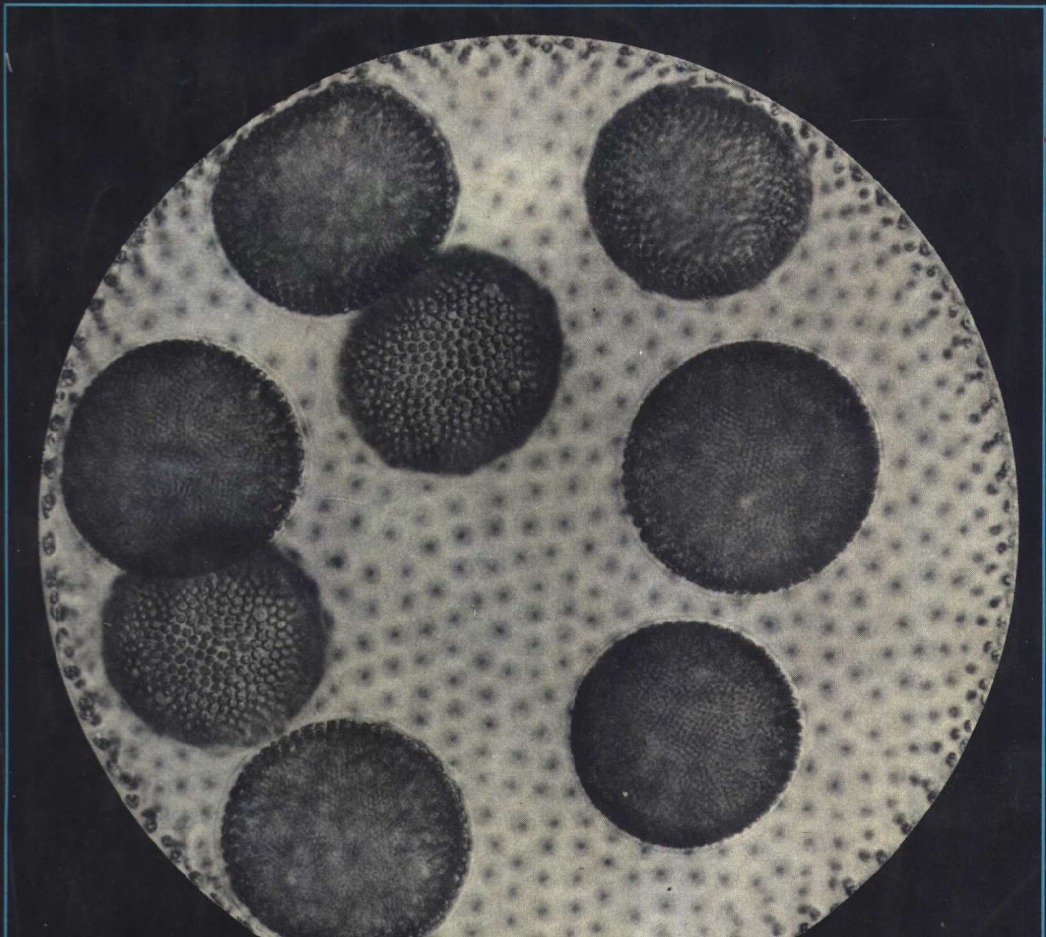


PAUL EDMONDS

MICROBIOLOGY

AN ENVIRONMENTAL PERSPECTIVE



MICROBIOLOGY

**An environmental
perspective**

Copyright © 1978, Paul Edmonds

Printed in the United States of America

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the Publisher.

Macmillan Publishing Co., Inc.
866 Third Avenue, New York, New York 10022
Collier Macmillan Canada, Ltd.

Library of Congress Cataloging in Publication Data

Edmonds, Paul, (date)

Microbiology : an environmental perspective.

Includes bibliographies and index.

1. Microbial ecology. I. Title

QR100.E35 576'.15 76-58450
ISBN 0-02-333580-7

Printing: 2 3 4 5 6 7 8 Year: 8 9 0 1 2 3 4

Preface

Environmental biology is one of many popular courses in environmental science programs that are being initiated and/or expanded on college campuses throughout the nation. Yet, there is a paucity of information in these programs that concerns the activities of microorganisms in nature. Traditional books on microbial ecology characterize these activities for microbiologists and students with advanced training in the biological sciences, but I know of no other book that has made this attempt for beginning students.

Microbiology: An Environmental Perspective is not intended to be a textbook for use in an introductory course for microbiology majors. The aim of this book is to provide students with an understanding of vital activities that microorganisms perform in nature. Although this book is written for the nonspecialist in microbiology, it is assumed that readers will have some command of basic biological concepts. In order to accommodate students with a diversity of backgrounds, the basic chemical concepts that are required for understanding environmental relationships are discussed in Chapter 2. The diversity of microbial habitats is discussed in Chapter 3, after which emphasis is placed on physiological activities of microorganisms in relation to broad-scale interactions that occur in natural ecosystems. Subsequent discussions deal with the epidemiology of some common human and animal diseases. Then, specific examples of influences that microorganisms have on the quality of the environment—human health, pollution (air, water, and land), and welfare (economic losses, etc.) are presented. The final chapter delineates specific roles that microorganisms play in polluted ecosystems and emphasizes the importance of controlling such activities.

I have taken a biased approach in the development of this book. It is not intended to be all-inclusive in the coverage of microbial activities in nature. Cell biology and basic physiology will be deemphasized except where necessary to clarify a functional concept. Also, culture methods and details of techniques used for studying microorganisms are deliberately omitted, because these aspects are covered thoroughly in many excellent general microbiology books.

In order to facilitate reading, a list of key words is provided at the end of each chapter. Pertinent periodicals and monographs are listed under

“Selected Readings” for those who may desire more details of a particular topic. A comprehensive glossary is provided at the end of the book.

I believe that *Microbiology: An Environmental Perspective* will provide the nonmicrobiologist with a broader dimension of organismic activities in the total ecosystem.

Finally, I wish to acknowledge my colleagues, friends, and relatives for their support during the preparation of this book. The names of those individuals who generously provided photographs for use as illustrations appear throughout the book in figure captions that acknowledge their contributions.

My special appreciations are expressed to those who read parts or all of the manuscript, and who took the time to offer constructive criticisms. Among this group are Dr. Daniel D. Burke, Department of Microbiology, University of Illinois, Urbana; Dr. Karl T. Kleeman, Department of Biology, California State University, Fresno; Dr. Michael G. Petit, Department of Microbiology, Colorado State University, Ft. Collins; Dr. Ramon J. Seidler, Department of Microbiology, Oregon State University, Corvallis; Dr. David L. Wright, Department of Biology, University of Wisconsin-Oshkosh, and my former students: Penny Schiller, Danielle Meyer, Kenneth L. Hobbs, and David M. Janssen.

Lastly, I wish to acknowledge the support of my family, and the cooperation of the staff at Macmillan Publishing Company. Without the courteous cooperation of Charles E. Stewart, Jr., Woodrow W. Chapman, Bruce Bumby, Mollie Horwitz, and Lola Peters this project could not have been completed.

Paul Edmonds

Contents

Introduction

1

Microbial groups 3

Historical perspective	3
Living cells	6
Procaryotic organisms	7
<i>Bacteria</i>	9
<i>Blue-green algae</i>	25
<i>Mycoplasmas</i>	26
Eucaryotic organisms	28
<i>Fungi</i>	30
Yeasts	30
Molds	32
Slime molds	34
<i>Algae</i>	35
<i>Protozoa</i>	36
Isolated cells of multicellular organisms	39
Viruses (noncellular agents)	40
<i>Bacterial viruses (bacteriophages)</i>	42
<i>Animal viruses</i>	44
Selected readings	50

2

Nutrition and metabolism 53

Essential chemical concepts	54
<i>Atoms and molecules</i>	54
<i>Chemical bonds</i>	56
<i>Acids and bases</i>	57

<i>Biological molecules</i>	60
Requirements for growth	70
Water	71
Carbon	72
Energy	72
Nitrogen	72
Accessory materials	73
Nutritional types of organisms	74
Autotrophs	74
Photoautotrophs	74
Chemoautotrophs	75
Heterotrophs	75
Photoorganotrophs	75
Chemoorganotrophs	75
Cellular metabolism	76
Enzymes	76
Energy-yielding processes	81
Photosynthesis	82
Fermentation	83
Aerobic respiration	85
Anaerobic respiration	88
Energy-utilizing processes	88
Biosynthesis of macromolecules	89
Biosynthesis of proteins	90
The molecular basis of mutation	92
Selected readings	95

3

Diversity of microbial habitats

97

Environmental selecting factors	99
Physical	99
Solar radiations (temperature and light)	99
Osmotic pressure	102
Hydrostatic pressure	103
Chemical	104
pH (acidity and alkalinity)	104
Available gases (O ₂ and CO ₂)	105
Biological	105

Types of microbial habitats	106
Atmospheric environments	106
Outdoor air	107
Indoor air	107
Aquatic environments	108
Fresh water	108
Salt water	110
Terrestrial environments	112
Biological environments	116
Microenvironments	117
Modes of dispersal	117
Selected readings	122

4

Microbial interference

123

Competition for survival in nature	124
Changes in ecosystems: succession	125
Competition for nutrients	129
Competition for oxygen	130
Competition for space	131
Role of antimicrobials in nature	132
Antibiosis from antibiotics	133
Antibiosis from bacteriocins	140
Antibiosis from other substances	141
Sensitive and resistant species	145
Selected readings	147

5

Intermicrobial and extramicrobial relationships

149

Types of symbiotic relationships	150
Mutualism	151
Commensalism	151
Parasitism	152
Intermicrobial associations in nature	153

<i>Lichens</i>	154
<i>Lysogeny</i>	155
<i>Miscellaneous associations</i>	157
<i>Protozoan associations</i>	157
<i>Bacterial associations: a triad</i>	160
<i>Mycoviruses</i>	163
<i>Cyanophages</i>	164
<i>Extramicrobial associations in nature</i>	165
<i>Microbial associations with animals and insects</i>	165
<i>Microbial-ruminant associations</i>	165
<i>Microbial-insect associations</i>	170
<i>Microbial associations with higher plants</i>	172
<i>Mycorrhizae</i>	172
<i>Bacterial-legume associations</i>	174
<i>Obligate microbial parasites of higher organisms</i>	177
<i>Selected readings</i>	179

6

Transformations in geochemical cycles 181

<i>Dynamic aspects of microbial populations</i>	182
<i>Determinants of population size</i>	182
<i>Unicellular growth</i>	183
<i>Population growth patterns</i>	185
<i>The significance of measuring microbial activity</i>	187
<i>Energy conversion and biosynthesis</i>	189
<i>Role of microorganisms in geochemical cycles</i>	193
<i>Carbon cycle</i>	193
<i>Nitrogen cycle</i>	195
<i>Phosphorus cycle</i>	198
<i>Sulfur cycle</i>	199
<i>Selected readings</i>	201

7

The human body: a natural ecosystem 203

<i>Inhabitable anatomical regions</i>	204
<i>The skin</i>	204

The gastrointestinal tract	208
Miscellaneous areas	210
The indigenous microflora	211
Normal ecological niches	211
Sterile (forbidden) zones	215
Defense mechanisms	215
Mechanical barriers	216
Immune barriers	216
Phagocytosis	216
Antibodies	217
Types of immunity	220
Natural immunity	220
Acquired immunity	220
Germ-free animals	221
Selected readings	224

8

Epidemiology of human microbial diseases

225

Sources of environmental pathogens	227
Living reservoirs	227
Inanimate reservoirs	228
Modes of transmission for pathogens	229
Direct transmission	229
Indirect transmission	229
Vehicle-borne	229
Vector-borne	230
Airborne	230
Epidemiological investigations	230
Retrospective studies	230
Prospective studies	231
Human infectious diseases	231
Selected bacterial diseases	234
Boils and carbuncles	234
"Strep" sore throat	235
Pneumonia	237
Tuberculosis	239
Typhoid fever	242
Cholera	244

Selected viral diseases	246
Smallpox	246
Polio	247
Measles	249
Hepatitis	251
Influenza	253
Selected fungal (mycotic) diseases	256
Dermatomycoses	256
Systemic mycoses	257
Selected protozoan diseases	260
Amebiasis	260
Giardiasis	260
Selected venereal diseases	262
Gonorrhea	262
Syphilis	263
Prevention and control of infectious diseases	265
Chemotherapy	266
Prophylactic immunization	269
Environmental sanitation	269
Selected readings	270

9

Epidemiology of zoonotic diseases

271

Selected types of zoonoses	271
Bacterial zoonoses	272
Anthrax	272
Brucellosis	274
Bubonic plague	276
Salmonellosis	277
Viral zoonoses	279
Encephalitides	280
Yellow fever	282
Rabies	283
Protozoan zoonoses	284
Malaria	285
Toxoplasmosis	287
Prevention and control of zoonoses	288

Prophylactic immunizations	289
Environmental sanitation	289
Selected readings	290

10

Microbial toxins in the environment	293
--	------------

Types of microbial toxins	293
<i>Bacterial toxins</i>	294
Exotoxins	295
Endotoxins	296
<i>Algal toxins</i>	297
Blue-green toxigenic algae	297
Eucaryotic toxigenic algae	299
<i>Fungal toxins (aflatoxins)</i>	301
Ecological consequences of microbial toxins	303
Effect on human beings	303
Effect on food chains	305
Microbial toxins as insecticidal agents	308
<i>Bacterial toxins harmful to insects</i>	310
<i>Fungal toxins harmful to insects</i>	312
Selected readings	313

11

The role of microorganisms in polluted environments	315
--	------------

Microbiological aspects of air pollution	316
Nonindustrial microbial aerosols	317
Industrial microbial aerosols	321
Microbiological aspects of water pollution	323
Drinking water—problems of purification	324
Sewage—problems of treatment	327
Solid wastes—problems of disposal	331

Microorganisms as tools for detecting specific
pollutants 333

Bacterial and protozoan assays 334

Tissue culture assays 335

Selected readings 337

Comprehensive glossary 339

Index 359

Introduction

In this era of ecological awareness, maintaining the quality of the environment is a major concern of many college students. Yet, the techniques and approaches of separate disciplines among the physical, social, and biological sciences in our institutions are inadequate to deal justly with the complexity and magnitude of environmental problems. Environmental science programs are numerous, but too often students develop obscure views of the environment as a totality—a functional system of subunits that include physical, chemical, and biological components. Among the biological components, the activities of some microorganisms are vital to the functioning of the system as a whole and to the existence of all other biological species including human beings.

Microbiology: An Environmental Perspective introduces nonmajors in microbiology to the functional aspects of microorganisms in nature. Many individuals harbor vague concepts about microorganisms and recognize them as “germs” that function to produce discomfort and dreaded human diseases; others view them only as complex agents studied by highly trained scientists. Although both views are within the vast scope of microbiology, they fail to convey the broad spectrum of activities in nature that are mediated by microorganisms.

CHAPTER 1

Microbial groups

- **Historical perspective**
- **Living cells**
- **Procaryotic organisms**
 - Bacteria*
 - Blue-green algae*
 - Mycoplasmas*
- **Eucaryotic organisms**
 - Fungi*
 - Yeasts*
 - Molds*
 - Slime molds*
 - Algae*
 - Protozoa*
 - Isolated cells of multicellular organisms*
- **Viruses (noncellular agents)**
 - Bacterial viruses (bacteriophages)*
 - Animal viruses*
- **Key words**
- **Selected readings**

What are microorganisms? Unlike terms used to describe higher forms of life (plants and animals), the term *microorganism* does not describe a unified group or a single biological entity with similar structures and function. Microorganisms are highly diverse, but all are microscopic or submicroscopic, all are undifferentiated unicells, and all share a common feature – smallness. This does not mean that all microorganisms are of an equal size. The size variation will become evident as we examine the types of cells found within the various groups of microorganisms.

Historical perspective

From the earliest recordings of ancient civilizations through the Middle Ages, human infirmities were ascribed to demons, evil spirits, and retributive gods. Such views were inadequate to satisfy the curiosity of a few. Those curious-minded individuals probed into the mysteries of life by collecting and examining all types of living things. At that time the world of microscopic organisms was unknown.

Between the fourteenth and seventeenth centuries, the fields of chemistry, botany, zoology, and medicine evolved from superstitious arts, filled with uncertainty and chaotic techniques, into well-disciplined subjects based on scientific principles. A few workers in the medical profession postulated the existence of invisible agents of disease. For example, Girolamo Fracastoro (1483–1553) published a book in 1546 which described three ways for the transmission of infectious agents: by direct contact, by fomites (inanimate objects), and by the air. Later, the microscope emerged as an important instrument. Athanasius Kircher (1602–1680), Robert Hooke (1635–1703), and Marcello Malpighi (1628–1694) used magnifying lenses in their studies of a variety of biological specimens, but Anton van Leeuwenhoek (1632–1723) is recognized as the first person to see and accurately describe the invisible creatures of the microbial world. Unlike most scholars of that era, Leeuwenhoek was not a trained scientist, but ground lenses and assembled them into microscopes as a hobby. Sketches of creatures that he had observed in saliva, teeth scrapings, and a variety of other aqueous mixtures were presented to the Royal Society of London in 1674. His drawings were highly accurate, because morphological descriptions were made relative to items such as grains of sand and mustard seeds. As a result of such comparisons, some of the organisms that he described are now recognized as bacteria and protozoans.

Although many divergent views relative to the origin of life had been publicized in the scientific community, debate over that controversial issue was intensified by the discovery of microorganisms. Some leading scholars of that time ardently supported the “theory of spontaneous generation” and attempted to prove its validity through experimentation. As a result of much confusion and inaccurate interpretation of experimental data, controversial debate on this subject continued for many years. Finally, through a series of carefully planned experiments, Louis Pasteur (1822–1895) proved that “germs” did not originate spontaneously in sterile solutions, but developed from other “germs” that had entered his flasks on contaminated dust particles; thus ended the debate over the theory of spontaneous generation. This was only one of many great contributions that Pasteur made to science; others were the establishment of concepts for the “germ theory of disease,” the characterization of life in the absence of air (anaerobic growth), the development of techniques for pasteurization, and the development of a vaccine for rabies.

While Pasteur’s accomplishments in France were unprecedented in the scientific community, a young physician, Robert Koch (1843–1910), was making news in Germany. Koch established himself as a capable scientist at an early age and proved subsequently to be