Nanotechnology in the Life Sciences

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Nano and biotechnology are two of the 21st century's most promising technologies. Nanotechnology is demarcated as the design, development, and application of materials and devices whose least functional make up is on a nanometer scale (1 to 100 nm). Meanwhile, biotechnology deals with metabolic and other physiological developments of biological subjects including microorganisms. These microbial processes have opened up new opportunities to explore novel applications, for example, the biosynthesis of metal nanomaterials, with the implication that these two technologies (i.e., thus nanobiotechnology) can play a vital role in developing and executing many valuable tools in the study of life. Nanotechnology is very diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, from developing new materials with dimensions on the nanoscale, to investigating whether we can directly control matters on/in the atomic scale level. This idea entails its application to diverse fields of science such as plant biology, organic chemistry, agriculture, the food industry, and more.

Nanobiotechnology offers a wide range of uses in medicine, agriculture, and the environment. Many diseases that do not have cures today may be cured by nanotechnology in the future. Use of nanotechnology in medical therapeutics needs adequate evaluation of its risk and safety factors. Scientists who are against the use of nanotechnology also agree that advancement in nanotechnology should continue because this field promises great benefits, but testing should be carried out to ensure its safety in people. It is possible that nanomedicine in the future will play a crucial role in the treatment of human and plant diseases, and also in the enhancement of normal human physiology and plant systems, respectively. If everything proceeds as expected, nanobiotechnology will, one day, become an inevitable part of our everyday life and will help save many lives.

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Ram Prasad • Elisabet Aranda
Editors

Approaches in Bioremediation

The New Era of Environmental Microbiology and Nanobiotechnology

Springer

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Foreword

The environmental and health impacts of contaminants mostly of anthropogenic origin are of an increasing interest due to their persistency and toxicity. Many of these compounds and materials were deliberately or inadvertently released into the environment. Others organic contaminants are personal care compounds, pharmaceuticals, or undesired chemical by-products that resist against microbial or chemical processes, either during wastewater treatment or in soil. As a consequence, there is a great demand for new technologies that can be employed for decontamination of polluted areas and environmental matrices. In this context, bioremediation stands for environmental-friendly decontamination technologies based on the application of organisms (or their parts) in order to decontaminate various compartments of the environment. This environmental biotechnology approach employs microorganisms and/or plants that represent essential components of the global carbon cycle. Apart from this, it was documented that most xenobiotic industrial chemicals can be decomposed by microorganisms and plants, either via cometabolism phenomenon yielding partial degradation, or by serving as growth substrate, which is accompanied by mineralization of at least part of the molecule. Contrary to expensive physicochemical approaches, bioremediation stands for methods typically less economically demanding. Nevertheless, the main advantage of these technologies is conservation of the treated matrix, e.g., soil structure including microbial biota. Noteworthy, the phenomenon of bioremediation has been studied since the 1980s; however, not all of the methods have been introduced into practice. The problem lies in the complexity of environmental matrices and interactions of organisms among each other. This book very greatly reflects these difficulties and brings an overview of advanced modern approaches within this research field. Attention is paid to the whole overview of application of microbes in soil and water with respect to new available research methods at the beginning of this book. Together with three following chapters, it shows the importance of modern omics approaches that could greatly enhance the understanding of transformation and decontamination processes and could enable new insights into the involved mechanisms. The whole book also reflects various types of pollution, and, besides classical contaminants, several chapters also describe problems related to the new types including fluorinated hydrocarbons, industrial dyes, and microplastics. Other chapters focus on roles and applications of fungi in environmental biotechnology processes, which is a subject often overlooked in other books and literature. Attention is also paid to possible applications of plants, namely, constructed wetlands and algae. A substantial part of this book also elaborates on topics related to a novel research field of nanotechnology and its possible applications together with bioremediation methods.

This book generally brings a contemporary outlook on the modern aspects of environmental decontamination technologies and will be greatly helpful to all the readers interested in the subject of bioremediation of the environment and related subjects.

Tomáš Cajthaml is an environmental chemist, the director of the Institute for Environmental Studies, Faculty of Science, Charles University, Prague, and the head of Laboratory of Environmental Biotechnology, Institute of Microbiology. He obtained his PhD in 2002 from the Charles University in the field of Applied and Landscape Ecology. Among his scientific interests are environmental biotechnology, microbial bioremediation and biodegradation mechanisms of organopollutants, toxicology, nanotoxicology and ecotoxicology, and bioavailability and degradation of relevant pollutants. In these topics, he has published more than 170 research papers, with an h-index of 34, and he has 5 patents, 6 verified technologies, and 1 utility model related to this field. He is a member of the scientific council of Faculty of Science, Charles University, Prague. He is a member of the editorial board of several journals – Folia Microbiologica, *European Journal of Environmental Sciences*, and *Frontiers in Microbiology*. He was awarded the Prize of Otto Wichterle for young researchers and the Prize of Carolinum Association for the research on the environment.

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Preface

The Earth is alarmingly polluted, and the current economic model and population growth do not give a progressive expectation. Thousands of new chemical compounds are released every day into the environment, producing changes in the environment, particularly in microbial populations and global effects which still remain unknown.

The knowledge of the microbial processes in the environment as well as microbial communities and their interactions with other living organisms and the environment are the basis of bioremediation. Microorganisms have long been the subject of bioremediation studies. These started in the 1950s using selective pressures to select microorganisms with the capacity to use different xenobiotic compounds as a source of carbon and energy, particularly. Nevertheless, fungi have been traditionally poorly studied, due to their slow growth, complex and often wrong classification, and scarcity of genome database in comparison with bacteria. In this book, we address different topics related to biodegradation processes involving bacteria and fungi, marine-derived fungi (Chap. 12), the binomial fungi-plant (Chap. 5), and Microalgae-bacteria consortia (Chap. 8). Among them, the degradation of plastics and polythene (Chap. 6), phenolic compounds (Chap. 8), distillery effluents (Chap. 9), residues from the petroleum refining industry (Chap. 10), and fluorinated compounds (Chap. 11) are discussed.

A new step was taken when the research community realized the importance of the interaction between communities for efficient bioremediation processes. Sequencing technologies of metagenomes have dealt with an ever-increasing rate of thousands of bacterial and hardly any fungal genomes, which are often studied as isolated communities. During this era, advances in new approaches have made significant progress to provide solutions to different environmental problems. The study of key gene expression during bioremediation processes or the regulation of proteins is helping to map these complex processes that occur under changes in the environment. Thus, the full understanding of the complexity of these interrelationships is still in its infancy. In this book, some critical reviews about advances on bacterial omics (Chap. 1), fungal transcriptomics (Chaps. 2 and 3), and fungal proteomics (Chap. 3) are given, including a revision of microbial dynamics during bioremediation of petroleum hydrocarbon stimulation (Chap. 7).

In order to understand the role that different genes play in environmental pathways, researchers need to be able to modify levels of gene expression. New technologies are currently being developed by using CRISPR-CAS9 technology, which is being tentatively applied to environmental problems. In this book, a critical overview on CRISPR-Cas in fungi is provided (Chap 4).

Finally, another growing field is nanobiotechnology, which integrates biotechnology at nanoscience scale, is addressed in the last chapters of this book. This discipline is being rapidly developed as a resource to support bioremediation processes and soil health (Chaps. 13 and 14) and energy and environmental remediation (Chap. 17). Here we address nanobioremediation and an innovative approach for fluoride contamination (Chap. 15) and dye effluents (Chap. 16).

We would like to express our gratitude to all the authors for their valuable contributions. We also thank the Springer Nature team, especially Eric Stannard, Anthony Dunlap, and Rahul Sharma for their continuous support during the preparation of this book. And finally, this book is dedicated to all of our family and friends, because sometimes it is difficult to understand this strange but fascinating profession.

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