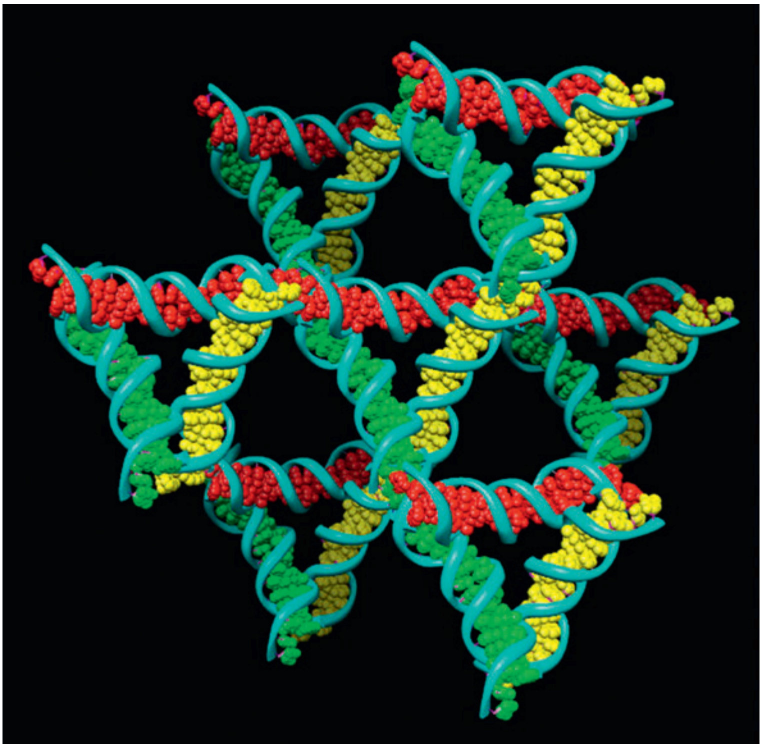
Structural DNA Nanotechnology

Written by the founder of the field, this is the first text of its kind, providing a definitive introduction to structural DNA nanotechnology. Readers will learn everything there is to know about the subject from the unique perspective of the leading expert in the field.

Topics covered range from origins and history, to design, experimental techniques, DNA nanomechanics devices, computing, and the uses of DNA nanotechnology in organizing other materials.

Clearly written, and benefiting from over 200 full-color illustrations, this accessible and easy-to-follow text is essential reading for anyone who wants to enter this rapidly growing field. It is ideal for advanced undergraduate and graduate students, as well as for researchers in a range of disciplines including nanotechnology, materials science, physics, biology, chemistry, computational science, and engineering.

NADRIAN C. SEEMAN is the founder of the field of structural DNA nanotechnology. He is currently the Margaret and Herman Sokol Professor of Chemistry at New York University, and is the recipient of a number of awards including the Sidhu Award, the Feynman Prize, the Emerging Technologies Award, the Rozenberg Tulip Award in DNA Computing, the World Technology Network Award in Biotechnology, the NYACS Nichols Medal, the SCC Frontiers of Science Award, the ISNSCE Nanoscience Prize, the Kavli Prize in Nanoscience, the Einstein Professorship of the Chinese Academy of Sciences, a Distinguished Alumnus Award from the University of Pittsburgh, and a Jagadish Chandra Bose Triennial Gold Medal from the Bose Institute, Kolkata. He is also a Thomson Reuters Citation Laureate and a Fellow of the American Crystallographic Association.



"The first of its kind, it will undoubtedly become the Bible for DNA self-assembly and nanoscale 3D printing. The visionary father of the field of structural DNA nanotechnology, Ned Seeman, lays out its principles lucidly and with superb graphics to match. For anyone curious about synthetic DNA technologies or in connecting these principles with current research, this is a must-have-must-read."

Yamuna Krishnan, University of Chicago

"Ned Seeman invented and pioneered structural DNA nanotechnology in the 1980s and he has been in the front line of the field since then. For many years he was alone in the field and it was considered as a mere curiosity by many scientists and ignored by most others. However, during the past 15 years the field has blossomed and today constitutes a unique approach to organize matter at the nanoscale by self-assembly. The book gives the best possible first-hand insight into this field and its amazing development."

Kurt Vesterager Gothelf, Aarhus University

"The book is an inspiring insight into the design and development of DNA motifs used as building blocks, molecular devices, and information processing tools. It is stimulating to both students and professionals with detailed introduction to blueprint composition and experimental strategies. These strategies have provided an exponential growth in the subject and established the field of DNA nanotechnology."

Natasha Jonoska, University of South Florida

"The pioneer of the field of structural DNA nanotechnology, Ned Seeman, presents the foundations, the state-of-the-art, and the stories leading to the development of this fascinating field that today allows researchers around the globe to control matter with sub-nanometer precision by means of self-assembly. Students in nanoscience-related fields will greatly benefit from this book, and for researchers planning to work in the fast growing field of DNA nanotechnology, it is a must."

Tim Liedl, Ludwig-Maximilians-Universität

"This is a wonderful book. It systematically covers all major aspects of DNA nanotechnology, a rapidly evolving research field. Though there are multiple books and reviews that cover the current topics of this field, this book is the only one that provides insights on how this field originated, developed, differentiated, and flourished. I enjoyed reading this book particularly because of its emphasis on structural bases of DNA molecules – quite often neglected by people now. I fully expect that this book will serve as a handy reference for practitioners in the field of DNA nanotechnology, as a textbook for graduate students and undergraduate students, and also as a historic book for people studying science history. For sure, this book will be the textbook for my graduate course, bionanotechnology, at Purdue University."

Chengde Mao, Purdue University

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Contents

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Nadrian C. Seeman
Frontmatter
More information

Preface

I was approached by many publishers in the early years of this century to write a book about structural DNA nanotechnology. At the time, I was working on the central goal of my program, the control of the assembly of matter in three dimensions. I was rightfully afraid that I could get distracted from achieving that goal, so I turned them all down. Ultimately, in 2009, we published the 3D structure of a self-assembled DNA lattice, and I felt it was time to put my stamp on the field. In 2010, Cambridge University Press agreed to publish the book, I applied for and got a Guggenheim Fellowship, and I took my first sabbatical, to write it.

During the twentieth century, the field and what we were doing in my laboratory were kind of the same thing, but as the new millennium dawned, interest in DNA nanotechnology grew, and many laboratories were attracted to the field. The directions that the field has gone are not entirely reflective of my take on the issue of controlling structure with branched DNA motifs. I am interested in making lattices, not objects, but that is the main thrust of the field these days, largely owing to the popularity of DNA origami and DNA bricks. Both of those approaches are themselves consequences of the dropping price of DNA, a sort of Moore's law of DNA synthesis.

Thus, this book is heavily laden with the things that I do and that I have thought about since 1980. These include topology, sequence control, and other issues that are not thought about much today. I was about 2/3 of the way through the book at the 3/4 point of my sabbatical. At that point, I suffered an injury that kept me from finishing the book until my deadline approached at the end of 2014. The field has grown substantially from 2011 until now, but I never saw this monograph as a big review article containing the latest and greatest. Thus, the final two chapters are really just highlights of their topics, and the reader should not expect them to be even close to comprehensive.

Those most directly responsible for my getting to this point at all are the John Simon Guggenheim Foundation, whose financial support is gratefully appreciated, and my old friend Greg Petsko, who made his San Francisco house available to me during the writing of this volume. I have to thank Bruce Robinson for coming down the hall one day in late 1978 and asking me to build a model of a Holliday junction. Everything followed from that moment and the moment on a plane to Hawaii in 1979 when Greg mentioned a scheme to prepare hemoglobin intermediates. I should also thank Kathy McDonough for listening to me ramble on during a conversation when I had the idea for immobile junctions built from oligonucleotides. The late Malcolm Casadaban asked me if I could make immobile junctions with more than four arms; when I figured out that the answer was "yes," it wasn't too long until I wandered off to the Campus Pub and had the epiphany described in Chapter 1. Neville Kallenbach facilitated the earliest days of this work, both financially and collaboratively; if he hadn't brought me to NYU in 1988, I doubt much of this work would have happened. Jim Canary has supplied organic chemical knowledge when it was needed, as has Paramjit Arora. There have been others involved, but I can't list all my friends. However, my students and postdocs were essential to the development of the field, particularly Junghuei Chen, Chengde Mao, and Hao Yan. Nothing happens in my laboratory without the help of Ruojie Sha, and there is no way to express my appreciation to him adequately. Over the years, Natasha Jonoska, Erik Winfree, Paul Rothemund, and Bill Goddard have been invaluable colleagues. Special thanks are due to Paul Chaikin for pushing the self-replication project. I thank Hendrik Dietz for Figure A-3 and David Goodsell for Figure 7-25.