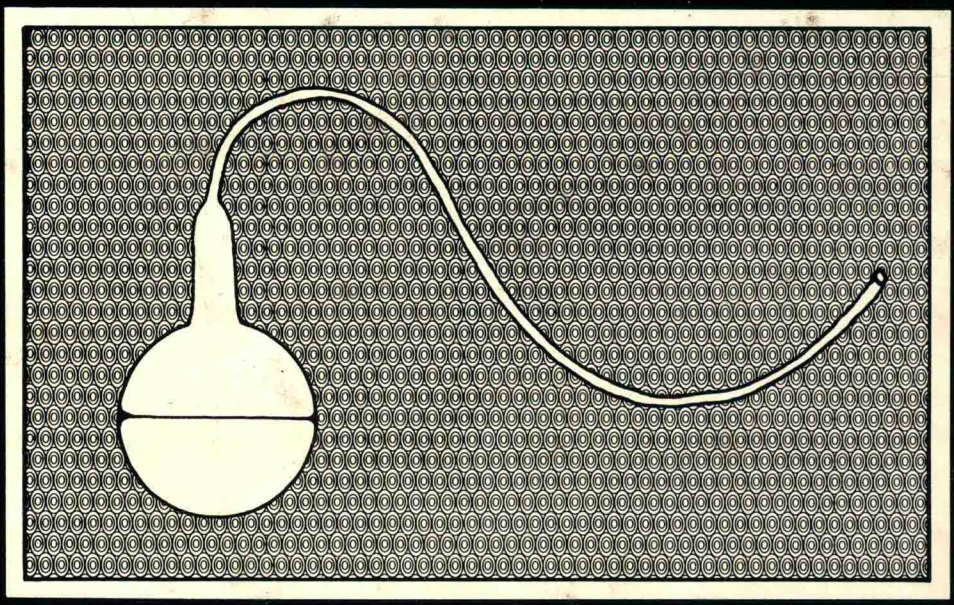
BACTERIA IN NATURE



Volume 1

Bacterial Activities in Perspective

Edited by
Edward R. Leadbetter
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Volume 1
Bacterial Activities in Perspective

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Volume 1 Bacterial Activities in Perspective
Volume 2 Methods for Bacterial Ecology

PREFACE TO THE TREATISE

The effects of bacteria on their environments were known and variously explained by human societies long before these microorganisms were recognized. Even after they had been detected microscopically, nearly two centuries elapsed before it was demonstrated that bacteria were causes, rather than effects, of fermentations, infectious diseases, and transformations of both organic and inorganic materials in soils, waters, and sediments. It was these demonstrations of the ecological roles of bacteria that gave birth to bacteriology as an experimental science. The applications of the understanding of ecological activities of bacteria have in no small part been responsible for this century's revolution in human health and longevity through changes in agricultural, medical, and sanitation practices.

However, the ecology of bacteria has only relatively recently emerged as a science in itself, having as its goal the elucidation of the interactions of bacteria and their habitats whether or not those activities appear immediately relevant to human affairs. In this ten-volume treatise, it is our intention to present this broadened view of bacterial existence, that the work may serve as a synthesis of current ideas and information that will be valuable both to basic scientists and to those directly engaged in applications of science to specific problems of human existence. Our hope is that the completed project will expose and explore the diversity of bacterial capabilities and culpabilities, limitations and sensitivities, and will imply the equally diverse ways in which they can be exploited. We hope, especially, that investigators trained in other disciplines—clinicians, oceanographers, molecular biologists, engineers—who may not expect that their disciplines are interrelated with bacterial ecology, will find this treatise both stimulating and valuable.

The introductory volume traces main points in the history of bacteriology that have led to the present state of bacterial ecology, to the awareness that bacteria constitute distinctive populations that separately and in concert affect the physiochemical conditions of the biosphere and interact, sometimes intimately, with other organisms. The second volume will review and evaluate the technical and philosophical tools presently available to the student of bacteria in nature. This volume is intended to provide evaluations of methods and not to serve as a procedural manual.

Although the initial stimulus to interest in bacteria arose from attempts to understand natural phenomena and to distinguish abiotic from biotic causes of these phenomena, most of the progress in managing and learning about bacteria has been accomplished in the laboratory, very largely through the study of pure cultures. While some devoted naturalists eschew the study of monotypic populations as artificialities, it would not be possible to understand the activities of a bacterial community in ignorance of the separate, respective potential activities of the members of the community. For this reason, two volumes will comprise information regarding structure, composition, genetics, physiology, and biochemistry of bacteria, obtained predominately from pure culture studies, that is essential to unraveling the interactions of bacteria with their environment and with each other. The goal of those volumes is not simply to review the information, but to demonstrate its importance to inferences based on studies of natural, polytypic populations.

The remaining six volumes in this series will explore bacterial habitats. Because a bacterial activity of any type—polymer solubilization, oxygen consumption, toxin production, or other—is not confined to one type of habitat, we anticipate that some groups of bacteria and some bacterial activities will be mentioned in more than one ecological context. However, since the emphasis throughout the series will be on interactions, the role of the habitat in influencing the extent and consequence of bacterial activities will vary with its own inherent stability, its resilience to the effects of bacteria, and its capacity for supporting and restricting those activities. An additional reason for organizing the treatise principally around habitats reflects the fact that human problems and advantages that arise from bacterial activities are most often met within the context of a particular kind of site. Similarly, the general ecological significance of a bacterial activity is proportional to the rate of activity allowed by a habitat, the geographical extent of the habitat, and the degree of dependence of other forms of life on the condition of the habitat affected by that activity. Accordingly, for all conceptual and practical purposes other than classification, the study of bacterial ecology is, we believe, most usefully presented by grouping the information into volumes that reflect the manner in which bacterial communities are gathered and interact in nature.

The treatise will conclude with a consideration of the frontiers and the relic habitats of the biosphere, those environments inhabited almost solely by bacteria. Modern biology recognizes bacteria as the pioneering populations—demonstrably so in the past and predictably so in the future—of this and possibly also of other worlds. It is the humble yet confident hope of the editors that the insights and experimental results of today's bacterial ecologists, compiled in these volumes, will contribute significantly to the continuing elucidation of the roles and potentials of our bacterial cohabitants—so long a major influence on this earth, yet only so recently appreciated.

This series was conceived partly as a result of our participation as instructors in the summer program in microbial ecology at the Marine Biological Laboratory, Woods Hole, Massachusetts. Our interests in bacterial ecology

antedate that participation by many years, having been earlier stimulated and guided by R. A. Slepecky and J. W. Foster (E.R.L.), by W. A. Konetzka and R. Y. Stanier (J.S.P.), and by one of the greatest appreciators of microorganisms, C. B. van Niel. To our colleagues—students and faculty—in the M.B.L. course, and to our several mentors, we dedicate this series.

The Editors

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PREFACE

Any branch of biology depends for its progress on the development of new concepts and to a lesser, but sometimes crucial, extent on the elimination of erroneous notions. Understanding the roles of bacteria required first the observation that such minute creatures existed, and subsequently the experimental demonstrations that their presence was necessary for the occurrence of particular phenomena.

In this first volume, the authors review the development of scientific understanding of the role of microbes as agents of diverse natural processes. Notably absent is a separate review of the history of microbes as agents of disease, a history available in many other publications. Regrettably absent is a review of the history of microbes as agents of inorganic transformations, a serious omission that resulted from the illness of the prospective author late in the preparation of this volume. The topic will of course be treated in later volumes, although not predominantly in a historical manner. Otherwise, the emphasis in this volume is on the history of understanding interrelationships between modes of bacterial existence and the inanimate environment. These relationships were established long before multicellular, differentiated organisms appeared as potential microbial habitats, and their recognition and elucidation contributed greatly to the widened appreciation of bacterial diversity and the importance of these simpler creatures to the physiochemical conditions of the biosphere.

As bacterial ecology matures as a microbiological discipline, an appreciation of the foundation constructed during the past two centuries is indispensable to its students, and so we offer this first volume to acknowledge the historical context in which current studies proceed. Some of the concepts that arose in the nineteenth century proved important to the development of several subdisciplines, and so are reviewed by more than one author; their recurrent mention serves to emphasize their central role in the development of our present understanding.

We especially thank the authors in this volume for giving time, energy, and consideration to topics which are not the immediate concern of their present research. None is a historian by trade, but all have responded to a call to review the background of today's view of bacterial activities in nature.

The Editors

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THE SCIENTIFIC STUDY OF BACTERIA, 1780–1980

Patricia H. Clarke

INTRODUCTION

This chapter covers a period of approximately 200 years that begins around 1780. The concept of "the bacterium" changed and developed during this time, and strong and often conflicting views were held by the leading scientists of the day. Leeuwenhoek's (1677) animalcules (described in his famous letter of 1676) are now considered to have included bacteria, and although at the beginning of the period under review there were those who thought that small living organisms might cause disease and bring about fermentations, there was no firm scientific evidence for either of these activities. The methods of the natural scientists, particularly the botanists, were used to observe and describe the teeming life that could be seen with the help of the improved microscopes. From a time when all very small organisms, including worms, protozoa, microfungi, and bacteria were regarded as similar creatures to be observed and described, we can trace an increasing awareness of the special attributes of bacteria. It took many years to settle the two major controversies over whether bacteria arose by spontaneous generation and whether fermentation was carried out by living organisms. The supporters of the spontaneous-generation origin of microorganisms had arguments of common sense to sustain them, together with weak experimental technique. Until good methods for sterilization were available, it was difficult to refute their claims, and until the heat resistance of bacterial spores had been recognized, it was difficult to ensure that sterilization methods were adequate. The most vociferous supporters of spontaneous generation were mainly biologists, and a few chemists, while the main opposition to the concept of the microbiological basis of fermentation came from the leading organic chemists. Berzelius, Liebig, and

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