Q & A

Laurent Keller

Laurent Keller is a professor at the University of Lausanne, where he directs the Department of Ecology and Evolution. After his PhD in Lausanne, he completed a postdoc with E.O. Wilson at Harvard and then returned to Bern and Lausanne with a special research and teaching grant from the Swiss NSF. He then applied with Nicolas Perrin to share a chair in the Department of Ecology in Lausanne; following a mitosis event within the department, this chair was split into Theoretical Ecology and Evolutionary Ecology positions, which are now hold by Perrin and Keller, respectively.

What turned you on to biology in the first place? Chance, laziness and the desire to work on something that could become a topic of discussion in a bar. As a teenager I hated biology. I had little interest in learning the names of all these organs, cell types and species that professors wanted us to know by heart. Not surprisingly, biology, along with English, were the classes where I got the worst grades. Luckily, at high school, I finally had an excellent teacher who interested many of us in evolution and biology. So when I had to choose a topic when starting University, biology was added to physics and medicine as possible options. Physics was probably where I was most gifted; but I really worried that it would not foster exciting topics for discussion in a bar. As for medicine, I thought this would be interesting, but I felt that six years of studies would be too long. So this is why I started biology, which did not require such long study and provided many interesting topics of discussion. Of course, I then had no clue that, ultimately, I would study for well over six years by continuing on with a masters degree and then a PhD.

So it appears you were not a highly motivated student? Right, particularly because when I studied in Lausanne, the curriculum was old-fashioned and still included a lot of information on anatomy and systematics that had to be learnt by heart. Nevertheless, I turned out to be a relatively good student because I liked physics, mathematics and statistics. I also had an interest in bird watching and natural history. I only really started to be excited about biology, however, once I had a chance to do my first experimental studies on reproductive isolation between alternative morphs of snails. That was when I decided to continue with a PhD. Luckily, at that time, mastering English was not yet a pre-requisite to getting a PhD position.

What made you choose ants as a research topic? I was interested in social behaviour in general. I first considered working with primates but quickly realised that to study these animals you either work in the field where you cannot really conduct experiments, or in a zoo with few animals in a very artificial environment. After hearing a talk on ants by the entomologist Daniel Cherix, it struck me that these insects could provide a good system for experimentally studying the dynamics of cooperation and conflict within animal societies. Consequently, I became interested in ants and started working on conflicts over reproduction in a species characterized by the presence of several queens within the same colony. After that, I moved to other types of conflict in ants, which turned out to be quite numerous even among these highly cooperative organisms.

But hasn't your research focus shifted now? Yes: during my postdoc, my collaborator Kenneth Ross and I found a gene associated with the existence of two social forms in the fire ant *Solenopis invicta*. This led us to conduct many studies investigating how a single genetic element can underlie so many differences between the two fire ant social forms. As a result, I have become increasingly interested in behavioural genetics, and we are now studying how interactions between genes and the social environment jointly influence individual behaviour, social organisation and the process of caste differentiation in social insects. In a recent study we found that the behaviour and pattern of gene expression of an individual in a colony does not only depend on its own genotype but also on the genotypes of the other group members.

Are you not also working with robots? Yes, I have been using robots in collaboration with Dario Floreano from EPFL to study how group structure influences the evolution of communication and cooperation. We conduct evolution experiments with small robots controlled by a neural network with genes coding for connection strength between neurons. So you start with robots having random genomes, and thus behaving in a completely uncoordinated manner. But within a few generations, the processes of mutation and selection translate into a rapid increase in the robots' performance. In a recent study, we investigated the role of genetic similarity (relatedness) among robots on their likelihood to be altruistic and share food items with other group members. Currently, we are studying whether species may interfere with each other's communication systems when they compete for the same resource. This robotic system is very useful to study evolutionary questions that are difficult to address with real organisms.

You seem to have a wide variety of interests? In a word, yes. With the help of gifted students and colleagues, I have also been working on bees, wasps, termites, bacteria, plants and worms, on

topics as diverse as development, pheromonal communication and meiosis. The overall theme of these studies remains the evolution of cooperation and conflict. The same logic can be used while studying the fate of paternally- and maternally-inherited genes during meiosis in *Caenorhabditis elegans* or the partitioning of reproduction in a wasp society. After all, this all has to do with tricks (be it at the cellular or organismic level) that evolved as a means to increase the transmission rate of genes over evolutionary time. An evolutionary perspective provides you with tools to understand many oddities that are found at the molecular, cellular and organismal levels.

Is it not dangerous to have so many interests? Yes and no. If you have many interests, there is of course the risk of not fully mastering any of the subjects you work on. To do good work, you thus have to associate with knowledgeable colleagues and good students. I believe that I have been lucky on both accounts. I also have been lucky to almost always keep excellent relationships with previous collaborators and students, which has helped immensely when I've needed advice in fields where I have limited expertise.

It seems that many of your students have been successful in science... Yes, most of my graduate students and postdocs are still in academia, and more than 20 of them currently hold permanent positions. I like to believe that their high success indicates that I provided them with an environment favourable for their scientific development. Now it has become almost a rule that my students, by the time they finish their PhD, are more competent than me in their field of research.

Is that not a bit disturbing? Not at all. Rather, I would think that it suggests I have been a good mentor, allowing students to develop their own line of research. Also, the wide range of interests in our group implies a lot of interdisciplinary work with people having very different backgrounds. The lab currently hosts students with backgrounds in molecular biology, ecology, ethology, computer science, bioinformatics, physics, and engineering. This diversity is very enriching and allows for many collaborations among group members.

What advice would you give to young scientists? More than anything, I would stress the importance of being critical of what you have been taught, and open to unexpected results. This can be illustrated by some recent discoveries in our lab on unusual modes of reproduction in ants. We found two ant species where workers are produced by sexual reproduction, while queens are all produced clonally from their mother and males clonally from their father. The funny thing about this system is that there is no longer any gene flow between the male and female gene pools, because their genes come together only in sterile workers. Other labs had similar data, but did not publish them because they did not make sense in light of what you find in textbooks (for example, queens produce sons that have none of her alleles at the microsatellite loci genotyped). I believe that this example unfortunately illustrates a common situation in science. Scientists have become too specialized and blind to potentially important findings if such findings do not fit their line of enquiry. Interesting scientific discoveries frequently do arise, however, from serendipitous findings. The important challenge is to be able to exploit unexpected results. Unfortunately, our current education systems do not sufficiently value originality and curiosity, the best example being provided by many funding agencies where of prime importance is the feasibility of the proposed studies rather than novelty of the work or the track record of the applicants (which is by far the best predictor of the quality of the work to be done). This is a real pity, especially for young scientists whose brains and energy are unfortunately too often devoted to get grants, have papers published in high profile journals and fit the too many requirements of their institutions to get tenured instead of conducting really risky and innovative research.

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Primer

Phagocytosis

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Phagocytosis is defined as the receptor-mediated engulfment of large (≥0.5 μm) particles into plasma membrane-derived vacuoles called phagosomes. Following scission from the plasma membrane, the phagosomes undergo a maturation process, sequentially fusing with endosomes and lysosomes, ultimately becoming phagolysosomes — highly acidic and hydrolase-rich organelles that degrade the internalized particles. This brief description is a gross oversimplification of a highly complex and precisely choreographed process. Indeed, phagosome formation and maturation have emerged as paradigms to investigate many key questions in cell biology, including signal transduction, cytoskeletal remodeling, membrane dynamics and trafficking, and even gene expression.

In higher metazoans, phagocytosis plays a central role in tissue maintenance and remodeling, by removing billions of apoptotic bodies and cellular debris that form daily. A striking example is provided by the specialized retinal epithelial cells that enable normal vision by clearing senescent fragments shed by photoreceptor cells. However, the truly professional phagocytes are cells of the innate immune system, such as the haemocytes of insects, and the macrophages, neutrophils and dendritic cells of mammals. The professional phagocytes of vertebrates not only hunt, engulf and kill pathogens, but also help to coordinate the adaptive immune response by presenting antigens to lymphoid cells.

Phagocytosis begins when specialized receptors engage cognate ligands on the target particle. Some phagocytic receptors recognize determinants inherent to the particle; mannose receptors and dectin-1, which bind microbial polysaccharides, belong to this category. Others interact with host serum factors (opsonins) that deposit on the surface of the invading particles. Opsonic receptors are