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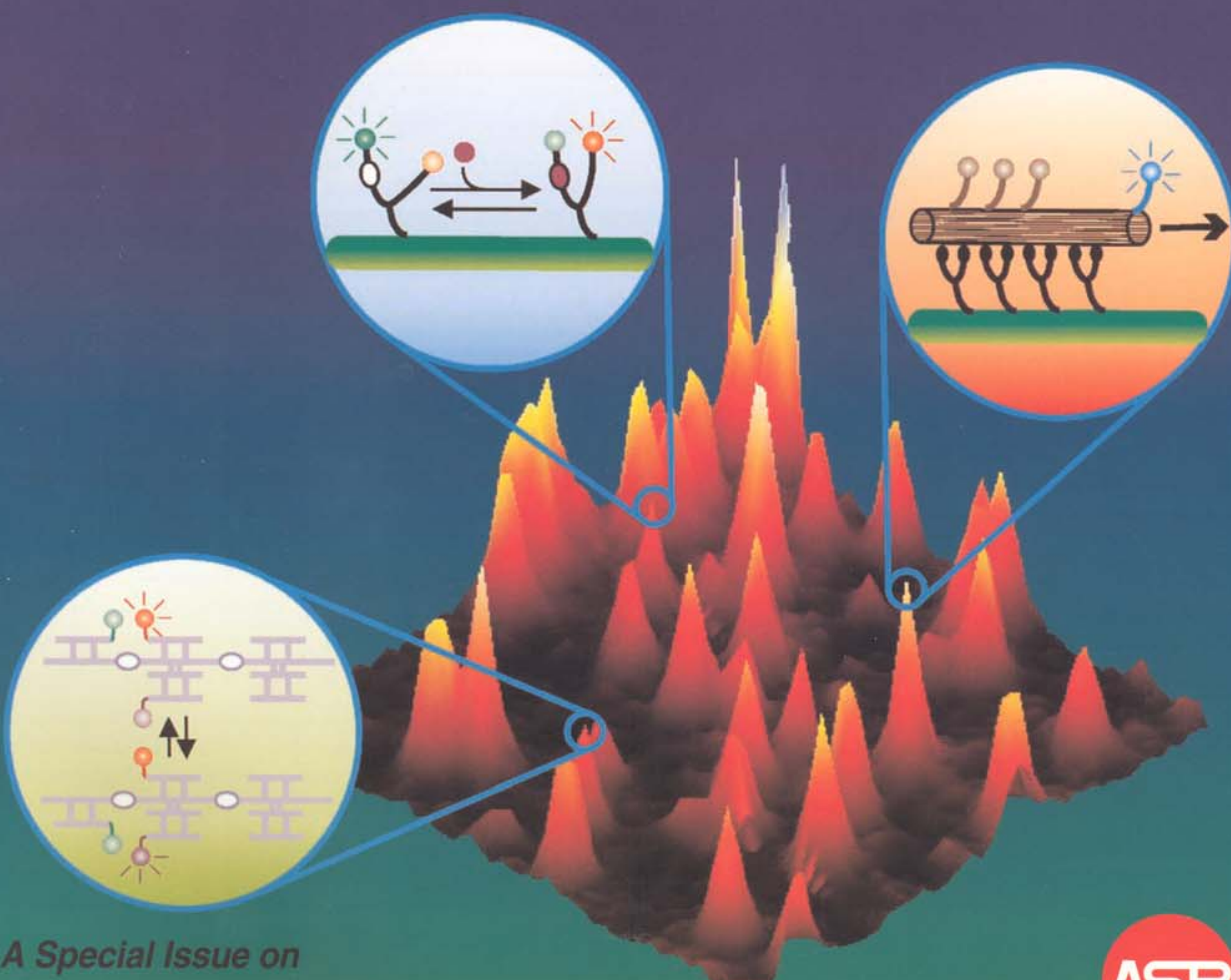

A Special Issue on

Bionanotechnology

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PREFACE

A Special Issue on Bionanotechnology

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Nanotechnology is concerned with the creation and manipulation of functional structures having dimensions ranging from a few to hundreds of nanometers.[1] This size range encompasses a scientific and technological gap. The most effective strategy for the development of viable new technology is, therefore, to close this gap at both ends through the use of the "top-down" or "bottom-up" approaches.[2] A top-down approach refers to the production of nanoscale structures by breaking, cutting, or etching techniques, whereas a bottom-up approach refers to the assembly of structures atom-by-atom or molecule-by-molecule.[3–6] A general and simple bottom-up approach used in bionanotechnology relies upon the cooperative interaction of individual macromolecules which spontaneously assemble in a predefined manner to form a larger two- or three-dimensional structure. Self-assembly can be viewed as either template or nontemplate in nature.[4, 6–8] Template assembly involves the interaction of biomacromolecules under the influence of a specific sequence, pattern, structure, external force, or spatial constraint. In contrast, nontemplate assembly involves the formation of a larger structure by individual components without external influence.[4, 6–8]

Living systems contain a wide variety of nanomachines or ordered structures in the nanometer range, including motors,[9–12] arrays, pumps, membrane pores, and valves. The novel and ingenious design of such naturally occurring machines has inspired the development of biomimetic nanodevices.[13, 14] Much current research has been devoted to making these machines perform as viable and effective entities outside their native environment. Once this is achieved, these nanomachines or ordered structures could be further exploited for the building of intricate arrays and chips, the gearing of other nanoparts, the operation of nanoelectromechanical systems (NEMS),[15] the activation of molecular sensors, or the driving of molecular sorters.[16] They might also be used as novel and complex actuators[17] in other revolutionary electronic and optical devices.[18] Nanotechnology can be expected to play a critical role in many scientific disciplines including chemistry, physics, biology, material science, engineering, and computer technology. In the medical field, application of these structures and their derivatives include the detection of pathogens, the diagnosis of diseases, and the delivery of drugs or other therapeutic genes.[7, 19–21]

The area of bionanotechnology includes both mechanistic studies of biological systems using nanotechnological approaches and the utilization of biomacromolecules in nanotechnological applications.[9, 12] Biological macromolecules, e.g., DNA,[22, 23] RNA,[4, 8] and protein,[13, 24] have inherently distinct features at the nanometer scale that could serve as unique and powerful building blocks for the bottom-up fabrication of nanostructures and nanodevices.[6, 25] In this issue, many aspects of bionanotechnology are discussed. The application of DNA in nanotechnology is reviewed by Mao and coworkers,[22] while the application of protein in nanotechnology is reviewed by Sleytr and coworkers.[24] Their reviews reveal new frontiers and provide inspiring insight for future research. Rueda and Walter[26] introduce the exciting application of single-molecule FRET for structure and functional analysis of these biomacromolecules.

The review by Guo[7] and the review by Jankowsky and coworkers[10] explore the applications of RNA in bionanotechnology. What makes RNA a particularly interesting candidate is the amazing diversity evident in its structure and function. RNA can be designed and manipulated with both a level of simplicity characteristic of DNA and versatility in structure and function similar to that of proteins. Typically, RNA molecules contain a large variety of single stranded loops for inter- and/or intra-molecular interaction. These loops can serve as mounting dovetails, thus obviating the need for external linking dowels in fabrication and assembly.[4, 8]

This special issue also includes four articles by Serwer,[27] Stockley,[28] Dragnea[29] and their coworkers, and

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Guo[7] concerning the use of viral components in nanotechnology. The size of viruses is typically between tens to hundreds of nanometers. Viruses also contain a wide variety of nanomachines and ordered structures including motors,[11,30] arrays, pentons, and hexons. The novel and resourceful designs of viral particles and structural components have long inspired the development of biomimetics. Viral components and assembly intermediates are exciting building blocks for nanotechnological and bionanotechnological applications.[20,31,32]

Another important area of interest in current nanotechnology is the synthesis of patterned arrays for technological applications. Arrays can be created that function as computerized memory elements or as ultra-high density data storage systems. They can also be engineered to serve as chips in the diagnosis of diseases. Ordered nanocrystals have already been assembled into superlattices by techniques such as colloidal crystallization, macromolecule self-assembly, complementary interactions, and patterned etch pits. Various applications involving replication, molding, embossing, and other related techniques have been emerging allowing for the utilization of a variety of materials to improve diversity and to enhance the resolution of nanomaterials. Five articles in this issue by Mao,[22] Sleytr,[24] Guo,[7] Zhang,[33] and Janisch[13] and their coworkers are related to array constructions. These arrays that are made up of biomolecules could be further converted into solid materials with the aid of metal spray or replica technology.

This special issue is devoted to bionanotechnology and its applications. Nanotechnology is an innovative and exciting tool to study traditional bio-systems, while biomacromolecules are significant building blocks for nanomachines and nanodevices.

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ABOUT THE GUEST EDITOR

Dr. Guo is a Professor of Molecular Virology and Biomedical Engineering at Purdue University where he serves as the Director of the Lab of Gene Therapy. His research expertise lies in viral DNA packaging and RNA biochemistry. He has been working on bottom-up assembly of biomacromolecules in nanoscale for more than twenty years. For example, he constructed an *in-vitro* phi29 DNA packaging motor (the most powerful biomotor studied to date) (*PNAS*, 1986); discovered the motor pRNA (the viral RNA that binds ATP) (*Science*, 1987); and served as the guest editor of the *Journal Viral Assembly* in 1994. However, he has not used the word "nanotechnology" until recently. Other pioneering work includes his demonstration that RNA can serve as building blocks for the construction of devices in nanotechnology. His latest contribution is the application of RNA nanotechnology for gene or drug delivery to treat cancers and viral-related diseases and for pathogen detection. His lab is the first to assemble infectious dsDNA virions in the test tube using synthetic components and purified recombinant nanomotors. His finding that pRNA binds ATP and forms a hexamer to gear the phi29 DNA-packaging motor suggests that RNA might play a role that protein enzymes (such as helicase) play. His research effort has led to an NIH "First Award" in 1992, the "Pfizer Distinguished Faculty Award for Research Excellence" in 1995, the "Purdue Faculty Scholar" in 1998, and the "Seed Award" in 2004. Dr. Guo came to the United States at the end of 1983. He finished his Ph.D. training in Microbiology and Genetics in Dr. Dwight Anderson's lab at the University of Minnesota/School of Dentistry in May of 1987. He was a postdoctoral fellow with Dr. Enzo Paoletti in Wadsworth Center and later a visiting scientist with Dr. Bernard Moss—a member of National Academy of Sciences at NIH. He joined Purdue in 1990 and became a full Professor in 1997. His lab has been affiliated with a number of interdisciplinary programs including Genetics, Biochemistry, and Molecular Biology, Virology, the Cancer Research Center, Veterinary Pathobiology, Nanotechnology, and Biomedical Engineering. He also founded the Purdue Graduate Program in Viral Research. He has also chaired and been the keynote speaker at many international conferences. He is an editor or editorial board member for six journals, including four in nanotechnology and bionanotechnology. He published 70 original papers in high impact refereed journals including *Science*, *PNAS*, and *Molecular Cell*. His web address is http://www.vet.purdue.edu/peixuanguo/