Acta Cryst D
STRUCTURAL
BIOLOGY

ISSN 2059-7983

Biophysics of DNA. By Alexander Vologodskii. Cambridge University Press, 2015. Pp. viii+254. Hardback. Price GBP 75.00, USD 120.00. ISBN 9781107034938

Mark C. Williams*

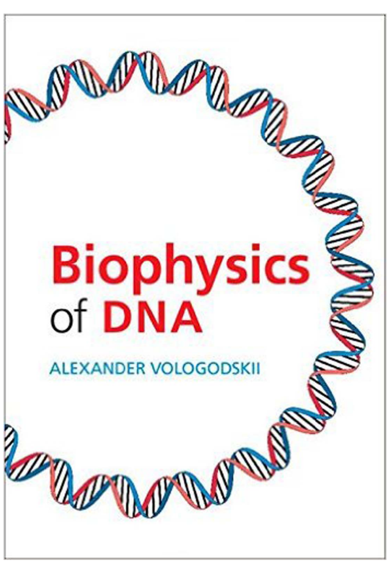
Department of Physics, Northeastern University, 111 Dana Research Center, 110 Forsyth Street, Boston, MA 02115, USA. *Correspondence e-mail: mark@neu.edu

Keywords: book review; DNA biophysics.

Biophysics of DNA provides a clear and relatively concise summary of the current state of our understanding of the fundamental problem of DNA biophysics. The focus is on the specific results of experimental measurements and the comparison of these results with phenomenological models and some simulation methods. It treats all aspects of DNA biophysics, from the polymer nature of DNA to the details of its interactions with proteins *in vivo*. Although much of the discussion of each problem can be understood without a detailed analysis of the models presented, to fully appreciate the book one should have some experience in analyzing statistical mechanics models at an introductory level, such as that presented in a modern physics or physical chemistry course. To reproduce some of the model results, it would also be helpful to have taken a full course in thermodynamics and statistical mechanics.

The book begins by treating DNA as a polymer and discussing how well specific polymer models, such as the wormlike chain model for double-stranded DNA, describe important properties of DNA. While such treatments are very well summarized in more complete texts such as the three volumes on *Biophysical Chemistry* by Cantor & Schimmel (1980), the treatment here is sufficient to fully understand the implications of DNA's polymer properties for its behavior in most experiments. One can always refer back to Cantor and Schimmel for the details if needed. Even here when discussing the general properties of DNA it is very important that this book has been so recently written, as much progress has been made in our understanding of DNA biophysics since the final edition of Cantor & Schimmel (1980).

Biophysics of DNA has the distinct advantage that it is focused purely on DNA in its many forms rather than just including DNA while considering a wide range of biopolymers. This allows the author to include all aspects of DNA behavior in significant detail, providing a definitive reference that can be used to determine the state of our understanding of any aspect of DNA relatively quickly. The referencing is very well done, allowing the reader to immediately determine which references are most relevant and give a reliable answer to the question being posed. There are very few people, if any, who are as qualified as the author to address this subject, and this is apparent in his ability to quickly identify the most important experiments in each area of DNA biophysics and let the reader know which specific experiments most reliably determine a specific property of DNA, while also pointing out the weaknesses of other less accurate experiments. Importantly, when a misleading result has been obtained in the past on a specific DNA property, the author identifies the work and explains why the result is incorrect. For example, the author points out that many early experiments on intercalation of DNA (and other DNA properties) used samples that contained a mixture of DNA lengths, leading to inaccurate results. This provides the reader not only with the author's opinion about specific studies, but also provides the reader with the ability to distinguish between other reliable and unreliable results on his or her own.



I very much appreciated the complete breadth of the book, which really does cover every important aspect of DNA to some extent, as well as the limited depth for many of the problems treated in detail elsewhere. Examples include DNA–protein interactions, which could easily double the length of the book, and interactions of small molecules with DNA. Both of these topics are treated in depth in the much longer text by Bloomfield *et al.* (2000), and are appropriately updated here without going into very much detail. Because of the choice of limiting the treatment of these topics, the book can be read like a novel from beginning to end. When finished, the reader will have a fairly complete understanding of DNA and will be armed with all of the information needed to knowledgably search the literature to analyze a specific problem in more detail.

Biophysics of DNA begins appropriately with a discussion of DNA structure. Although we are all familiar with the standard B-form DNA double helix, this helical structure is described in detail and the author clarifies the issues surrounding the actual DNA helical twist, which was under some debate a few decades ago. Although early crystal structures identified the helical twist of DNA to be 10 bp per turn, solution studies by NMR indicate that the helical twist is actually 10.5 bp per turn. The author attributes the difference to crystal-packing effects, making it clear to the reader which aspects of the structural measurements are reliable. The author also spends a lot of time on alternate forms such as A-form and Z-form, and also identifies alternate base-pairing configurations including G-quadruplexes. These states are described in sufficient detail so that the reader will know exactly what conditions could be expected to form such alternate structures. In addition to a detailed discussion of DNA structural states, there is also a lot of detailed analysis of transitions between these states, as well as the transition to the denatured single-stranded state. Understanding of these transitions does require familiarity with statistical mechanics.

Overall, the treatment of polymer models and transitions between states is done very well at the level of phenomenological models and simple simulations such as Brownian dynamics methods, which is often what is needed to obtain a useful picture of DNA interactions. Methods such as molecular-dynamics modeling are addressed only cursorily by identifying one study that incorrectly determined DNA sequence-dependent twist angles, and this is probably the greatest weakness of the book. Although the author is correct in stating that the results of MD simulations must be compared with experiments, there are still MD studies that reveal new information on DNA interactions. However, the field of DNA simulations with MD is vast and it would be difficult for the author to make definitive statements about a large number of DNA studies using this method. As it stands, readers should look elsewhere to determine the state of MD simulations of DNA.

The last chapter of the book is entitled ‘Circular DNA’, and it occupies 65 pages of the 250-page book. At first I thought this was excessive, but after reading the chapter it is clear that all of the topics of the previous part of the book have to be revisited to some extent in the context of DNA topology. This section treats in detail how DNA topology is characterized and how changes in topology affect the occupancy of DNA states and transitions between these states. There is a very nice detailed discussion of DNA topology in cells and how topoisomerases resolve topological problems such as knots or accumulation of positive or negative supercoiling owing to molecular motors such as RNA polymerase. As is done throughout the book, the discussion is grounded in important thermodynamic considerations such as why some topoisomerases require energy to change the DNA linking number, while others do not.

I highly recommend this book to any researcher who is studying DNA or its interactions, or who studies anything that may interact with DNA. The level is such that one does not need to be familiar with DNA properties to read it, but after reading it from beginning to end one will have a real understanding of how DNA is expected to behave under almost any experimental conditions. I found it a pleasure to read, and despite having worked in this field for almost 20 years I still gained a more complete understanding of many aspects of DNA biophysics.

References

Bloomfield, V. A., Crothers, D. M. & Tinoco, I. (2000). *Nucleic Acids: Structures, Properties, and Functions.* Sausalito: University Science Books.

Cantor, C. R. & Schimmel, P. R. (1980). *Biophysical Chemistry.* San Francisco: W. H. Freeman & Co.