# Preface

The 4-week school held in July 2014 addressed current approaches and concepts for understanding the relation between the regulation of gene expression, synthesis and structural assembly of proteins, the forces that dictate the structural, dynamic and functional properties of protein complexes and the properties of cells and their interactions in the formation of tissues and organisms. Students and early stage researchers from different fields of biology, physics and chemistry attended these multidisciplinary lectures. Several practical courses and seminars were also organized.

## From molecules to cells and organisms

With the generalized application of genomics and proteomics the molecular level has become an important aspect of biology. At the core of molecular biology is the structure–function hypothesis. In recent years, new imaging approaches allowing the visualization of single molecular complexes within cells have paved the way for further understanding of biological processes at the molecular level. Integrating the detailed molecular description of individual proteins or complexes into the cellular environment and understanding the structures, architectures and interactions that guide fundamental cellular pathways and cellular responses to external stimuli are major challenges for the near future. At higher levels of organization, organisms that adopt precise shapes are built up from cells. Although several signaling pathways that guide development have been identified, many aspects cannot be explained just by the chemical nature of the molecules involved. Indeed, in several examples, physical forces have been shown to be responsible for the shapes of cells or cellular compartments and cellular the assemblies forming organisms. The generation of these forces is often related to structural assemblies of macromolecules and their dynamical rearrangement.

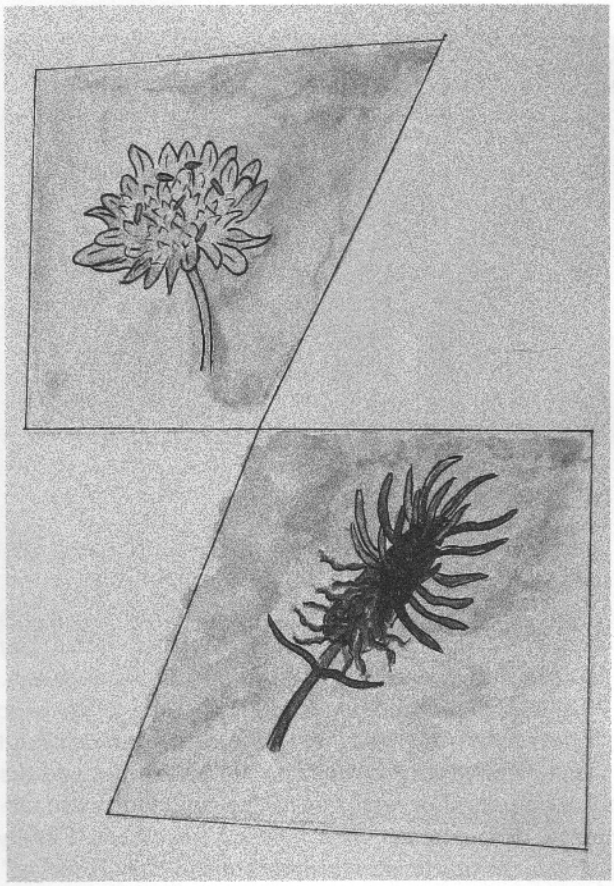
The context of this school is the emerging field of integrated biology (biomolecule↔cell↔organism) in the light of recent advances in cellular biophysics and modeling approaches. In particular, bridging data from different types of approaches and the provision of information on various scales (space and time) are far from well established. The aim of the school was to teach these new topics. The audience comprised structural biologists looking towards cell and organismal biology, biologists interested in the molecular view of biological pathways and physicists interested in biological processes for both the biology and the physics underlying the biology. Understanding the principles behind each method, and also their limitations and the complementarity between methods, was an important aim of the lectures. A large number of the interdisciplinary lectures were on subjects at the frontier between biology and physics.

## A new way of thinking and teaching biology: a combination of interdisciplinarity and cutting-edge methods

Important new developments are expected in the coming years that may well introduce paradigm shifts in biological science. This school aimed to prepare participants to become major actors in these breakthroughs. It looked at opening a new way of teaching (and thinking) biology, bridging physics and biology beyond current biophysics. This book contains the proceedings of the main lectures given at the school. After an introduction to cell biology in Chapter 1 (Franz Bruckert), the power of integrated approaches from molecules to cells and organisms, including imaging, biophysics and structural biology, is illustrated through two examples. In Chapter 2 Hans-Georg Kräusslich and colleagues, demonstrate how the interactions between HIV and host cells can be deciphered, while in Chapter 3 François Parcy and his team highlight how floral development can be understood from the gene to the flower. Concepts in physics such as thermodynamics, important for understanding the behavior of biological macromolecules in solution, are recalled by Giuseppe Zaccai in Chapter 4, and in Chapter 6 Albert Guskov and Dirk Jan Slotboom show how some aspects of these behaviors can be experimentally characterized. Emerging and novel approaches such as in-cell NMR are described by Enrico Luchinat in Chapter 5. The next part of the book is dedicated to plant development, from innovative biological approaches, described by George Coupland in Chapter 7, to experimental evidence of the role of forces in plant development by Olivier Hamant in Chapter 8, and mathematical modeling based on this experimental knowledge by Christophe Godin and colleagues in Chapter 9. Forces also drive the shapes of membranes and their remodeling, as described in Chapter 10 by Michael Kozlov, Winfried Weissenhorn and Patricia Bassereau. These authors nicely illustrate the complementarity between experiments exploring physical parameters of proteins embedded in membranes, theoretical modeling based on physical principles and applications to a biological question, namely the budding of viruses out of host-cell membranes. The most predominant molecules in cells are proteins, and their shapes but also their conformational changes are responsible for their functional properties, as analyzed in Chapter 11 by Yves Gaudin. Membrane proteins are naturally embedded in a lipid bilayer with mesoscopic properties. Their handling necessitates special treatments, as shown by Christine Ziegler in Chapter 12. François Dehez, in Chapter 13, illustrates how such studies have benefited from an ensemble of tools based on molecular simulations in the light of experimental work. Chapters are grouped into six parts as indicated in contents list to facilitate structured reading. Altogether, the chapters show how the examination of a biological system from different viewpoints in a multidisciplinary fashion often brings new ideas to controversial arguments. Please note, that the online version of this book provides color figures that will be helpful to the reader.

## Science and art

Observation was a key element in the development of biology, and more specifically botany. By drawing what they observed in the field, botanists could deduce important features in plants and define the various classifications. Nowadays, structural biologists spend a substantial amount of their time examining three-dimensional protein



structures on a computer screen in order to relate structural features to function by comparison with structures that are already known. Serge Aubert guided the participants through the alpine garden of the Col des Montets, illustrating the recent findings on molecular-level adaptation of plants to harsh mountain conditions that he presented during the conference. Anja Kieboom organized a few afternoon sessions during which she demonstrated some basic techniques for drawing flowers. These practical sessions were very successful and contributed to social team building. Graphic printouts of protein structures as well as plant drawings are not only informative, they are also intended to be attractive in themselves. Art in science contributes to the message that scientists aim to deliver.

While we were finishing this book, our colleague Serge Aubert died. Serge was a very talented and passionate scientist and he liked to share this passion with students. We would like to dedicate this book to him.