

Preface

This book was conceived following the completion of *Microbiology of Extreme Soils* in this *Soil Biology* series. That volume was characterized by the remarkable diversity of the microorganisms it considered, and by the wide range of extreme soil environments that they inhabited. As bacteriologists with a special interest in the taxonomy of *Bacillus* and its relatives, this set us thinking that, while soils are generally considered to be the main habitats of the aerobic endospore-formers, our understanding of their behaviour in soil environments seems to be greatly outweighed by our knowledge of individual species as studied, exploited, or combated by human activities. Most laboratory-based studies of the properties and behaviour of aerobic endospore-forming bacteria have been in-depth studies of single species or strains – especially *Bacillus subtilis*, which is the most extensively studied Gram-positive bacterium and probably the best understood prokaryote after *Escherichia coli* – and it seems that the diversities of these various organisms' habitats and natural existences have often been given scant attention by investigators.

While a small number of aerobic endospore-forming species are opportunistic or obligate pathogens of animals – including humans, other mammals and insects – most species are saprophytes widely distributed in the natural environment. Their habitats are soils of all kinds, ranging from acid through neutral to alkaline, hot to cold and fertile to desert, and the water columns and bottom deposits of fresh and marine waters. It is well known that endospores confer special properties of dormancy, survival and longevity upon their owners in their natural environments, play dominant parts in their life cycles and dispersal and influence our detection and cultivation of the organisms. We no longer believe that these organisms simply exist in soil as dormant spores, or that their vegetative forms are free-living organisms; we recognize that they are active and dynamic members of the soil flora and that they may interact with other soil inhabitants such as fungi, the roots of plants, insects and nematodes.

Much has been written about these bacteria, on their spores, their genetics, their importance in medical and food microbiology and their industrial applications; some individual species such as *B. subtilis*, *B. cereus* and *B. anthracis* merit their own books or reviews. Much has also been written about soil ecology, including the contribution of microbes to soil fertility, interactions of soil microorganisms with

plants, the control of pests and diseases, the floras of extreme environments and the impacts of heavy metals – and these and other such topics have been the subjects of several notable titles in the *Soil Biology* series. There is, however, little literature that brings together the different aspects of behaviour and character of aerobic endospore-formers with their contributions to the lives of soils and the lives of the plants and animals that occupy them.

This book is an attempt to fill that gap to some extent, in a volume having four broad and loosely defined themes (1) diversity, (2) growth, spores and survival, (3) interactions and (4) contributions to soil ecosystems. When considering diversity, we need to appreciate the huge expansion there has been in the number of aerobic, endospore-forming taxa in the last 20 years, and our opening chapter outlines these developments in classification and nomenclature, in order to bring the reader up to date, and provides a listing of the new genus names that we have to learn. Chapter 2 is focused on endospore-former diversity and community composition in soil and the mechanisms that contribute to the diversity. Notwithstanding the many novel species cultivated from soils in recent years, it is clear that many further taxa await detection and cultivation, and Chap. 3 gives an account of approaches to studying endospore-former diversity in soil without cultivation and describes some current protocols for such studies. However, Chap. 4 emphasizes that cultivation-based methods continue to be of value, and it reviews such approaches – both with and without spore selection – including immunocapture or selective media in combination with molecular techniques. Turning to growth, spores and survival, Chap. 5 considers the life cycles of *Bacillus* species, especially *B. cereus*, in soil, and these organisms' parts in the horizontal gene pool, while Chap. 6 is devoted to the methods available for undertaking such studies, including the use of soil extracts, artificial soil microcosms and proteomics. Given that endospores can survive dispersal from soils to a wide variety of other habitats, Chap. 7 looks at their contamination of foods, drinks and animal feeds, and the implications for food safety and quality. The next three chapters examine interactions of aerobic endospore-formers with other members of the soil flora. Chapter 8 describes a positive contribution of these organisms to agriculture, describes the protection of plants from fungal diseases and includes protocols for the study of these effects. Further interactions with eukaryotes are considered in both Chap. 9, with a timely review of the remarkable nematode-parasitic organism *Pasteuria penetrans* and the potential for its exploitation in the protection of plants, and Chap. 10, which gives an account of endospore-formers as members of the intestinal microbial communities of soil invertebrates. The subject of Chap. 11, the diversity of *Bacillus thuringiensis* in soil and phylloplane, straddles several of our themes. The remaining five chapters look at the roles of some aerobic endospore-formers in soil ecosystems. While the presence of spores in a soil may not indicate that the organisms are growing there, isolations of organisms showing special adaptations to extreme environments in which they are found implies that they are metabolically active in these niches. However, spores of such organisms are often to be found in non-extreme soils. Chapter 13 considers the surprisingly widespread presence of thermophiles in temperate soils and reviews the potentials of *Geobacillus* species in the bioremediation

of oil contamination. Most of our knowledge of halophiles and haloalkaliphiles has emerged from studies of aquatic habitats, but Chap. 16 surveys the presence of these organisms in soils and sediments and also notes their unexpected frequency in non-saline soils. With another example of bioremediation, Chap. 12 describes the potential applications of *Brevibacillus* species as plant growth-promoting rhizobacteria (PGPR) in metal-polluted soils, their associations with arbuscular mycorrhizal fungi and how these phenomena may be studied. Our remaining two chapters deal with two opposed aspects of the nitrogen cycle and methods for their study: Chap. 15 covers the nitrogen-fixing activities of *Paenibacillus* species and their roles as PGPR and contributors to soil fertility, while Chap. 14 examines denitrification by species of *Bacillus* and related genera, a process that deserves much further study.

It is clear from these chapters that many questions in the field remain unanswered, and we hope that this book will stimulate further studies into aerobic endospore-forming bacteria as important members of the soil microbiota. We take this opportunity to record our warmest thanks to the book's contributors, for their chapters, cooperation and patience. We also extend our special gratitude to Dr Jutta Lindenborn at Springer, for her generous support during the book's gestation, and Prof. Ajit Varma, Editor of the *Soil Biology* series, for inviting us to prepare this book.

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