Multiple Aspects of DNA and RNA: from Biophysics to Bioinformatics: Lecture Notes of the Les Houches Summer School 2004

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This book is dedicated to the multiple aspects, that is, biological, physical and computational of DNA and RNA molecules. These molecules, central to vital processes, have been experimentally studied by molecular biologists for five decades since the discovery of the structure of DNA by Watson and Crick in 1953. Recent progresses (e.g. use of DNA chips, manipulations at the single molecule level, availability of huge genomic databases...) have revealed an imperious need for theoretical modelling. Further progresses will clearly not be possible without an integrated understanding of all DNA and RNA aspects and studies.

The book is intended to be a desktop reference for advanced graduate students or young researchers willing to acquire a broad interdisciplinary understanding of the multiple aspects of DNA and RNA. It is divided in three main sections:

The first section comprises an introduction to biochemistry and biology of nucleic acids. The structure and function of DNA are reviewed in R. Lavery's chapter. The next contribution, by V. Fritsch and E. Westhof, concentrates on the folding properties of RNA molecules. The cellular processes involving these molecules are reviewed by J. Kadonaga, with special emphasis on the regulation of transcription. These chapters does not require any preliminary knowledge in the field (except that of elementary biology and chemistry).

The second section covers the biophysics of DNA and RNA, starting with basics in polymer physics in the contribution by R. Khokhlov. A large space is then devoted to the presentation of recent experimental and theoretical progresses in the field of single molecule studies. T. Strick's contribution presents a detailed description of the various micro-manipulation techniques, and reviews recent experiments on the interactions between DNA and proteins (helicases, topoisomerases, ...). The theoretical modeling of single molecules is presented by J. Marko, with a special attention paid to the elastic and topological properties of DNA. Finally, advances in the understanding of electrophoresis, a technique of crucial importance in everyday molecular biology, are exposed in T. Duke's contribution.

The third section presents provides an overview of the main computational approaches to integrate, analyse and simulate molecular and genetic networks. First, J. van Helden introduces a series of statistical and computational methods allowing the identification of short nucleic fragments putatively involved in the regulation of gene expression from sets of promoter sequences controlling co-expressed genes. Next, the chapter by Samsonova et al. connects this issue of transcriptional regulation with that of the control of cell differentiation and pattern formation during embryonic development. Finally, H. de Jong and D. Thieffry review a series of mathematical approaches to model the dynamical behaviour of complex genetic regulatory networks. This contribution includes brief descriptions and references to successful applications of these approaches, including the work of B. Novak, on the dynamical modelling of cell cycle in different model organisms, from yeast to mammals.

. Provides a comprehensive overview of the structure and function of DNA and RNA at the interface between physics, biology and information science.

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