Preface

The long-lasting commonplace that physics is the science that studies inert matter while biology is the science that studies living matter have fallen into disuse for several years. Even the misconception that physics adopts a reductionist approach to the study of complex systems has now lost its meaning.

The physics that was the first discipline to make a massive use of the language of mathematics defined a methodological protocol for the study of complex systems that was recently also adopted by systems biology and which led to the birth of computational biology. The use of ordinary differential equations for the modelling of network dynamics, the use of advanced statistical concepts for the inference of models and parameters of biological process models as well as for the interpretation of experimental data is now widespread in biology.

However, in order to build mathematical models of natural phenomena, physics and in particular theoretical physics are not restricted to the aforementioned tools but employ tools and concepts of mathematical logic, algebra, general topology, analysis and measurement theory and differential geometry. Theoretical physics uses these tools to describe mathematically the representation of an observable phenomenon or of a conjecture. The contribution brought by theoretical physics to systems biology is twofold: on the one hand it offers abstract representations that are at the base of models or that can be useful for validating a conjecture, and, on the other it identifies the mathematical tools with which to describe these representations. Modern biology is essentially systems biology, but, above all, it is a quantitative discipline. This new role of biology allows the convergence of mathematics, physics and life sciences in general.

This book focuses on two branches of theoretical physics that prove promising in the description of the static and dynamic properties of biological systems: quantum physics and statistical mechanics. Recent experiments have confirmed the occurrence of quantum phenomena in many biological processes, but, above all, quantum physics and statistical mechanics inspire computational models of network dynamics at each scale.

The book is addressed both to those readers with a mathematical and physical background facing the world of modern systems biology, and to those readers with a biological and/or computational background who wish to explore and take inspiration from the models of theoretical physics. The book does not want to be a textbook of quantum biology, nor does it want to deepen specific case studies, but rather to provide the reader with the basic concepts of quantum physics and statistical mechanics of useful application in the computational systems biology. The first Chapter introduces the reader to quantum mechanics and presents the most common biological processes and systems governed by quantum phenomena. The second Chapter introduces the concepts of statistical mechanics that have become the theoretical foundations of the modern biological network simulation algorithms. The third Chapter presents the measures of network centrality that are inspired by models of physical systems. The fourth Chapter presents the application contexts of these centrality measures and the best known algorithms of quantum computating, currently implemented by many IT systems, and which have recently proved to operate in many processes regulating the energetic efficiency of various biological systems. The fifth Chapter summarizes the motivations that are leading towards an increasingly fruitful convergence between theoretical physics and systems biology and figures out some future perspectives.

The book proposes thirty exercises for the self-assessment of the understanding of the its contents, and useful also for didactic purposes. The level of mathematical knowledge required to understand the contents of the book and solve the exercises is that provided in the basic university courses common to the various scientific disciplines.

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