Biology of the Prokaryotes
Preface

Microbiology is More Than the Biochemistry or Molecular Biology of Microorganisms

Bacteria were detected in the 17th century as minute unicellular organisms that lacked any detectable structure and occurred almost everywhere. Late in the 19th century, they were identified as a large group of organisms with distinct and specific physiological properties, such as the ability to ferment carbohydrates, to grow photoautotrophically, and to act as pathogens. The microbes were grouped systematically together with other small and allegedly primitive organisms, in particular unicellular algae, fungi, and protozoa. Today we distinguish between prokaryotic and eukaryotic microorganisms. In contrast to eukaryotic cells, prokaryotes lack a nuclear membrane (i.e., a nucleus), mitochondria and plastids, and mitosis and meiosis, but they contain particular cell wall and membrane components not found in eukaryotes. Prokaryotes are small, but neither simple nor primitive. At the morphological level, they are not “bags full of enzymes,” but highly structured cells, able to grow and multiply at an astonishing speed, with cell divisions as accurate as in the eukaryotes, and with compartments that separate various metabolic activities. At the physiological level, however, the immense diversity of the prokaryotes has always been considered as their hallmark, together with their surprising adaptability to environmental changes.

Biology has been subdivided traditionally, according to the main types of organisms, into botany, zoology, and microbiology. The latter dealt with bacteria (prokaryotes), with eukaryotes of lower complexity, and with viruses. Modern biology, however, is subdivided into sections more defined by structures and organisms of increasing complexity, in particular from macromolecules and genes to the living cells, organisms, and populations. This classification facilitates the recognition of universal principles common to all living systems. In unicellular organisms, the cell is by definition also the organism. Their biology thus includes everything from the molecular structures of the cell and from cellular physiology to differentiation processes and their behavior as members of complex ecosystems.

Why a new Textbook on the Biology of the Prokaryotes?

Although many cellular components and universal biochemical mechanisms are present in all living organisms, the tremendous physiological diversity and adaptability of the prokaryotes, together with their fundamental role in environmental, biotechnological, and medical research and application, justify their separate treatment. Hence, this book is restricted to prokaryotic organisms, i.e., the true bacteria (eubacteria) and the archaea (archaebacteria), and their viruses (bacteriophages), which at the DNA- or RNA-level correspond to plasmids and not to true organisms.

Molecular biology has developed largely through studies with bacteria. This includes the rise of recombinant DNA or gene technology. It is safe to conclude that despite a shift of interest in recent times to eukaryotic organisms, the prokaryotes will continue to retain a central place both in fundamental and in applied biological research. This will, however, require new textbooks, such as this one, which presents an integrated view of the prokaryotic cell as an organism and of all prokaryotes as a large population in which all organisms communicate among themselves and with the rest of the environment.

Bacteria, although autonomous cells and complete organisms, cannot be fully understood if viewed as single cells, much as a sequenced gene cannot be understood unless its role in the biology of its organism is also considered. In this context, one of the most outstanding capacities of the prokaryotes is their extended horizontal gene transfer under natural conditions. A bacterium has access to any useful gene of any other strain and the sum of all the genes of all organisms of a community constitutes a large collective genome. Gene transfer, however, is optional and involves only a small percentage of the genes in a single transfer event. Of these, only the species-specific genes will recombine into the cellular chromosome of a cell. All others will be lost by curing unless under counter-selection. Life in temporary ecosystems of mixed populations with complementary metabolic and mor-
phological capacities is the prokaryotic equivalent of multicellular life. Any bacterium with its cellular chromosome and variable autonomous genetic elements which is a member of an ecosystem thus resembles a differentiated cell in an eukaryotic multicellular organism. Furthermore, because no strict genetic isolation exists, speciation is not as pronounced in the prokaryotic world as in the eukaryotic world. This requires a new type of systematics. Viewed in this way, the lifestyle of the archaea (archaebacteria) resembles, despite important biochemical differences, the lifestyle of the bacteria (eubacteria) more than it resembles that of the eukaryotes.

How Is the Book Organized?

This book is based on a physiological and functional approach in which the diversity of the prokaryotic world is made visible by characteristic examples and in which up-and-coming developments are indicated. The book is divided into nine sections; the beginning sections provide the basic facts needed to understand the later sections. In this way, the book proceeds from the description of cellular structures through metabolic pathways and metabolic reactions to the genes and regulatory mechanisms. At a higher level of complexity, cell differentiation processes will be followed by a description of the diversity of prokaryotes and of their role in the biosphere. The book will end with a section on man and microbes, i.e., applied microbiology.

What Are the Aims and Scope of the Book?

The book is written for upper-level undergraduates, graduate and postgraduate students and for researchers working in fundamental research or using bacteria only as a tool, for example, in recombinant DNA technology, in biotechnology, and in medicine. Rather than presenting all the details known in biochemistry and in genetics and that can be found in such corresponding textbooks, this book concentrates on central concepts of the bacterial lifestyle and on the physiological significance that the various cellular structures, metabolic pathways, and regulatory networks have. Parts of the book, especially those dealing with the genetics of the prokaryotes and gene control, may appear "colicentric." This is because much more is understood at all levels about *Escherichia coli* than about any other bacterium, even after the complete sequencing of several other bacterial chromosomes. Wherever similar phenomena are suspected to exist or have been analyzed in molecular detail and wherever new phenomena have been reported in other bacteria, e.g., sporulation and antibiotic biosynthesis, these have been used as examples. Moreover, it has been forgotten all too often that basic research in microbiology is the foundation on which applied microbiology rests. Most techniques dealing with or using prokaryotes in modern medicine, agriculture, industrial production, and environmental processes profited vastly from progress in basic research. Wherever new developments and promising areas in applied microbiology can be anticipated, they have been pointed out.

Pedagogical Aids

Each section is preceded by a general introduction in which the subjects treated and the connections which link them are briefly described. Where possible, links to other sections are also indicated. This is especially conspicuous for Table 20.1, in which major global regulatory networks of prokaryotes are listed. These networks can best be used, as has been attempted in this book, to define the inherent logic of bacterial metabolism and to bring together seemingly unrelated phenomena that are parts of the same global network, e.g., bacterial taxes and carbon catabolite control, both involved in the quest for food; sporulation and antibiotic biosynthesis, both part of the same differentiation process; cell surface and chromosomal rearrangements, both part of pathogen strategies in host infection. In all chapters, essential definitions are given and essential conclusions are highlighted in shaded areas. The corresponding pages are listed in the Index, and the sum constitutes a glossary. Historical and outstanding experiments, basic and new methods, or information for the "specialist" appear in boxes. All of the chapters offer Further Reading in which mostly recent papers and reviews are listed that can be used for further studies and research. Writing, editing, and coordination of the work was done by a team of individuals, each with expertise in the area that they covered. A list of their names and their contribution is given below. We hope that the general concept of the book and its content will increase the fascination of a broad readership for the world of the prokaryotes.

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The Editors
Addresses

Sankar Adhya
Laboratory of Molecular Biology
National Cancer Institute
Bethesda, Maryland 20892
USA

Carl-Alfred Alpert
INRA Institut National de la Recherche Agronomique
Laboratoire Vivande
78352 Jouy-en-Josas Cedex
France

Ian R. Booth
University of Aberdeen
Dept. of Molecular + Cell Biology
Marshall College
Aberdeen AB9 1AS
Great Britain

Wolfgang Buckel
Fachbereich Biologie
Universität Marburg
Karl-von-Frisch-Straße
35043 Marburg
Germany

Arnold L. Demain
Department of Biology
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Mass. 02139
USA

D. N. Dowling
Dept. of Food Microbiology
University College Cork
Cork
Ireland

Gerhart Drews
Albert-Ludwigs Universität
Institut für Biologie II
Mikrobiologie
Schänzlestraße 1
79104 Freiburg/Br
Germany

Bärbel Friedrich
Humboldt-Universität
Mathemat.-Naturwissenschaft. Fakultät
Institut für Biologie/Mikrobiologie
Chausseestraße 117
10115 Berlin
Germany

Georg Fuchs
Albert-Ludwigs-Universität
Inst. für Biologie II – Mikrobiologie
Schänzlestr. 1
79104 Freiburg
Germany

Fergal O’Gara
Dept. of Food Microbiology
University College Cork
Cork
Ireland

Mike Goodfellow
Department of Microbiology
The Medical School
Framlington Place
Newcastle upon Tyne NE2 4HH,
Great Britain

Jörg Hacker
Institut für Molekulare Infektionsbiologie
Röntgenring 11
97070 Würzburg
Germany

Wolfgang Hillen
Institut für Mikrobiologie und Biochemie der Universität
Staudtstraße 5
91058 Erlangen
Germany

Gary R. Jacobson
Boston University
Department of Biology
2, Cummington Street
Boston, Mass. 02215
USA

Klaus Jann
Barbara Jann
Max-Planck-Institut für Immunobiologie
Stibeweg 51
79108 Freiburg
Germany

Börries Kemper
Institut für Genetik der Universität zu Köln
Zülpicher Str. 47
50674 Köln
Germany

Rolf Knippers
Fakultät für Biologie
Universität Konstanz
Universitätsstraße 10
78464 Konstanz
Germany

Werner Köhler
Adolf Reichwein Str. 26
07745 Jena
Germany

Reinhard Krämer
Institut für Biochemie der Universität Köln
Zülpicher Str. 47
50674 Köln
Germany

Achim Kröger
Institut für Mikrobiologie
Biozentrum Niederrursel
Marie-Curie-Str. 9
60439 Frankfurt a.M.
Germany

J. Gijs Kuenen
Laboratory of Microbiology
Delft University of Technology
Julianalaan 67A
2628 BC Delft
The Netherlands
Addresses

Giancarlo Lancini  
Lepetit Research Center  
Via R. Lepetit 34  
21040 Gerenzano (Varese)  
Italy

Erich Lanka  
MPI für Molekulare Genetik  
Ihnesstraße 73  
14195 Berlin  
Germany

Joseph W. Lengeler  
FB Biologie/Chemie  
Universität Osnabrück  
Postfach 4469  
49076 Osnabrück  
Germany

Edmond C.C. Lin  
Harvard Medical School  
Dept. of Microbiology and Molecular Genetics  
Longwood Avenue  
Boston, Mass. 02115  
USA

Wolfgang Ludwig  
Lehrstuhl für Mikrobiologie  
Technische Universität München  
Arcisstraße 21  
802890 München  
Germany

Mohamed A. Marahiel  
Universität Marburg  
Fachbereich Chemie  
Hans-Meerwein-Straße  
35043 Marburg/Lahn  
Germany

Frank Mayer  
Institut für Mikrobiologie  
Georg-August-Universität  
Grisebachstraße 8  
37077 Göttingen  
Germany

Walter Messer  
MPI für Molekulare Genetik  
Abteilung Trautner  
Ihnesstraße 73  
14195 Berlin  
Germany

Kurt Nordström  
Department of Microbiology  
Uppsala University  
Biomedical Center  
Box 581  
75123 Uppsala  
Sweden

M.P. Nuti  
Dip. di Biotechnologie Agrarie  
Università di Padova  
Via Gradenzigo 6  
Padova  
Italy

Werner Pansegrau  
Institute for Molecular Plant Sciences  
Clusius Laboratory  
Leiden University  
2333 AL Leiden  
The Netherlands

Pieter W. Postma  
Universiteit van Amsterdam  
E.C. Slater Institute for Biochemical Research  
Plantage Muidergracht 12  
1018 TV Amsterdam  
The Netherlands

Ursula B. Priéfer  
Institut für Botanik  
Rheinisch-Westfälische Technische Hochschule  
Worringer Weg  
52056 Aachen  
Germany

Alfred Pühler  
Fakultät für Biologie VI (Genetik)  
Universität Bielefeld  
Postfach 10 01 31  
33615 Bielefeld  
Germany

Hermann Sahm  
Institut für Biotechnologie I  
Forschungszentrum Jülich GmbH  
Postfach 1913  
52428 Jülich  
Germany

Bernhard Schink  
Fakultät für Biologie  
Universität Konstanz  
Universitätsstraße 10  
78464 Konstanz  
Germany

Hans-Günter Schlegel  
Institut für Mikrobiologie  
Universität Göttingen  
Grisebachstraße 8  
37077 Göttingen  
Germany

Eriko Stakebrandt  
DSM – Deutsche Sammlung von Mikroorganismen u. Zellkulturen  
Mascheroder Weg 1b  
38124 Braunschweig  
Germany

Brian Tindall  
DSM – Deutsche Sammlung von Mikroorganismen u. Zellkulturen  
Mascheroder Weg 1b  
38124 Braunschweig  
Germany

Gottfried Unden  
Institut für Mikrobiologie u. Wein-  
Forsschung  
FB 21/Biologie  
Joh. Gutenberg-Univ. Mainz  
Becherweg 15  
55099 Mainz  
Germany

Peter Zuber  
Department of Biochemistry and Molecular Biology  
Louisiana State University  
Shreveport, Louisiana  
USA
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