Edited by
C. M. Niemeyer, C. A. Mirkin

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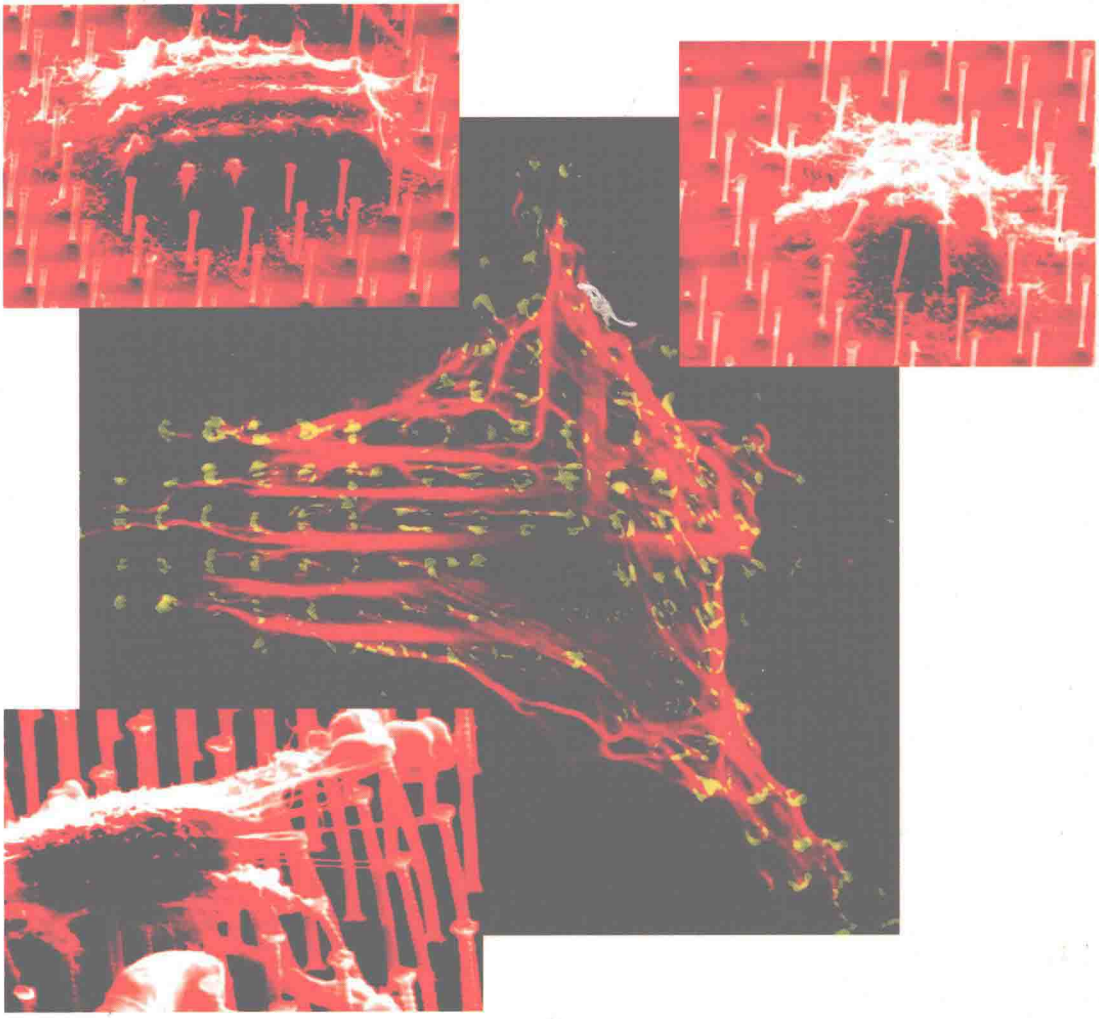
Concepts, Applications and Perspectives



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Concepts, Applications and Perspectives

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Cover illustration
Malign (top) and normal cells (bottom) on pillar interfaces which sense cellular forces. In the middle illustration, the molecular distribution of integrin (green) and actin (red) is shown. All micrographs were kindly provided by W. Roos, J. Ulmer, and J.P. Spatz (University of Heidelberg, Germany).

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Preface

Nanobiotechnology is a young and rapidly evolving field of research at the crossroads of biotechnology and nanoscience, two interdisciplinary areas each of which combines advances in science and engineering. Although often considered one of the key technologies of the 21st century, nanobiotechnology is still in a fairly embryonic state. Topical areas of research are still being defined, and the entire scope of technological applications cannot be imagined. At present, nanobiotechnology is a field that concerns the utilization of biological systems optimized through evolution, such as cells, cellular components, nucleic acids, and proteins, to fabricate functional nanostructured and mesoscopic architectures comprised of organic and inorganic materials. Nanobiotechnology also concerns the refinement and application of instruments, originally designed to generate and manipulate nanostructured materials, to basic and applied studies of fundamental biological processes.

This book is intended to provide the first systematic and comprehensive framework of specific research topics in nanobiotechnology. To this end, the current state-of-the-art has been accumulated in 27 chapters, all of them written by experts in their fields. Each of the chapters consists of three sections, (i) an overview which gives a brief but comprehensive survey on the topic, (ii) a methods section which orients the reader to the most important techniques relevant for the specific topic discussed, and (iii) an outlook discussing academic and commercial applications as well as experimental challenges to be solved.

Nanobiotechnology: Concepts, Applications and Perspectives combines contributions from analytical, bioorganic, and bioinorganic chemistry, physics, molecular and cell biology, and materials science in an attempt to give the reader a feel for the full scope of current and potential future developments. The articles in this volume clearly emphasize the high degree of interdisciplinary research that forms the backbone of this joint-venture of biotechnology and nanoscience.

The book is divided into four main sections. The first concerns interphase systems pertaining to biocompatible inorganic devices for medical implants, microfluidic systems for handling biological components in analytical lab-on-a-chip applications, and microelectronic silicon substrates for the investigation and manipulation of neuronal cells. Moreover, two chapters describe methodologies regarding the microcontact printing of proteins and the use of nanostructured substrates to study basic principles of cell adhesion.

The second section is devoted to protein-based nanostructures. Individual chapters concern the use of specific proteins, such as S-layers to be used as building blocks and templates for generating functional nanostructures, bacteriorhodopsin for photochromic applications, protein nanopores as nanoscopic cavities for analytical and synthetic tasks, and biomolecular motors for the translocation of cargo in synthetic environments. The use of a variety of functional proteins as transducers and amplifiers of biomolecular recognition events is described in the chapters on nanobioelectronic devices and polymer nanocontainers. Contributions concerning the microbial production of inorganic nanoparticles and magnetosomes as well as the discussion of genetic approaches to generate proteins for the specific organization of particles provide insight into the body of classical biotechnology, implemented in nanobiotechnology.

In the third section, DNA-based nanostructures are described, beginning with semisynthetic conjugates of DNA and proteins, which link the advantages of nucleic acids to the unlimited functionality of proteins. Three contributions concern the use of the topographic and electrostatic properties of DNA and proteins for the templated growth of inorganic materials. Hybrid conjugates of gold nanoparticles and DNA oligomers are described with a focus on their applications in the high sensitivity analyses of nucleic acids. Finally, the use of pure DNA molecules for applications in nanomechanics and computing is discussed.

The fourth section deals with the area of nanoanalytics, which currently includes the majority of commercial products in nanobiotechnology. In particular, four chapters describe the use of metal or semiconductor nanoparticles, supplemented with nucleic acid- and protein-based recognition groups, for biolabeling, histochemical applications and for signal enhancement in optical detection methods. Nanoparticles are also employed as carriers for genetic material in the non-viral transfection of cells. To exemplify the use of modern nano-instrumentation for the study of biological systems, two chapters describe the use of the scanning probe microscope, the key instrument in nanotechnologies, for investigating biomolecular structure, conformation and reactivity.

The purpose of *Nanobiotechnology: Concepts, Applications and Perspectives* is to provide both a broad survey of the field and also instruction and inspiration to all levels of scientists, from novices to those intimately engaged in this new and exciting field of research. Although the collection of articles addresses numerous scientific and technical challenges ahead, the future of nanobiotechnology is bright and appears to be limited, at present, only by imagination.

Dortmund, November 2003 — Christof M. Niemeyer
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