Basic Bacteriology

AND ITS BIOLOGICAL AND CHEMICAL BACKGROUND

BASIC BACTERIOLOGY

Its Biological and Chemical Background

CARL LAMANNA, Ph.D.

Associate Professor of Bacteriology in The Johns Hopkins University School of Hygiene and Public Health

M. FRANK MALLETTE, Ph.D.

Associate Professor of Biochemistry in The Johns Hopkins University School of Hygiene and Public Health

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Preface

This book is intended to present the nature of the cytological, morphological, taxonomic, physiological, and biochemical problems which confront the bacteriologist. From this survey it should be evident that the worker in bacteriology requires knowledge of general biological, chemical, and physical principles if he is to be competent in his own area of specialization.

Departments of bacteriology generally require that their major students receive some preparation in these basic sciences. Yet, the courses in which one acquires the necessary background for an approach to bacteriology do not treat the principles presented from the point of view of the interests and needs of the bacteriologist. Thus, we feel that a need exists for an oriented treatment of the information acquired in general physics, chemistry, and biology courses. This is the justification for our treatment of fundamental physical, chemical and biological problems in a bacteriology text.

Inasmuch as a large number of textbooks are available at the elementary level and numerous monographs and reviews have been written at the most advanced level, it has been our desire to bridge the gap between these two sources of information. Therefore, our treatment has been aimed at producing a work of intermediate complexity. It is assumed that the reader has mastered the basic vocabulary of biology and chemistry and has already had some experience in the laboratory with the techniques and materials of bacteriology.

Out of our experience with students, particularly those intending to do graduate work in bacteriology and in biochemistry using bacteria as tools, we have drawn the conclusion that the available textbooks tend to emphasize the same subject matter. As a result, certain lacunae that should be filled exist in the source books used by students. In an attempt to meet this need we have introduced subject matter new to textbooks of bacteriology and treated certain traditional matters with a different emphasis than exists in the popular texts. In the light of this objective we have no desire to duplicate satisfactory texts but rather hope to supplement and round out the treatments already in existence.

An ever-present deficiency in education is the failure to stress the necessity for some grasp of the overall significance of general ideas in order that fundamental principles may be employed in achieving an understanding of diverse topics. Consequently, in the earlier chapters a certain amount of

"elementary" but basic material is included in order to provide a fully integrated picture of the subject under discussion. To help the reader integrate ideas we have included simple things at various points and attempted to develop from these elementary concepts the more complex ideas present in the same or later chapters. We have attempted to explain bacteriological phenomena rather than to merely state their occurrence.

Few compendia of data are presented, and we hope to have succeeded in emphasizing ideas and principles rather than factual knowledge. Specific facts are introduced only as they make a contribution to the development of knowledge of principles and as they may be employed to illustrate established principles. In general the use of graphic illustrations has been favored rather than tabulated data.

It is also our hope to communicate some insight into the nature of the general methodology of science. For this reason we have injected a measure of scientific philosophy into various portions of the work and have treated critically some of the problems, methods, and data of bacteriology. In the latter cases we have chosen situations which seemed particularly suitable for the purpose.

We believe that the science of bacteriology has matured to the extent that a textbook need not be cluttered with references. In other sciences it has been generally appreciated that certain principles and data exist which are accepted by all serious investigators and that it serves no essential purpose in these fields to refer the student to the original literature. We have adopted this attitude for the areas of bacteriology considered. On the other hand, we must admit that the situation in bacteriology is more fluid than in some of the older sciences; therefore, we have not entirely abandoned reference to the original literature. In order to avoid interruptions of the flow of thought occasioned by the inclusion of any large number of references within the body of the textual material, we have listed essential references and review articles at the end of each chapter as a guide for further reading. Papers outside the bacteriological journals which may be useful to the bacteriologist have been included.

We wish to take this opportunity of expressing our thanks to Doctors Roger M. Herriott, Winston H. Price, and Sol H. Goodgal for their constructive criticism of the chapter on bacterial genetics. In particular we wish to thank Doctor Jack J. R. Campbell for the great assistance rendered us in the preparation of the chapter on metabolism and for his suggestions on other portions of the book.

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Foreword

The teacher of advanced courses in bacteriology usually is faced with one or both of two unfortunate facts: the students do not know enough about the biological principles of bacteriology and about bacteria as such; and the students are not familiar with the necessary essentials of physics and chemistry, or at least some of the particular aspects of these subjects that apply especially to bacteriology. Although books dealing with the most advanced and specialized phases of bacteriology must, in order to keep within proper bounds, assume a proper preparation on the part of the student, this is rarely the case. The authors of this volume have attempted the difficult task of writing a book that will fill the void between those texts that deal in a very elementary way with the essentials of bacteriology, and those, on the other hand, that treat the advanced aspects of the subject.

Although a greater integration in the teaching of the various sciences is doubtless possible and desirable, it is too much to expect that the sciences of physics and chemistry, which have so many and so important applications in the other sciences and in everyday life, can teach all of the specialized phases that are of importance to students in the various branches of biology. It is therefore essential for the student in biology to have some familiarity with chemical and physical principles and phenomena that are not emphasized in the conventional courses that are taught to the undergraduate college student. Teachers of bacteriology are not alone in feeling a need for supplementary reference volumes in order to fill in the deficiencies in the training of their students. It is exactly this need on the part of teachers of students of medicine, physiology, and biochemistry that has led in the past to the writing of books dealing with such subjects as the physical chemistry of proteins and colloidal chemistry in physiology and medicine, and more recently to such an invaluable classic as *Topics in Physical Chemistry* by William Mansfield Clark.

The present volume, *Basic Bacteriology and its Biological and Chemical Background*, the result of the combined efforts of a bacteriologist and a biochemist who have shown brilliance and versatility in their own research, should be of great value to both students and teachers of bacteriology.

JAMES M. SHERMAN
Cornell University

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CHAPTER I

The Scope of Bacteriology

Bacteriology is, of course, the study of particular kinds of microorganisms, the bacteria. It is the science in which is summarized mankind's scientific knowledge of particular kinds of living organisms. As such it is but one aspect of man's curiosity about the universe of living organisms and only one subdivision of the science of biology. Scientific knowledge is the accumulation of factual data about the universe, gained and verified by observation and experiment, and reduced by means of ordered and logical thinking to laws of nature descriptive of the relations of things and events. Bacteriology as a pure science is concerned with the study of the morphology, physiology, and taxonomy of particular microorganisms and their occurrence, variation, heredity, and evolution. It includes the integration of knowledge of physics, chemistry, and general biology with a particular aspect of biology, and on occasion is the vehicle by means of which some general biochemical or biological relation is discovered or verified.

It is in the nature of science that in its infancy it can only be concerned with objects obvious to man in his natural environment. It is only as instrumentation develops and extends man's senses beyond the immediately perceived, that science can concern itself with the less apparent objects and events of nature and the more subtle relations existent between things. Inevitably, this evolution has meant that bacteriology developed as a science long after scientific study of other organisms had begun. It has also meant that the original students of bacteriological phenomena had received their training in other sciences. This breadth of experience reflected to the immense benefit of bacteriology, since investigators could make unusually rapid progress in extending knowledge of general applicability from other fields to bacteriology. It has also resulted in the fact that bacteriology never has had a tradition of conservatism in the extension, practical application, and adaptation of the technics and theoretical knowledge of other sciences. In view of this historical background, and because bacteria as sources of material for study present certain unique advantages, particularly in both their rapid growth rate and the technical feasibility of amassing large numbers of organisms economically, bacteria have been and are becoming increasingly important as objects of study in many different sciences.

But if the nature of the historical development of bacteriology has had advantages sometimes denied in degree to other sciences, it has also had

its disadvantages. The chief of these has been a relative lack of creative interest in bacteria as such. There has not been in existence a great pool of scientific personnel studying bacteria out of a love for the bacteria. Thus, as the applications of bacteriological knowledge became evident, and they became evident early in the history of the science, major emphasis shifted to applied bacteriology. A person was trained as, and felt himself to be, not a bacteriologist so much as a medical bacteriologist, dairy bacteriologist, soil bacteriologist, etc.

The study of pure bacteriology is motivated by the desire to understand the nature of bacteria and their place in the scheme of the universe. Practical bacteriology seeks to control the harmful activities of bacteria and direct their useful activities. The line between applied and pure bacteriology is tenuous, and no universal agreement can be expected as to where it should be drawn. Nor would any great purpose be served by any strict definition of the difference between the two phases of the science. But it is useful to recognize that progress in any science, including bacteriology, and its practical utility for society, is most rapid when there is some balance of effort expended on practical phases and the esoteric or academic studies. Each category of investigation feeds the other. Applied science often helps in the discovery or more precise definition of phenomena. It makes possible the creation of the material means and leisure time that society can invest in the pursuit of pure science for its intellectual satisfactions. Pure science provides the rational basis for practice and suggests new applications. When technology becomes more than merely empirical in methods and outlook, it is because pure science has provided a firm foundation of factual data and theoretical concepts which practicing engineers, technologists, and physicians have mastered.

The science of biology can be divided into sub-sciences by a number of means. The generic system which separates bacteriology as a discipline is the consequence of a logical recognition of one of the historical trends in the development of biology. It is inherent in the nature of biological studies that as the body of biological knowledge expands, individual students of life will tend to concentrate their studies upon particular and phylogenetically related organisms.

The recognition of living forms invisible to the unaided eye was a dramatic experience in the intellectual history of mankind. So it is no wonder that a word, *microbe*, was invented (1878) to describe these apparently related organisms, and there eventually developed the concept of microbiology as a separate science. But microbes form a large group of very diverse organisms, so that their study is actually the fundamental task of virologists, bacteriologists, mycologists, algologists, protozoologists, hel-

minthologists, etc. The diversity of forms properly called microbes has meant that in recent times few persons, if any, have mastered the essential components of all the sciences that can be catalogued under the heading of microbiology. The technics used to study bacteria have had wide application in the study of other microbes, so that there is possibly more in common between the technics of the microbiological sciences than between the phylogeny of the organisms studied. In any case, the lexicographer, if not always those calling themselves microbiologists, has recognized the limitations so that a popular dictionary notes that the term microbiology as generally employed is synonymous with bacteriology. In this sense the use of the term bacteriology is to be preferred.

If a generic concept is to be used in defining the sub-branches of biology there is no compelling logic in considering microbiology as a distinct science. Certainly there is no reason more compelling than those which have prevented anyone from volunteering to father the sibling science, the monstrosity which would be labeled *macrobiology*. The use of common technics, the discovery of general laws, provided the stimulus for thinking in terms of a unified science and the invention of the concept of a science of microbiology. But this term, generic in its implications, violates the logic of a generic system of separation of the biological sciences. Yet the boundaries between organisms must be crossed and identified. For this purpose it would seem better to think in terms of sciences of systematics such as comparative cytology, comparative physiology, and comparative biochemistry. This latter cataloging is also more truly descriptive of the actual situation of the social organization of the sciences. It permits the use of restricted labels with more scientific meaning than the term microbiology. And also important, because science is an agency in the hands of men, its use would help preserve scientific modesty.

The efforts of bacteriologists may be conveniently listed as occurring in five areas of activity:

1. *General or pure bacteriology*. This would include the studies devoted to understanding the fundamental nature of bacteria and their relations to one another and to other organisms.

2. *Soil bacteriology*. Studies in this field have contributed particularly toward understanding of the problem of the fertility of soil and the natural mechanisms for the cyclic biological utilization and deposition of elements in soil and large bodies of water.

3. *Medical bacteriology*.

   A. Animal pathology

      human

      veterinary