

Preface

Over the last two decades, nanotechnology has produced a myriad of different nanosized structures with enormously interesting material properties and potential applications. Quantum dots (QDs), carbon nanotubes (CNTs), carbon dots (CDs), gold nanoparticles, and pigment particles are among the most well-known representatives. But also less ‘famous’ nanomaterials made from polymers, noble metals, or inorganic materials have raised considerable interest for applications in the biomedical field and other areas of our daily life. Despite of their undisputed usefulness in certain areas, there is a constant and justified concern that these nanomaterials may have unwanted biological effects on cells and organisms that have not yet been discovered and understood entirely. Thus, research into the biological impact of nanoparticles on human and animal health as well as possible hazards for the environment is of outmost importance. As a deeper and more systematic understanding about the potential impact of nanomaterials on living cells, tissues, or ecosystems is in many ways based on state-of-the-art bioanalytical techniques, this volume of *Bioanalytical Reviews* is entirely devoted to this topic.

The first chapter of the book, written by Eslahian and colleagues, provides a concise summary of the most prominent, highly tailored approaches to physically characterize nanomaterials. The various techniques are described in principle before their individual analytical performance is highlighted and critically compared to other methods. Special emphasis is placed on material characterization under physiological conditions to describe the particles as they are when they encounter biological systems like cells, tissues, or organs.

The second chapter provided by Domey and coauthors addresses biochemical assays that are used extensively in labs around the globe to study the cytotoxicity or other cell responses to nanomaterials. Besides presenting model studies, this contribution critically highlights the pitfalls and possible artifacts that might be associated with these assays due to an interaction of the nanomaterials with the assay constituents. Often the possible artifacts can be accounted for by a carefully thought-out experimental design and proper controls. But the evidence accumulates that label-based assays should be used with great care to avoid misleading conclusions from cytotoxicity studies.

Following up on this discussion on the pros and cons of label-based biochemical assays to assess the impact of nanomaterials, the subsequent chapter by Sperber et al. discusses the use of label-free approaches for this purpose. After a more general introduction to the field of label-free detection techniques for cell observation, focus is placed on impedance analysis as one of its major representatives. The chapter describes the general concept of impedance-based cell monitoring, introduces the physical background, and illustrates its performance on a set of examples. These examples highlight that noninvasive impedance measurements can be used to monitor a huge variety of different cell-based assays including the analysis of cell adhesion and proliferation, time-resolved observation of cytotoxicity, or the quantitative examination of cell migration. After these introductory paragraphs, the article summarizes in how far these assays have been used already to describe the impact of nanomaterials on animal cells and tissues at these very different points of cell physiology. Inspired by the possibilities of impedance analysis to study one cell type subsequently in different physiological settings, the authors suggest a new perspective for nanotoxicology: instead of interpreting just one assay, we should establish response profiles for a given nanomaterial derived from a sequence of individual assays.

As the airways are one major route of nanomaterial invasion into the human body, the fourth chapter addresses a set of model systems to study the impact of nanomaterials on the alveolar lung surfactant that is literally of vital importance to our breathing cycle. Here Dwivedi et al. describe model systems from simple lipid monolayers to more complex model surfactants and their response to nanoparticle encounter. The impact of nanoparticles on lipid organization is mostly demonstrated by Langmuir film-balance measurements and state-of-the-art microscopy.

As one example of nanomaterials that do not only raise health and environmental concerns but show very interesting bioanalytical applications, Lemberger et al. summarize in the fifth chapter what is known about carbon nanodots (CDs), a member of the emerging class of photoluminescent carbon-based nanomaterials that can be produced from rather simple and cheap starting materials using low-tech equipment. The various strategies of CD synthesis are grouped and discussed. Deeper inside the article, the authors provide a concise summary of the particles' spectroscopic properties together with their most established bioanalytical application as a label in microscopic imaging.

The final chapter provided by Maximilien and coauthors takes it to the next level: nanomaterials as drug delivery vehicles in biomedicine. The authors start their discussion with lipid-based nanomaterials (liposomes) and their reversible loading with drugs. This discussion is followed by a concise overview of the available inorganic nanoparticles including quantum dots (QDs) and upconverting nanoparticles (UCNPs) with their inherent capability of absorbing two or more NIR photons before a photon of shorter wavelength in the visible range (higher energy) is emitted. This upconversion has several distinct advantages. Most prominently it provides a fluorescence labeling of biological specimens without producing an unwanted and disturbing background fluorescence of biomolecules as the latter

require excitation by UV/VIS. The description of polymeric nanoparticles as drug delivery vehicles starts with nanomaterials made from natural polymers. Within the class of nanoparticles produced from synthetic polymers, the authors highlight those materials that are either responsive to temperature, pH, or light because of their outstanding potential to allow for a localized unloading of the vehicle. The final paragraph describes polymeric nanoparticles with imprinted recognition sites for different low-molecular-weight analytes (MIPS) that provide many new opportunities for nanoparticle-based sensors or the specific separation and enrichment of complex samples.

The current volume of *Bioanalytical Reviews* presents a blend of different aspects that tackle the problem of measuring the biological impact of nanomaterials. This timely collection of articles will hopefully help to oversee the fast-developing field of nanotoxicology and emphasize its tight connection to bioanalysis. New instrumental developments, analytical assay formats, and new means of data deconvolution are needed to get a few steps closer to the big goal of a conceptual understanding about the bioresponse to nanoscale particles. This is particularly important as this topic is likely to stay relevant throughout the next decades given the increasing integration of nanomaterials in our daily lives.

This book would not have been possible without the fine work of all authors and coauthors to whom I would like to express my deepest gratitude. I hope you all agree that this big effort and the long hours of work have been worthwhile. Moreover, I would like to thank Dr. Rudolf Hutterer for his constant support in general and the editorial preparation of several chapters in particular.

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