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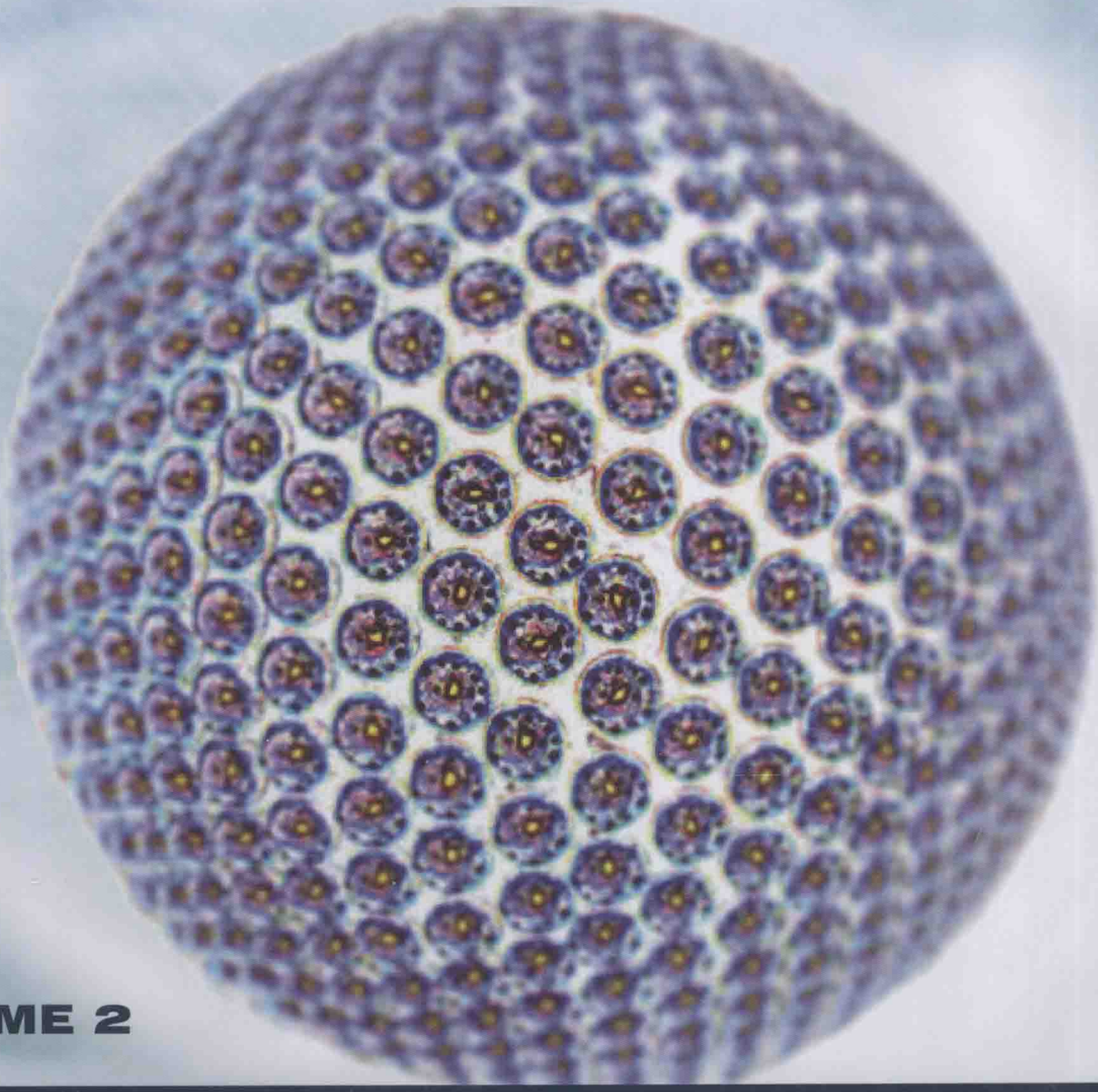

VOLUME 2

COMPREHENSIVE NANOSCIENCE AND TECHNOLOGY

BIOLOGICAL NANOSCIENCE

COMPREHENSIVE NANOSCIENCE AND TECHNOLOGY

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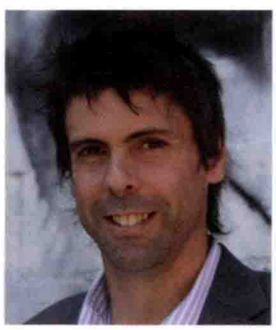
COMPREHENSIVE NANOSCIENCE AND TECHNOLOGY

Editors-in-Chief Biographies

David Andrews is Professor of Chemical Physics at the University of East Anglia, where he leads a theory group conducting wide-ranging research on fundamental photonics, fluorescence and energy transport, nonlinear optics and optomechanical forces. He has 250 research papers and ten other books to his name, and he is a regularly invited speaker at international meetings. In North America and Europe he has organized and chaired numerous international conferences on nanoscience and technology. Professor Andrews is a Fellow of the Royal Society of Chemistry, the Institute of Physics, and the SPIE – the international society for optics and photonics. In his spare time he enjoys relaxing with family and friends; he also is a keen painter of the British landscape. His other interests generally centre on music, art and graphics, and writing.



Greg Scholes is a Professor at the University of Toronto in the Department of Chemistry. His present research focuses on elucidating the principles deciding electronic structure, optical properties, and photophysics of nanoscale systems by combining synthesis, theory, and ultrafast laser spectroscopy. Recent awards honoring his research achievements include election to the Academy of Sciences, Royal Society of Canada in 2009, the 2007 Royal Society of Canada Rutherford Medal in Chemistry, a 2007 NSERC Steacie Fellowship, the 2006

Canadian Society of Chemistry Keith Laidler Award, and an Alfred P. Sloan Fellowship (2005–2006). Dr. Scholes serves as a Senior Editor for the Journal of Physical Chemistry and Associate Editor for the Journal of Nanophotonics. He enjoys basketball, hiking, photography, family and friends.

Gary Wiederrecht is the Group Leader of the Nanophotonics Group in the Center for Nanoscale Materials at Argonne National Laboratory. His research interests center on the photochemistry and photophysics of nanoparticles and periodic assemblies, hybrid nanostructures, photochemical energy conversion, and non-linear optical responses resulting from photoinduced charge separation. His experimental expertise is in the areas of ultrafast optical spectroscopy and scanning probe microscopy, including near-field scanning optical microscopy. He has received an R&D100 award, the Department of Energy Young Scientist Award, and the Presidential Early Career Award for Scientists and Engineers. He has authored or co-authored approximately 80 peer-reviewed research articles, and works collaboratively with scientists around the world. He enjoys traveling, nature, and spending time with his family.

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Self-Assembly and Nanochemistry

Preface

Volume 2: Biological Nanoscience

While nanotechnology has grown into a large and active field of science over the last two decades, nature has been using and perfecting nanoscale design for far longer. All living organisms incorporate nanoscale machines and other assemblies that are critical to their existence, ranging from delicate structures that mediate appropriate tissue growth and organization to the exquisite machines that convert, store, and use chemical energy. By understanding the design principles that underlie these biological systems, scientists hope to gain a better understanding of our natural world including human health and disease, as well as to gain insights into improving modern nanotechnology.

This volume illustrates many aspects of nanoscience that are critical to biological understanding and application. Chapters highlighting techniques used to examine biological nanoscale systems include the use of near-field scanning optical microscopy (Stebounova *et al.*), Förster resonance energy transfer (Lemke and Deniz) and protein nanomechanics (Li). Chapters on protein nanoparticle structures (Rong *et al.*), and biomimetic membranes (Jeon *et al.*) shed light on how scientists are seeking to better understand and mimic natural nanostructures. Studies of the first step in photosynthesis, light-harvesting, are detailed by van Grondelle and Novoderezhkin, while artificial photosynthetic systems are described by Němec *et al.*

Practical application of nanotechnology to human health has already been realized through nanoparticles for imaging (Ip *et al.*), photodynamic therapy (Burda), tissue engineering (Chiu *et al.*) and a variety of DNA diagnostic methods (Chen *et al.*). A better understanding of signaling events (Hoff) will help to address a number of the world's most pressing health issues.

Each chapter includes an extensive introduction to bring new readers into the field as well as in-depth discussion of the state-of-the-art that will be valuable to specialists. While this volume contains a considerable breadth of topics, the vast array of nanoscale biology dwarfs what could be contained in any single text. Thus, it is hoped that in addition to informing and enlightening a variety of readers, this volume will also inspire readers to seek an understanding of or application to their own field of *Biological Nanoscience.*

Brent P. Krueger and Gilbert C. Walker

Foreword

Nanotechnology and its underpinning sciences are progressing with unprecedented rapidity. With technical advances in a variety of nanoscale fabrication and manipulation technologies, the whole topical area is maturing into a vibrant field that is generating new scientific research and a burgeoning range of commercial applications, with an annual market already at the trillion dollar threshold. The means of fabricating and controlling matter on the nanoscale afford striking and unprecedented opportunities to exploit a variety of exotic phenomena such as quantum, nanophotonic, and nanoelectromechanical effects. Moreover, researchers are elucidating new perspectives on the electronic and optical properties of matter because of the way that nanoscale materials bridge the disparate theories describing molecules and bulk matter. Surface phenomena also gain a greatly increased significance; even the well-known link between chemical reactivity and surface-to-volume ratio becomes a major determinant of physical properties, when it operates over nanoscale dimensions.

Against this background, this comprehensive work is designed to address the need for a dynamic, authoritative, and readily accessible source of information, capturing the full breadth of the subject. Its five volumes, covering a broad spectrum of disciplines including material sciences, chemistry, physics, and life sciences, have been written and edited by an outstanding team of international experts. Addressing an extensive, cross-disciplinary audience, each chapter aims to cover key developments in a scholarly, readable, and critical style, providing an indispensible first point of entry to the literature for scientists and technologists from interdisciplinary fields. The work focuses on the major classes of nanomaterials in terms of their synthesis, structure, and applications, reviewing nanomaterials and their respective technologies in well-structured and comprehensive articles with extensive cross-references.

It has been a constant surprise and delight to have found, among the rapidly escalating number who work in nanoscience and technology, so many highly esteemed authors willing to contribute. Sharing our anticipation of a major addition to the literature, they have also captured the excitement of the field itself in each carefully crafted chapter. Along with our painstaking and meticulous volume editors, full credit for the success of this enterprise must go to these individuals, together with our thanks for (largely) adhering to the given deadlines. Lastly, we record our sincere thanks and appreciation for the skills and professionalism of the numerous Elsevier staff who have been involved in this project, notably Fiona Geraghty, Megan Palmer, Laura Jackson, and Greg Harris, and especially Donna De Weerd-Wilson who has steered it through from its inception. We have greatly enjoyed working with them all, as we have with each other.

David L. Andrews
Gregory D. Scholes
Gary P. Wiederrecht

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2.01 Nanoparticles for Photodynamic Therapy

Y Cheng and C Burda, Case Western Reserve University, Cleveland, OH, USA

2.01.1 Introduction

2.01.1.1 Photodynamic Therapy

Photodynamic therapy (PDT) is a highly selective treatment modality whereby only the light-irradiated areas containing a photosensitizer and sufficient amounts of oxygen can be affected, and the photosensitizer ideally is nontoxic in the absence of light [1,2]. As a minimally invasive therapy, PDT has been considered as a novel treatment for a variety of cancers including prostate, brain, pancreatic, breast, and skin cancer [2]. Moreover, this treatment has been expanded to noncancerous diseases, such as age-related macular degeneration (AMD), periodontal diseases, coronary heart disease, and microbial infections [3–6].

2.01.1.2 History of PDT

The origins of photoactivated therapy can be traced back from antiquity to the modern day [7]. Light was employed in the treatment of diseases by the early Greeks, Egyptians, and Indians, but this practice disappeared for centuries and was only rediscovered again by Western cultures at the turn of the twentieth century [8,9]. The work of the Danish physician Niels Finsen, who used light for the treatment of various medical conditions, resulted in furthering the development of phototherapy in modern times [10]. In 1903, he was awarded the Nobel prize following his work on the development of carbon arc phototherapy for the treatment of cutaneous