Preface

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Physicists have been interested in biology for a long time. In several chapters of this book the historical contributions of Hooke and Vans Leeuwenhoek to biology in the seventeenth century are rightly mentioned. The identification of the cell as the building block of the living world results directly from the development of the optical microscope they pioneered. More recently, during the twentieth century, physicists contributed to about one major experimental contribution per decade and one conceptual contribution every fifteen years. The explosion of the research activity at the interface between physics and biology over the last twenty years thus follows a long tradition of interest of physicists in the living world. But the scale of this investment is new. From the femto-second in the study of mechanisms of bio-catalysis to the geological time in the modeling of evolution processes, from the fraction of a nanometer in protein structures to macroscopic scales in developmental biology or to the continental scales of population dynamics, physicists have shown an insatiable curiosity. They also proved that a physicist's approach is useful when it goes with a good collaboration with biologists, as explained and practiced very well by the coordinators of this work. Michèle Leduc and Michel Le Bellac were right to ask Jean-Francois Allemand and Pierre Desbiolles to coordinate a book accessible to everyone and that can illustrate the impressive results that have been accumulated these past twenty years at the physics-biology interface. The explosion of the activity and associated success deserve to be popularized.

I can imagine the hesitations of Jean-François and Pierre upon choosing the content of the book. Some omissions were obvious: who now realizes that the electrophoresis, centrifugation, mass spectrometry were once research subjects in physics? These techniques have become daily tools in biology. The same goes for electron microscopy, crystallography and nuclear magnetic resonance: they became part of "structural biology". The beautiful ultrafast optical experiments designed to study the mechanisms of intimate biocatalysis could have been chosen, but eminently physical, they seek to answer more "chemical" than physical questions. Jean-François and Pierre could also have thought of the adaptation processes in biology, the physics of protein networks, statistical physics of folding proteins or RNA, evolution, bacterial resistance to antibiotics, the physics of tissues, etc. The list is long.

Yet the choice of Jean-François and Pierre is logical and consistent. Two types of studies have seen particularly dramatic evolutions during the last two decades: the single molecule mechanical studies and physical approach of the cell. It was then natural to introduce the concepts needed to understand these aspects: basic concepts of cell biology, leading technologies starting from fluorescence microscopy, which has contributed so much to biology. Since the discovery of "green fluorescent proteins" biologists know how to use them as a "reporter" for studying specific mechanisms. The presentation, while remaining very affordable, describes the latest developments that give access to information well below the theoretical limits of the optical resolution of microscopes. But the reader must be reassured, the laws of physics are met! With this new knowledge, it is natural to try to understand the single molecule experiments. In fact the first single molecule experiments have been carried out on membrane ion channels in the 1970s. Significant improvement of the measurement of low currents opened this field of investigation. Similarly, in the 1990s, measurements of weak forces, typically in the pico-newton range, and visualization of single molecules have paved the way for a series of great experiments on the exceptional mechanical properties of molecules. Again, the presentation, while keeping the simplicity required for a wide audience, goes to the most recent technical developments in the field. The example of DNA mechanical properties shows the high degree of knowledge that one is now able to obtain on this molecule, which is the custodian of our identity. And this is not an esoteric game for physicists! We need to know all these properties if we want to understand the exquisite mechanisms of life! The next logical step is then to use single molecule experiments to study "molecular motors". These molecules are real engines: they consume chemical energy, and are able to provide mechanical work. Some, like the spectacular rotatory motor named F1 ATPase can also work in reverse, and it is even its natural physiological function: it converts mechanical energy into chemical energy. The RNA polymerase provides both mechanical work and causes very specific chemical changes. The concepts of thermodynamics apply quite well, provided that we use the correct averaging, and the study of fluctuations proves to be very rich. If one of the engines described in this chapter is deficient, that's life which disappears! This field of engines and of "machinery" active on DNA and RNA has taken a great importance and several chapters could have been devoted to this subject. Jean-François and Pierre have kept a reasonable size while providing a good measure of the importance of the addressed issues. It was then natural to go to the cellular level. If the engines are extremely complex, the cell is infinitely more. In continuation of the previous chapters, the authors have chosen to focus the scope of the book on the mechanical properties and cellular movement, as both are more accessible to the physicist. They introduce the intricacies of a world where viscosity dominates (life at low "Reynolds number") and those of the cytoskeleton with or without engines! The cell as a "homunculus"? Not quite, but it contains all the information necessary for the formation of an individual! From the cell to the organ: is there something nobler than the brain? The choice was again quite natural. I remember Pierre-Gilles de Gennes, explaining in the preamble of a remarkable lecture, on the functioning of the brain, that many famous physicists investigated in vain this subject in their old years. Here, physicists in the prime of life describe the spectacular progresses achieved in recent years in the knowledge of the brain! After reading this chapter you will be convinced that soon we will understand how it works. Most of the brain processes information conveyed by peripheral detection systems. The most sensitive of them are the auditory system and the surface shape detection system, skin for primates, whiskers for rodents. You will learn that the ear is not only a sound detector but also an emitter, that it is strongly non-linear and that it can detect better than its own noise! You will also learn why the fingerprints are essential for assessing a surface roughness and what whiskers have in common with fishing rods! Mainly oriented towards experiments, it was necessary that this book had at least one chapter describing a theoretical advance. Again there were many possible choices. Optimization of search strategies from molecular to animal scales is a good example of the use of statistical physics to concrete problems and it illustrates very well the type of concepts that theory introduces. After reading this chapter you will not go search your lost keys under the only shining street lamp! You will take example from your dog, running in one direction with conviction, and seemingly random rummaging for some time and so on! I'm not sure this technique replaces a good memory, but you will see it is very effective on many scales. I encourage you to dive into this book. You will find a strong body of information essential to the understanding of life and I am convinced that you will be even more eager to learn after reading it. It was designed exactly for this purpose, I think.