation in the small, isolated populations typical for endangered species is virtually unknown. This research project addresses this gap by applying conservation genomics to an ideal study organism, the Alpine Ibex.

Subproject 6.1 and 6.2: Conservation Biology of the Alpine Ibex

PhD student, subproject 6.1: Deborah Leigh (EBES); PhD committee: Lukas Keller (EBES), Andreas Wagner (EBES), Arpat Ozgul (EBES), Simon Aeschbacher (University of California Davis, US)

PhD student, subproject 6.2: Kasia Sluzek (EBES); PhD committee: Lukas Keller (EBES), Andreas Wagner (EBES), Thomas Wicker (IPMB), Arpat Ozgul (EBES), Simon Aeschbacher (University of California Davis, US)

These two projects investigate the post bottleneck evolutionary processes across populations of Alpine ibex. The aim is to examine patterns in genome wide variation and responses to selection in bottlenecked populations. Samples have been sequenced and the genomic data analyzed. We are currently conducting analysis on the SNP data to address the above questions, with the aim to finish the PhD theses in 2017.

Pilot Projects

To further promote young scientists, the URPP Evolution in Action called twice for research proposals in the wider field of evolutionary biology. We particularly encouraged applicants to hand in proposals involving an interdisciplinary approach to evolutionary questions. Proposals could be submitted by PhD students and postdocs working in UZH research groups that either are members of the URPP Evolution in Action or have applied for membership. The funding per proposal was

limited to CHF 20'000. The purpose of these calls was to fund innovative pilot projects necessary for subsequent larger grant applications. We received many highly interesting project proposals that were reviewed and rated by the Steering Committee of the URPP Evolution in Action. About one third of the submitted projects could be granted in both calls.

Open Call of November 2014 (Projects started in 2015)

Applicant: *Sinisa Bratulic, PhD Student*
Title of project: Measuring phenotypic mutation rates using mass spectrometry-based proteomics
Granted funding: CHF 4'400

Applicant: *Dr. Christine Grossen, Postdoc*
Title of project: Genomic signatures and mechanisms of introgression in Alpine ibex
Granted funding: CHF 19'873

Applicant: *Dr. Mélissa Lemoine, Postdoc*
Title of project: Assessing hidden diversity of *Borrelia* pathogens along altitudinal gradients in the Swiss Alps
Granted funding: CHF 19'730

Applicant: *Marta Pinto, PhD Student*
Title of project: Estimation of effective population sizes and identification of possible transmission bottlenecks of obligate leaf nodule symbionts of *Psychotria*
Granted funding: 12'090

Applicant: *Dr. Yolanda Schaerli, Ambizione Fellow*
Title of project: Evolution of duplicated genes
Granted funding: 20'000

Applicant: *Dr. Samuel Wuest, Ambizione Fellow*
Titel of project: Characterization of mutant loci affecting fitness through altered reproductive allocation patterns in an annual plant
Granted funding: 15'000

Open Call of October 2015 (Projects starting in 2016)

Applicant: *Sofia Nobre, PhD Student*
Title of project: Parental conflict in imprinting of the endosperm in apomictic seed development
Granted funding: CHF 20'000

Applicant: *Dr. Hiromi Matsumae, Postdoc*
Title of project: Finding evolutionary trails of highly diverged languages from genomes of Asian isolated language speakers
Granted funding: CHF 20'000

Applicant: Dr. *Yolanda Schaerli, Ambizione Fellow*
Title of project: Evolutionary innovation of Escherichia coli populations
Granted funding: CHF 20'000

Applicant: Dr. *Kathleen Sprouffske, Postdoc*
Title of project: The repeatability of colon cancer genome evolution within a single patient
Granted funding: CHF 20'000

Applicant: *Claudia Vigano, PhD Student*
Title of project: Pre-bottleneck genetic diversity of Alpine ibex
Granted funding: CHF 19'800

3.2 Scientific Activities

Scientific Retreat
In September 2015, the third URPP Evolution in Action Retreat took place in Flüeli-Ranft, with 65 participants. Progress reports of all current research projects funded by the URPP Evolution in Action provided an overview of our ongoing research activities. The PhD students conducting the projects held the presentations. A special focus was laid on the scientific background of the research topics as well as on the progress made since the first annual retreat in 2013. The aim was to make the scientific questions of the diverse fields understandable to all, and to enable discussion across different disciplines. Additionally, many of our new members gave a brief 5-minutes insight into their research areas, which led to stimulating discussions.

The retreat was combined with the site visit of our Scientific Panel. Both Laurent Keller (University of Lausanne) and Karl Schmid (University of Hohenheim), members of the Scientific Panel, gave fascinating keynote lectures (titles were "Supergenes, Sex and Sociality" and "Wild Barely as a Model of Local Adaptation", respectively). Their feedback regarding both the URPP Evolution in general and the annual retreat in Flüeli-Ranft was very positive.

Similar to the previous annual meetings, the retreat 2015 was also the opportunity to meet all other members and PhD students of the URPP Evolution in Action and to discuss general aspects; as in previous years, faculty and PhD student meetings were held during the retreat. The scientific sessions and meetings were complemented by a social program, during which lots of informal discussions and interactions took place.

Bioinformatics Tutorials
The successful series of bioinformatics tutorials was continued in 2015, based on the inputs from the URPP Evolution in Action members and PhD students. These tutorials were organized and taught by Stefan Wyder and Heidi Lischer and are listed in the university calendar (Vorlesungsverzeichnis) as "BIO396 Tutorials in Practical Bioinformatics". At the retreat 2015, an interactive session on teaching was held with the PhD students and topics were chosen according to students' feedback. In detail, the following 3-hour-tutorials were offered:

- Introduction to R Part 3: Repetition, Programming Exercises
- Introduction to git/Github
- Genomic utilities: tools for working with BAM alignments, genomic intervals, FASTA/FASTQ and variant files (SAMtools, Picard, bedtools, seqtk, vcftools, bcftools)

In addition, the following one-day tutorials were offered:

- Introduction to Python Part 1: Basics, Control Flow, Lists, Input/Output, Functions, Libraries, Dictionaries, Tuples, Sets
- Introduction to Python Part 2: Object-Oriented Programming, BioPython, Programming Exercises

Each of the tutorials was held twice (with the exception of the git/Github tutorial) such that all interested persons could participate. Every tutorial consisted of a theoretical introduction to the topic, and most time was spent on guided exercises. The tutorials were very well attended, with ten to 20 participants for each topic. The students generally gave a very positive feedback, and for all past tutorials there were requests to repeat the tutorial. The participants were mostly PhD students of the URPP Evolution in Action, but also more senior scientists and guests from neighboring departments attended the tutorials. The series is being continued in 2016.

In addition to the tutorial series, the URPP Evolution in Action bioinformaticians organized and taught a 2-day course: BIO 634 Next-Generation Sequencing 2 for Model and Non-Model Species: Transcriptomes, Variant Calling and Biological Interpretation that was organized as a follow-up course to a 2-day introduction to Next-Generation Sequencing (BIO 610 Next-Generation Sequencing 1 - Introductory Course: Assembly, Mapping, and Variant Calling) organized by Prof. Kentaro Shimizu and others. BIO 634 aimed to extend the knowledge of NGS analysis and skills in computing taking a hands-on approach. The course was attended by 15 persons, mostly PhD students in Plant Sciences or Evolutionary Biology from the University of Zurich and ETH. Students' evaluations were very favorable and the course will be offered again in 2016.

The quarterly one-to-one meetings between each PhD student and an embedded bioinformatician were continued in 2015 to discuss project designs, methods and challenges. The aim is to keep up-to-date with the progress and to help connecting the PhD students using similar methods.

Courses for the PhD Program in Evolutionary Biology

- Next –Generation Sequencing for Model and Non-Model Species (BIO610); May 11-12, 2015; Lecturers: Kentaro Shimizu, Satoru Akama, Masaomi Hatakeyama, Jun Sese, Rie Shimizu Inatsugi
- Next-Generation Sequencing 2 – Advanced Course: Transcriptomes, Variant Calling and Biological Interpretation (BIO634); May 18-19, 2015; Lecturers: Kentaro Shimizu, Masaomi Hatakeyama, Heidi Lischer, Stefan Wyder
- Introduction to Genome-Wide Association Studies (GWAS); 12-13 October, 2015; Lecturers: Nuno Pires (IPB), Arthur Korte (GMI Vienna), Ueli Grossniklaus (IPB)
- Concepts in Evolutionary Biology (BIO395) NEW; March 9-10, 2015; Lecturers: Barbara König, Andreas Wagner, Lukas Keller, Kentaro Shimizu, Barbara Tschirren, Wolf Blanckenhorn, Anna K. Lindholm Krützen, Michael Krützen, Erik Postma, Kathleen Marie Sprouffske.

Recruitment of an Academic Fellow

The URPP Evolution in Action aims at targeting young researchers with outstanding potential, offering them the opportunity to develop their own, independent research. To this aim, we have set up an Academic Fellow position, which is modeled after the successful CSHL-, Harvard- and UCSF-Fellowships. In 2015, we have been preparing the arrival of our designated Academic Fellow, Dr. Matthew Horton, in Zurich. Preparatory works included problem solving of HR, visa and relocation issues. These organizational aspects were solved by the end of 2015. The Academic Fellow will take up his position in the URPP Evolution in Action as of February 2016.

Recruitment for the Assistant Professor Position

The Professorial Appointment Process for the non-tenure track Assistant Professorship of the URPP Evolution in Action was initiated in January 2015 and took almost the entire year. Due to a last-minute withdrawal of commitment of the candidate in December 2015, the position has to be readvertised. Readvertisement will take place in the first week of January 2016 and the Professorial Appointment Process will be executed as fast as possible.

New Members

Group leaders addressing evolutionary questions at the organismal, molecular, and/or conceptual level at UZH can apply for membership in the URPP Evolution in Action. Applications are subject to approval by the Steering Committee. In 2015 the Steering Committee approved the following membership applications:

Prof. Dr. Florian Altermatt, Department of Evolutionary Biology and Environmental Studies
Dr. Natasha Arora, Institute of Forensic Medicine
Dr. Abigail Bouwman, Institute of Evolutionary Medicine
Prof. Dr. Urs Greber, Institute of Molecular Life Sciences
Dr. Michael Griesser, Department of Anthropology
Prof. Dr. Hanna Kokko. Department of Evolutionary Biology and Environmental Studies
Prof. Dr. Roger Kouyos, Department of Infectious Diseases and Hospital Epidemiology
Prof. Dr. Mark D. Robinson, Institute of Molecular Life Sciences
Prof. Dr. Marcelo R. Sánchez-Villagra, Paleontological Institute and Museum
Dr. Rie Shimizu-Inatsugi, Department of Evolutionary Biology and Environmental Studies
Dr. Péter Szövényi, Institute of Systematic Botany

Scientific Minisymposium

PhD students and Postdocs organized a Scientific Minisymposium with internationally renowned speakers on October 21, 2015. The topic of the symposium was Evo-Devo, and the speakers (Detlev Arendt from EMBL, Jody Banks from Purdue University, and Armin Moczek from Indiana University) lectured on cutting-edge topics of evolutionary developmental biology in the plant and animal kingdoms.

PhD Student Organized Seminars

The Seminar Series of the URPP Evolution in Action were continued in a successful new format. With the support of the coordination office, PhD students of the URPP Evolution in Action invited speakers for reserved slots in the department seminars of our participating departments. Workshops took place in combination with these seminars, with the speakers teaching in their areas of expertise. The organizing students found this a great opportunity and experience and feedback from the audience was very positive.

The following two seminars took place in 2015:

- February 24, 2015
  Title: Genomic analyses of historical pathogens
  Speaker: Dr. Kirsten Bos, Max Planck Institute for the Science of Human History

- November 17, 2015
  Title: Lessons about virus biology from molecular clocks
  Speaker: Gytis Dudas, Institute of Evolutionary Biology, University of Edinburgh

4 Academic Career Development

4.1 Academic Career Development for Young Academics

Most of the budget granted to the URPP Evolution in Action is currently used to fund PhD studies: in 2015, the URPP Evolution in Action funded salaries and research consumables for 13 PhD students and two postdocs, thereby contributing substantially to their career development on the financial level.

Beyond direct financial support, we are dedicated to providing a network supporting young academics in the field of evolutionary biology, and to creating an atmosphere of lively interaction across the borders of faculties, institutes, and seniority. Besides scientific meetings, we also organize social events and see such activities deliberately as a means to grant young academics access to a community of experienced researchers. PhD students, postdocs, and junior professors who do not receive funding from the URPP Evolution in Action, but work in research areas close to ours, are equally invited to attend events and courses organized by the URPP Evolution in Action. A successful format of social events are the "Informal Get-Togethers", taking place about 3 times per year on weekday evenings in Zurich. These events are generally attended by many of our members and students. Notably, we invited all members of the URPP Global Change and Biodiversity to one of these events to foster interactions, and this get-together was particularly well attended.

The two embedded bioinformaticians of the URPP Evolution in Action have supported all PhD projects from the beginning, such that experimental design, probe preparation, analysis methods etc. are optimally adapted to the questions asked. In doing so, the bioinformaticians themselves expand their research experience, and the wealth of data available from several projects allows them to develop productive research activities on their own. The embedded bioinformaticians have regular meetings with the PhD students and developed a very well attended tutorial series, which endows the PhD students with the necessary bioinformatics skills. We have taken care to enable a close contact between the embedded bioinformaticians of the URPP Evolution in Action and the bioinformatics community at the UZH. The URPP Evolution in Action bioinformaticians regularly work one day per week in the von Mering (IMLS) and Wagner (EBES) groups, respectively, where they are in touch with the newest developments in bioinformatics research, and take part in the weekly group meetings. This approach allows for a continued transfer of knowledge at the forefront of current research topics and trends in bioinformatics.

We put a lot of effort into developing courses and tutorials that address the needs of the PhD students in the URPP Evolution in Action community. These teaching efforts should allow them to become researchers with a comprehensive understanding of the fields of evolutionary biology, genomics, bioinformatics, population genetics, and ecology (see also chapter 3.2).

PhD students and postdocs have the possibility to invite keynote speakers from abroad, thereby gaining experience and new contacts who may well become mentors for their further career. To invite speakers, PhD students and postdocs can organize minisymposia with several speakers. In addition, PhD students have the possibility to invite speakers for reserved slots in the department seminars of our participating departments. In both cases, they receive organizational support from the URPP coordination office and the necessary funding. One minisymposium and two seminars took place in 2015 (see also chapter 3.2).

The PhD students in the URPP Evolution in Action have the possibility to bring in their view in various ways. At our retreats, they were invited to formulate their needs in a workshop specifically dedicated to this aim. Furthermore, the PhD students have elected a representative who serves on the Steering Committee of the URPP Evolution in Action and also the Search Committee for the Academic Fellow position.

4.2 Gender Equality Development

Hiring of personnel is on an equal opportunity basis and according to the "Gender Equality Action Plan UZH" guidelines. We mention our equal opportunity efforts in all job advertisements. Already now, the gender ratio in the URPP Evolution in Action is very balanced. At the PhD student level and among the applicants for positions and research grants, there is a majority of women. This is reflected by the fact that more than 80% of our open call research grants were awarded to women scientists.

Wherever possible, we support efforts to create a family-friendly work environment, for instance by enabling part-time work. Our experience with providing such opportunities is highly positive. Furthermore all our social events are, if convenient for children, open to the families of our co-workers. At future retreats we plan to provide a child-care opportunity to enable parents to attend.

5 Publications

5.1 Peer-reviewed publications

Akama S, Shimizu-Inatsugi R, Shimizu KK, Sese J (2014) Genome-wide quantification of homeolog expression ratio revealed nonstochastic gene regulation in synthetic allopolyploid Arabidopsis. Nucleic Acids Research 42: e46.

Michael Baumgartner, Jakob Pernthaler. Adaptive phenotypic defence is only preserved in a bacterial strain at alternating conditions of predator presence and absence. (Submitted)

Michael Baumgartner, Stefan Roffler, Thomas Wicker, Jakob Pernthaler. Letting go: genome streamlining allows for simultaneous adaptation to top-down and bottom-up constraints in a phenotypically plastic bacterial strain. (Submitted)

Michael Baumgartner, Thomas R. Neu, Judith F. Blom, Jakob Pernthaler. Predation on a bacterial strain outweighs substrate limitation in selecting for defence over growth optimized morphotypes (Submitted)

Biebach et al. (2016). Genetic issues in animal reintroductions. Reintroduction of Fish and Wildlife Populations. USA: University of California Press. NA.

Carlier, A., Fehr, L., Pinto, M., Schäberle, T., Dessein, S., König, G., and L. Eberl. The cyclic depsipeptide FR900359 from Ardisia crenata Sims is produced by the plant's obligate leaf nodule symbiont Candidatus Burkholderia crenata. Environ. Microbiol. 2015 Dec 10. doi: 10.1111/1462-2920.13184.

Collier K, Bickel B, van Schaik C, Manser MB, Townsend SW (2014). Language evolution: Syntax before phonology? Proceedings of the Royal Society B: Biological Sciences 281: 20140263.

Collier, K, Townsend, S.W., Manser M.B., in review. Call concatenation in wild meerkats. Animal Behaviour.

Cornetti, L, Lemoine, M., Hilfiker, D., Morger, J., Reeh, K., Tschirren, B. (in press) Higher genetic diversity on mountain tops: the role of historical and contemporary processes in shaping genetic variation in the bank vole. Biol. J. Linn. Soc.

Didion, J. P., A. P. Morgan, L. Yadgary, T. A. Bell, R. C. McMullan, L. Ortiz de Solorzano, J. Britton-Davidian, C. J. Bult, K. J. Campbell, R. Castiglia, Y.-H. Ching, A. J. Chunco, J. J. Crowley, E. J. Chesler, J. E. French, S. I. Gabriel, D. M. Gatti, T. Garland, E. B. Giagia-Athanasopoulou, M. D. Giménez, S. A. Grize, İ. Gündüz, A. Holmes, H. C. Hauffe, J. S. Herman, J. M. Holt, K. Hua, W. J. Jolley, A. K. Lindholm, M. J. López-Fuster, G. Mitsainas, M. Mathias, L. McMillan, M. G. Ramalhinho, B. Rehermann, S. P. Rosshart, J. B. Searle, M.-S. Shiao, E. Solano, K. L. Svenson, P. Thomas-Laemont, D. W. Threadgill, J. Ventura Queija, G. M. Weinstock, D. Pomp, G. A. Churchill, and F. Pardo-Manuel de Villena. 2015 under revision. R2d2 drives selfish sweeps in the house mouse. Molecular Biology and Evolution.

Fabrizio Menardo, Coraline R Praz, Stefan Wyder, Roi Ben-David, Salim Bourras, Hiromi Matsumae, Kaitlin E McNally, Francis Parlange, Andrea Riba, Stefan Roffler, Luisa K Schaefer, Kentaro K Shimizu, Luca Valenti, Helen Zbinden, Thomas Wicker & Beat Keller (2016). Hybridization of powdery mildew strains gives rise to pathogens on novel agricultural crop species. Nature Genetics doi:10.1038/ng.3485

Morger, J., Råberg, L., Hille, S.M., Helsen, S., Štefka, J., Al-Sabi, M.M., Kapel, C.M.O., Mappes, T., Essbauer, S., Ulrich, R.G., Bartolommei, P., Mortelliti, A., Balčiauskas, L., van den Brink, N.W., Rémy, A., Bajer, A., Cheprakov, M., Korva, M., García-Pérez, A.L., Biek, R., Withenshaw, S., Tschirren, B. (2015) Distinct haplotype structure at the innate immune receptor Toll-like receptor 2 (TLR2) across bank vole populations and lineages in Europe. Biological Journal of the Linnean Society. doi: 10.1111/bij.12593

Morger, J., Banjok, J., Craig, P.S., Rogan, M.T., Lun, Z.R., Hide, G, Tschirren, B. (2014) Naturally occurring Toll-like receptor 11 (TLR11) and Toll-like receptor 12 (TLR12) polymorphisms are not

associated with Toxoplasma gondii infection in wild wood mice. Infection, Genetics and Evolution, 26, 180-184.

Pinto-Carbó, M., Sieber, S., Dessein, S., Wicker, T., Verstraete, B., Gademann,K., Eberl, L., and A.L. Carlier. Evidence of horizontal gene transfer between obligate leaf nodule symbionts. ISME J., in press.

Tedder A, Helling M, Pannell JR, Shimizu-Inatsugi R, Kawagoe T, van Campen J, Sese J, Shimizu KK (2015) Female sterility associated with increased clonal propagation suggests a unique combination of androdioecy and asexual reproduction in populations of Cardamine amara (Brassicaceae). Annals of Botany 115: 763-776

Tschirren, B. (2015) Borrelia burgdorferi sensu lato infection pressure shapes innate immune gene evolution in natural rodent populations across Europe. Biology Letters: doi: 10.1098/rsbl.2015.0263

6 Structures

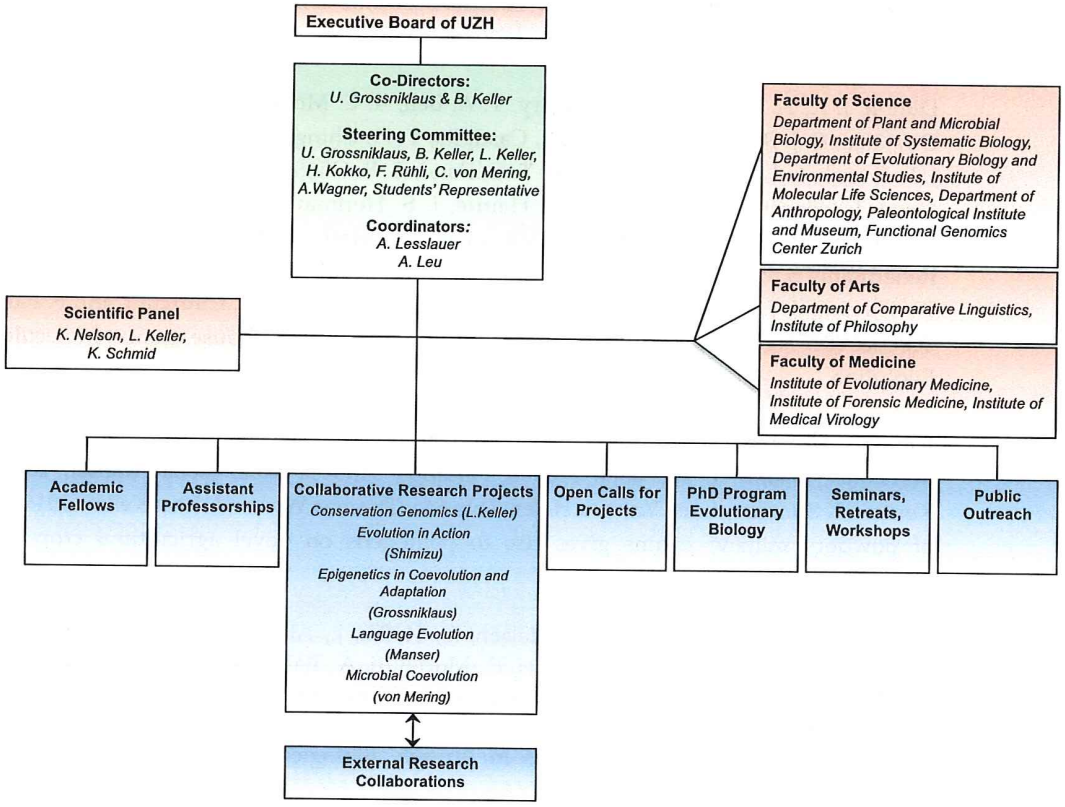

Figure 1: Organizational chart of the URPP Evolution in Action

7 Third-Party Funds

7.1 Third-party Funding Raised in the Context of the URPP Evolution in Action Research Projects

Data obtained through this URPP project helped setting up the basis of an SNF Sinergia grant proposal (number CRSII3_154430) to investigate the functional aspects of leaf nodule symbiosis. CHF 1'037'274 were awarded to our group, together with the groups of Prof. K. Gademann (University of Basel) and Dr. T. Wicker (UZH). (Subproject 1.2)

Mélissa Lemoine obtained a Marie-Heim-Vögtlin grant to work in the project. Grant from the Baugarten Foundation for fieldwork and consumables. (Subproject 2.2)

2014 CHF 4'500 (Claraz Stiftung) (Subproject 2.5)

- De novo sequencing and bioinformatics of 4 *Sepsis* species at Beijing Genomics Institute conducted and paid for by grants to Bonn University;
- Funding for field work from the Claraz Foundation (CHF 2500) (Subproject 2.6)

Related projects addressing similar questions:
PSC Syngenta Fellowship for the projects "Epigenetic Contributions to Hybrid Vigor in Apomictic Offspring" (Fr. 150'000, together with Bernhard Schmid) and "Causes and consequences of epigenetic variation in plant interactions with pollinators and herbivores" (Fr. 50'000, together with Florian Schiestl and Heather Kirk). (Subproject 3.1)

"Causes and consequences of epigenetic variation in plant interactions with pollinators and herbivores." PSC Syngenta Research Fellowship. (Subproject 3.2)

Travel grants for PhD students, Institute of Evolutionary Biology UZH: 800 CHF (SMBE Vienna)

Third-party funds: ESF Congenomics travel grant to visit Uppsala University €945

7.2 Funded Projects within the Profit-Center of the URPP Evolution in Action

- Subproject 1.1: Microbial Networks in Lake Zurich
  - Project leader: Jakob Pernthaler
  - Funding: CHF 65'700
- Subproject 1.2: Evolutionary Degeneration of an Obligate Symbiont
  - Project leader: Leo Eberl
  - Funding: CHF 65'700
- Subproject 2.1: Virulence evolution in past human pathogens
  - Project leader: Frank Rühli
  - Funding: CHF 65'700
- Subproject 2.2: Understanding Variation in Borrelia Resistance in Swiss Natural Host Populations
  - Project leader: Barbara Tschirren
  - Funding: CHF 65'700
- Subproject 2.3: Adaptation of a Fungal Pathogen to New Host Species

  - Project leader: Beat Keller
  - Funding: CHF 65'700
- Subproject 2.4: Hybrid Speciation and Male Invasion in Action in Switzerland
  - Project leader: Kentaro Shimizu
  - Funding: CHF 32'900
- Subproject 2.5: Speciation through Chromosomal Rearrangements in Wild House Mice in Switzerland
  - Project leader: Barbara König
  - Funding: CHF 65'700
- Subproject 2.6: Incipient Speciation Due to Thermal Adaptation or Sexual Selection in Sepsid Flies
  - Project leader: Wolf Blanckenhorn
  - Funding: CHF 65'700
- Subproject 3.1: Epigenetic Variation and Selection
  - Project leader: Ueli Grossniklaus
  - Funding: CHF 131'500
- Subproject 3.2: Epigenetics in Plant Adaptation
  - Project leader: Florian Schiestl
  - Funding: CHF 32'900
- Subproject 3.3: Epigenetics in Microbial Adaptation
  - Project leader: Owen Petchey
  - Funding: CHF 32'900
- Subproject 5.1: The evolutionary origins and selective conditions promoting the evolution of human language
  - Project leader: Marta Manser
  - Funding: CHF 65'700
- Subproject 6.1: Conservation Biology of the Alpine Ibex (Genomic Aspects)
  - Project leader: Lukas Keller
  - Funding: CHF 65'700
- Subproject 6.2: Conservation Biology of the Alpine Ibex (Transcriptomic Aspects)
  - Project leader: Andreas Wagner
  - Funding: CHF 65'700

Pilot projects: see page 11.