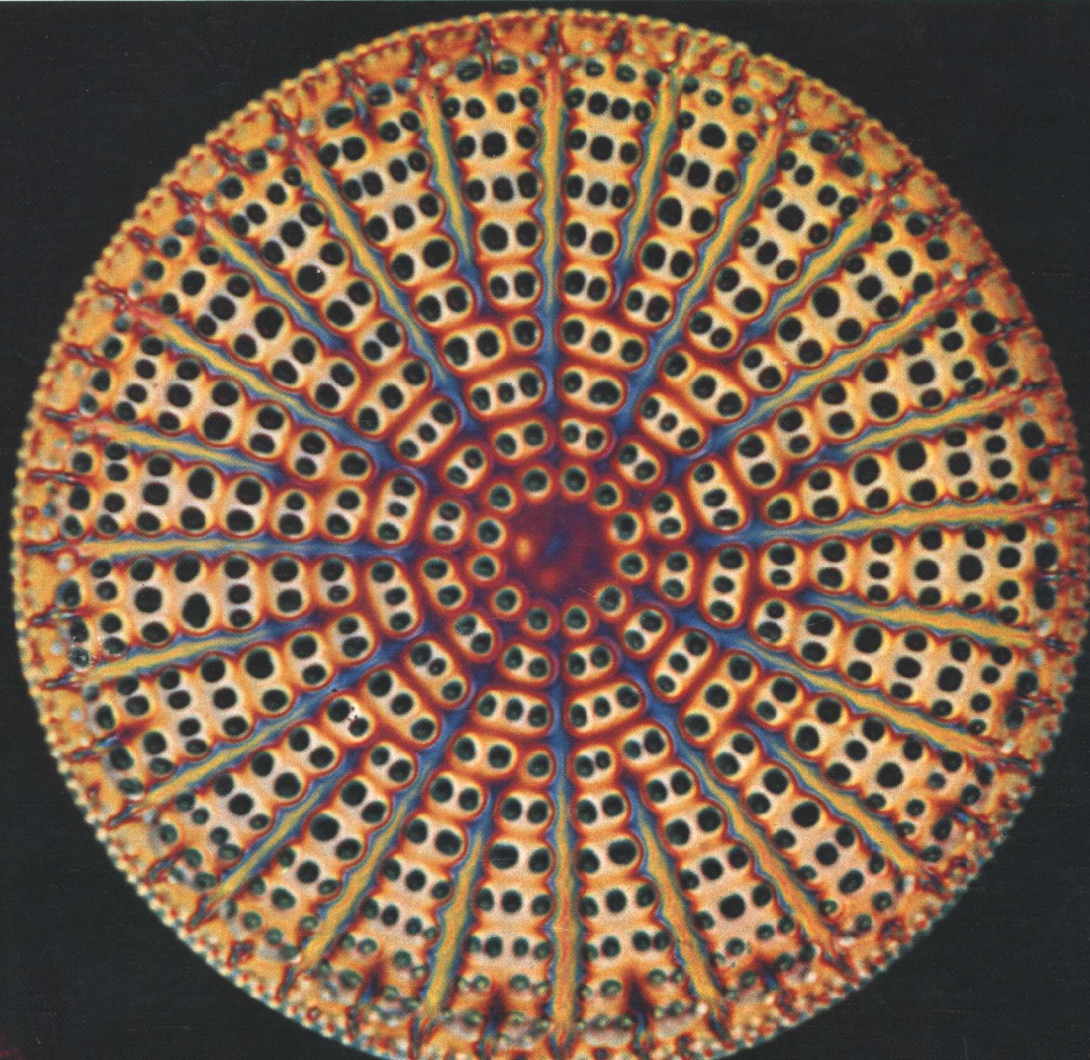


BROCK and BROCK

Basic Microbiology

WITH APPLICATIONS

Second Edition



Basic Microbiology

WITH APPLICATIONS

For Emily and Brian

Editorial and production supervisor: Joyce Fumia Perkins
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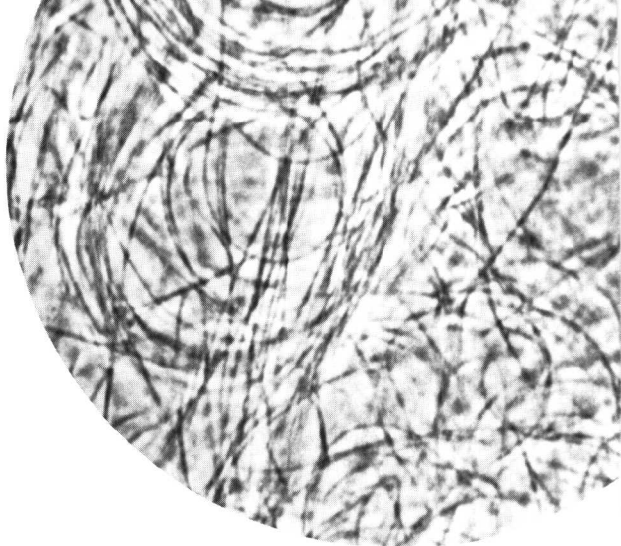
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BIOLOGICAL SCIENCE SERIES

William D. McElroy and Carl P. Swanson, editors

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PREFACE



Basic Microbiology with applications, second edition, is intended to serve as an introduction to microbiology for students interested in science, as well as for liberal arts students who are not going to major in biology or microbiology. The book is oriented in a very practical way and deals primarily with those aspects of microbiology that directly affect human affairs. Such fields as nursing, environmental protection, agriculture, food technology, and public health are given special attention.

We have been pleased that students and instructors alike found the first edition of this book to be readable as well as informative. A primary objective in writing the second edition was to bring the same level of accessibility to the discussion of several new, user-suggested topics, including chemistry, molecular biology, and genetics. Some exposure to chemistry is inevitable in the field of microbiology, and so we have added a chapter on chemistry sufficient for comprehending this text. Previous college chemistry is neither assumed nor required.

Chapter 5, "Chemical and Physical Background," also serves to prepare students for the discussions of microbial metabolism and biosynthesis and microbial genetics in Chapters 6 and 7. This important new triad of chapters comprises Part 2, "Molecular Biology." We have attempted to present a readily understandable introduction to this aspect of microbiology for students at this level.

The history of microbiology is introduced in Chapter 1 not only because it is a fascinating topic but also as a means to present to readers ideas and themes that are amplified throughout the book. Thus, although this chapter is rather long, it need not be read as a unit; relevant sections may be read to accompany various topics in later chapters.

Material on host-parasite relationships, immunology, and epidemiology has been considerably expanded. Emphasis is given in this edition to infectious disease and disease-causing organisms. We have chosen to organize this material around the organisms themselves rather than around organ systems affected or portals of entry. We elect this approach because it seems to us more logical from a practical microbiological point of view. In diagnostic microbiology, the main emphasis is on identification of the causal agent. The pathologist may be concerned with organ systems and the epidemiologist with portals of entry but the microbiologist is concerned with microorganisms.

Suggested readings lists are descriptive and direct readers to noteworthy publications, both basic and specialized, that further explore the subject of each chapter. The glossary, classification appendix, and index are useful for readers during the course of study and even, we hope, beyond.

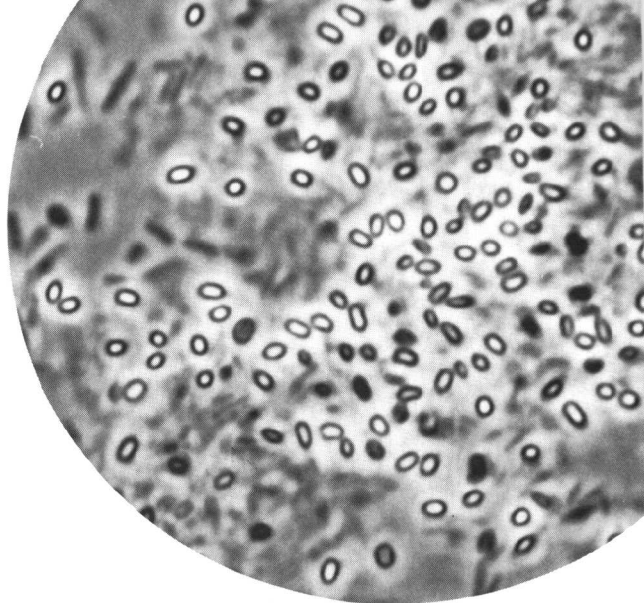
Another important concern in the choice of material and manner of presentation has been to keep the size of the book within reasonable bounds. We have had clearly in mind in this regard the fact that this text will be used for courses of varying lengths and emphases,¹ and we have tried to select material with the broadest interest and appeal. We have included a great many photographs, in particular, of real-world situations.

This book has a distinctly ecological flavor. Our own research interests lie in this direction, so that it has been easy for us to weave environmental thinking into the fabric of the text; but we have been further encouraged to do so by the obvious need for a textbook with more ecological emphasis. We hope that this book will stimulate students to turn to careers in the increasingly crucial fields of environmental studies and public health.

Thomas D. Brock
Katherine M. Brock

CONTENTS

Chapter 1 Introduction: the roots of microbiology 1



Preface v

1.1 The discovery of microorganisms 2	1.2 Spontaneous generation 5	1.3 The germ theory of disease 6	KOCH'S EARLY WORK
KOCH'S PURE CULTURE METHODS	KOCH AND TUBERCULOSIS	KOCH'S POSTULATES	1.4 Cholera, typhoid fever, and water purification 12
SNOW AND CHOLERA	KOCH AND CHOLERA	TYPHOID FEVER AND WATER PURIFICATION	1.5 Canning and pasteurization: the legacy of Nicolas Appert 17
APPERT'S METHOD	PASTEURIZATION	1.6 Vaccination and the prevention of infectious disease 22	JENNER'S WORK ON SMALLPOX
PASTEUR'S WORK ON VACCINATION	THE RABIES VACCINE	1.7 Antibiotics and chemotherapy 27	1.8 Root-nodule bacteria and the rise of agricultural microbiology 29
Suggested readings 31			

PART



GENERAL MICROBIOLOGY 32

Chapter 2 What are microorganisms? 34

2.1 Seeing microorganisms 35	THE LIGHT MICROSCOPE	SPECIMEN PREPARATION	STAINING	SPECIAL LIGHT MICROSCOPES	THE ELECTRON MICROSCOPE
2.2 Cell size 42	2.3 Prokaryotic cell				

structure 42 2.4 Eucaryotic cell structure 44 2.5 Kinds of microorganisms 46 2.6 Procaryotic microorganisms 47
 BACTERIA IDENTIFICATION OF BACTERIA BLUE-GREEN ALGAE (CYANOBACTERIA) 2.7 Eucaryotic microorganisms 56
 ALGAE FUNGI PROTOZOA VIRUSES Summary 62 Study questions 63 Suggested readings 63

3.1 Nutrition of microorganisms 64 ENERGY SOURCES ELEMENTAL REQUIREMENTS GROWTH FACTORS 3.2 Acidity, alkalinity, and neutrality 69 3.3 Preparation of culture media 70 SYNTHETIC AND COMPLEX MEDIA LIQUID AND SOLID MEDIA 3.4 Environmental requirements 73 TEMPERATURE OXYGEN ANAEROBES MAINTENANCE OF ANAEROBIC CONDITIONS 3.5 Enrichment cultures 79 3.6 Selective and differential media 79
 3.7 Isolation and maintenance of pure cultures 80 PURIFICATION VERIFICATION OF PURITY STOCK CULTURES CULTURE PRESERVATION CULTURE COLLECTIONS 3.8 Aseptic technique 86 STERILIZATION OF CULTURE MEDIA DRY-HEAT STERILIZATION GAS STERILIZATION INCINERATION FILTRATION CLOSURES ASEPTIC HANDLING AEROSOLS AND THEIR PREVENTION SPECIAL PRECAUTIONS WITH PATHOGENS Conclusion 96 Study questions 96 Suggested readings 97

4.1 Growth 98 EXPONENTIAL GROWTH GROWTH CYCLE
 4.2 Measurement of growth 101 TOTAL CELL COUNT VIABLE COUNT MEASUREMENT OF POPULATION WEIGHT 4.3 Sterility testing 107 4.4 Control of microbial growth 107 HEAT STERILIZATION PASTEURIZATION INCINERATION CONTROL OF MICROORGANISMS BY DRYING CONTROL OF MICROBIAL GROWTH BY LOW TEMPERATURES EFFECT OF RADIATION ON MICROORGANISMS
 4.5 Antimicrobial agents 113 DISPOSAL OF TOXIC AGENTS
 4.6 Antibiotics 116 ASSAY OF ANTIBIOTICS TESTING CULTURES FOR ANTIBIOTIC SENSITIVITY KINDS OF ANTIBIOTICS AND THEIR ACTIONS ANTIBIOTIC RESISTANCE THE SEARCH FOR NEW ANTIBIOTICS
 Summary 128 Study questions 129 Suggested readings 129

PART

2

MOLECULAR BIOLOGY 130

5.1 Matter 132 CHEMICAL SYMBOLS 5.2 Structure of atoms 133 THE PERIODIC TABLE ISOTOPES 5.3 Molecules and ions 136 MOLECULES IONS POLYATOMIC IONS
 5.4 Expressing concentrations 138 5.5 Acids and bases: the pH

Chapter 3 Care and feeding of microbes 64

Chapter 4 Microbial growth and its control 98

Chapter 5 Chemical and physical background 132

Chapter 6
Microbial metabolism and biosynthesis 163

Chapter 7
Genetics 197

Chapter 8
Infection and immunity 216

scale 140 5.6 Chemical bonds 141 IONIC BONDS
COVALENT BONDS MULTIPLE COVALENT BONDS COVALENCE NUMBERS
COVALENT VERSUS IONIC BONDS BOND ENERGY 5.7 The importance
of weak bonds in biochemistry 144 HYDROGEN BONDS VAN DER
WAALS FORCES HYDROPHOBIC BONDING COOPERATIVE ACTION OF WEAK
BONDS 5.8 Chemical reactions 147 IONIC REACTIONS
ACID-BASE REACTIONS HYDROLYSIS REACTIONS GROUP-TRANSFER
REACTIONS OXIDATION-REDUCTION REACTIONS 5.9 Energy and
chemical reactions 152 CHEMICAL EQUILIBRIUM FREE ENERGY AND
CHEMICAL REACTIONS 5.10 Activation energy and catalysts 154
CATALYSTS 5.11 Enzymes as catalysts 155 ENZYME ACTION
NAMING OF ENZYMES 5.12 Organic chemistry 157 WRITING
STRUCTURES OF ORGANIC COMPOUNDS ISOMERS OPTICAL ISOMERS
IMPORTANT CLASSES OF ORGANIC COMPOUNDS POLYMERS Suggested
readings 162

6.1 Obtaining energy: catabolism 164 OXIDATION AND
REDUCTION SYNTHESIS OF HIGH-ENERGY PHOSPHATE BONDS
(PHOSPHORYLATION) 6.2 Biochemistry of energy generation 169
FERMENTATION RESPIRATION ENERGY YIELD IN CATABOLISM
ANAEROBIC RESPIRATION 6.3 Kinds of energy sources 174
LIGHT INORGANIC ENERGY SOURCES ORGANIC COMPOUNDS
6.4 Proteins 177 AMINO ACIDS AND PEPTIDE BONDS AMINO ACID
STRUCTURE PROTEIN STRUCTURE 6.5 Nucleic acids 181
NUCLEIC ACID BASES NUCLEOTIDES 6.6 Biosynthesis:
anabolism 184 PROTEIN SYNTHESIS NUCLEIC ACID SYNTHESIS
OTHER MACROMOLECULES 6.7 Regulation of metabolism 189
INDUCTION AND REPRESSION FEEDBACK INHIBITION 6.8 Mode of
action of antibiotics 192 Summary 195 Study
questions 196 Suggested readings 196

7.1 Mutation 198 THE EFFECT OF MUTAGENTS KINDS OF
MUTANTS 7.2 Genetic recombination 201
7.3 Transformation 203 7.4 Conjugation 204
7.5 Transduction 207 7.6 Plasmids 209 7.7 Genetic
engineering 210 Summary 212 Study questions 213
Suggested readings 213

PART

3

INFECTIOUS DISEASES 214

8.1 The normal flora of the body 217 SKIN MOUTH
GASTROINTESTINAL TRACT OTHER REGIONS 8.2 Germ-free
animals 221 8.3 Infectious diseases 223

SPECIFICITY OF CAUSAL ORGANISMS	8.4 How do microorganisms cause disease? 225
INVASION AND GROWTH IN THE HOST	
OVERCOMING HOST DEFENSE MECHANISMS	PATHOGENICITY
ATTENUATION OF VIRULENCE	DISEASE STAGES
8.5 Immunity 233	BLOOD AND ITS COMPONENTS 8.6 Nonspecific immunity 234
PHAGOCYTOSIS	ANTIMICROBIAL SUBSTANCES
INFLAMMATION	8.7 Specific immunity 239
ANTIBODIES	ANTIGENS
8.8 Kinds of antibodies and their properties 241	
8.9 Antigen-antibody reactions 243	8.10 Complement and complement fixation 245
8.11 Mechanism of antibody formation 247	8.12 Cellular immunity 250
8.13 Hypersensitivity (allergy) 252	TRANSPLANTATION AND IMMUNITY
8.14 Blood groups 254	ABO SYSTEM Rh SYSTEM
BLOOD TYPING	8.15 Immunization against disease 257
IMMUNITY	PASSIVE IMMUNITY
ACTIVE IMMUNITY	IMMUNIZATION PRACTICES
IMMUNIZATION OF TRAVELERS	8.16 Antibiotics and other drugs in the treatment of infectious disease 262
8.17 Clinical microbiology 264	Summary 267
Study questions 268	
Suggested readings 270	

9.1 Stages in the infection process 271	STEPS IN INFECTION	EXIT FROM THE HOST
9.2 Dispersal 273	AIR DISPERSAL	WATER AND FOOD DISPERSAL
DIRECT CONTACT	OBJECTS	WOUND INFECTIONS
TRANSMISSION FROM ANIMALS TO HUMANS	9.3 Health of the population 279	MORTALITY
FACTORS INFLUENCING MORTALITY	MORBIDITY	WORLD HEALTH
9.4 Reportable diseases 282	KINDS OF REPORTABLE DISEASES	9.5 Epidemics 284
CYCLES OF DISEASE	THE CARRIER STATE	9.6 Control of epidemics 288
RECOGNITION OF AN EPIDEMIC	QUARANTINE	PREVENTION OF AN EPIDEMIC
SCHOOLS AND PUBLIC HEALTH	STATISTICS	
9.7 Eradication of disease 292	IMMUNIZATION	ERADICATION OF INSECT VECTORS
DRUG TREATMENT	9.8 Hospital sanitation 295	ORGANISMS INVOLVED IN HOSPITAL INFECTIONS
9.9 Nursing and hospital practices 297	NURSING PRACTICES	
HOSPITAL HOUSEKEEPING	SURGICAL SKIN ANTISEPSIS	9.10 Hospital sterilization procedures 303
STEAM STERILIZATION	GAS STERILIZATION	CHEMICAL STERILIZATION
ORGANIZATION OF THE STERILE-SUPPLY DEPARTMENT	MICROBIOLOGICAL SAMPLING IN THE HOSPITAL	9.11 Hospital isolation procedures 308
PROTECTIVE ISOLATION	9.12 Embalming and disposal of the dead 310	
Summary 312	Study questions 312	Suggested readings 313

10.1 Streptococcus 314	10.2 Staphylococcus 317
10.3 Neisseria 319	10.4 Bacillus 322
10.5 Clostridium 324	10.6 Corynebacterium 326
10.7 Mycobacterium 327	10.8 Enteric bacteria 330
10.9 Yersinia and plague 334	

Chapter 9 The spread of disease 271

Chapter 10 Bacterial diseases 314

Chapter 11
Fungal and protozoal
diseases 352

Chapter 12
Viruses and viral
diseases 366

Chapter 13
Environmental
microbiology 390

Chapter 14
Microbiology of water
and wastewater 419

10.10 *Franciscella* and tularemia **336** 10.11 *Hemophilus* and
Bordetella **336** 10.12 *Brucella* **337**
10.13 *Pseudomonas* **338** 10.14 *Vibrio* **339**
10.15 *Spirochetes* **340** 10.16 *Mycoplasma* **346**
10.17 *Rickettsia* **347** 10.18 *Chlamydia* **349** Study
questions **351** Suggested readings **351**

11.1 Fungal diseases **352** SYSTEMIC MYCOSES SUPERFICIAL
MYCOSES MYCOTOXINS 11.2 Protozoal diseases **358**
FLAGELLATED PROTOZOA AMOEBAS MALARIA PARASITE Study
questions **365** Suggested readings **365**

12.1 Virus structure and reproduction **367** 12.2 Interference with
viral activity **369** 12.3 Virus diseases of higher
animals **371** 12.4 Polio **372** 12.5 Influenza **375**
12.6 Smallpox **377** 12.7 Measles **378** 12.8 Rubella, or
German measles **379** 12.9 Adenoviruses **379**
12.10 Rabies **381** 12.11 Tumor viruses **383**
12.12 Common cold **384** 12.13 Hepatitis **385** Study
questions **386** Suggested readings **386**

PART

4

ENVIRONMENTAL MICROBIOLOGY 388

13.1 Symbiosis **391** LICHENS INSECT SYMBIOSES ALGAE AND
INVERTEBRATES MYCORRHIZAL FUNGI 13.2 Microorganisms and
ecosystems **398** 13.3 The carbon cycle **400**
13.4 Petroleum microbiology and the carbon cycle **401** PETROLEUM
PROSPECTING HARMFUL EFFECTS 13.5 The nitrogen cycle **404**
NITROGEN FIXATION NITRIFICATION DENITRIFICATION 13.6 The
sulfur cycle **407** SULFATE REDUCTION SULFUR OXIDATION
SULFIDE OXIDATION 13.7 Mining microbiology and the sulfur
cycle **408** ACID MINE DRAINAGE ROLES OF THIOBACILLUS
FERROOXIDANS IN MINERAL-MINING OPERATIONS Summary **416**
Study questions **417** Suggested readings **417**

14.1 Water supply **419** DRINKING WATER URBAN WATER SUPPLY
KINDS OF CONTAMINANTS IN WATER AND THEIR SOURCES
14.2 Pathogenic organisms transmitted by water **424** BACTERIA
VIRUSES PROTOZOA 14.3 Ensuring the safety of drinking

water 427	COLIFORMS AS INDICATORS	STANDARD METHODS
OTHER INDICATOR BACTERIA	14.4 Water purification 432	
DOMESTIC WATER PURIFICATION	EMERGENCY WATER-SUPPLY	
TREATMENT	14.5 Drinking-water standards 436	SAMPLING
FREQUENCY	COLIFORM STANDARDS	REPORTING AND PUBLIC
NOTIFICATION	CHLORINE SUBSTITUTION FOR COLIFORM	
DETERMINATIONS	STANDARD PLATE COUNT REGULATIONS	
14.6 Microbiology of water pipelines 441	CORROSION	
PRECIPITATE FORMATION	PATHOGENIC ORGANISMS	14.7 Water
pollution 443	TYPES OF POLLUTANTS	BIOCHEMICAL OXYGEN DEMAND
(B.O.D.)	SELF-PURIFICATION OF WATER	14.8 Microbial indicators of
sewage pollution 446	FECAL COLIFORMS	14.9 Sewage-treatment
systems 448	14.10 Anaerobic digestion processes in sewage	
treatment 450	STEPS IN SLUDGE DIGESTION	SLUDGE DISPOSAL
14.11 Aerobic sewage-treatment systems 452	TRICKLING	
FILTERS	ACTIVATED SLUDGE	SUBSTANCES RESISTANT TO
DECOMPOSITION	14.12 Discharge of treated sewage 457	
CHLORINATION	VIRUSES IN SEWAGE EFFLUENTS	HEALTH HAZARDS OF
TREATMENT PLANTS	14.13 Advanced treatment methods 458	
COAGULATION-SEDIMENTATION	ADSORPTION	ELECTRODIALYSIS
REVERSE OSMOSIS	CHEMICAL OXIDATION	14.14 Lagoons, septic
tanks, and privies 460	SEWAGE LAGOONS	SEPTIC TANKS
PRIVIES	14.15 Algae and water pollution 463	RESERVOIRS
SWIMMING POOLS	EUTROPHICATION AND DOMESTIC SEWAGE	
14.16 Water pollution from the pulp and paper industry 465		
SULFITE PROCESS	SODA ASH PROCESS	PAPER MAKING
MICROBIOLOGICAL PROBLEMS	14.17 Solid-waste disposal 469	
Summary 472	Study questions 473	Suggested readings 474

15.1 Food spoilage 476	FACTORS AFFECTING MICROBIAL GROWTH IN
FOODS	CONDITIONS OF STORAGE
CONSEQUENCES OF MICROBIAL	
GROWTH IN FOODS	15.2 Pathogens in foods 482
FOOD	
POISONINGS AND TOXINS	SALMONELLA FOOD INFECTION
INVESTIGATING AN OUTBREAK	15.3 Assessing microbial content of
foods 487	15.4 Food preservation 489
DRYING	
LOW-TEMPERATURE STORAGE	PICKLED OR FERMENTED FOODS
PRESERVES, JELLIES, AND SALTED PRODUCTS	CANNING
15.5 Dairy	
microbiology 500	THE NATURE OF MILK
MICROORGANISMS IN MILK	
PASTEURIZATION	TESTING MILK
BACTERIOLOGICAL EXAMINATION OF MILK	
GOVERNMENT REGULATION OF MILK	FERMENTED MILKS
STARTER	
CULTURES	15.6 Cheese 513
STEPS IN CHEESE MAKING	
15.7 Meat microbiology 517	SLAUGHTERHOUSE HYGIENE
REFRIGERATION	MEAT SPOILAGE
ASSESSING THE MICROBIAL CONTENT	
OF MEAT	MEAT PRESERVATION AND CURING
SAUSAGE	15.8 Food
sanitation 524	Summary 527
Study questions 529	
Suggested readings 529	

Chapter 15

Food microbiology 476

PART

5

AGRICULTURAL AND INDUSTRIAL MICROBIOLOGY 530

Chapter 16 Agricultural microbiology 532

16.1 The soil 532 SOIL FORMATION KINDS OF SOILS
MICROORGANISMS AND SOIL FERTILITY 16.2 Compost 535
16.3 Pesticides 536 16.4 Root-nodule bacteria and nitrogen
fixation 539 ROOT-NODULE BACTERIA OF LEGUMES NODULE
FORMATION NODULE FUNCTION AGRICULTURAL ASPECTS OTHER
ROOT-NODULE RELATIONSHIPS 16.5 Microbial transformations of
nitrogen fertilizers 543 NITRATE FERTILIZER AMMONIA
UREA 16.6 Plant diseases 545 NORMAL FLORA OF PLANTS
PLANT ORGANS AND PLANT DISEASES FACTORS AFFECTING PLANT
DISEASE CONTROL OF PLANT DISEASES 16.7 Retting 548
16.8 Microbial insecticides 548 16.9 Mycotoxins and grain
storage 550 16.10 Animal husbandry 552 ANIMAL
DISEASES RUMINANTS AND MICROORGANISMS ANTIBIOTICS IN ANIMAL
FEEDS SILAGE AS AN ANIMAL FEED Summary 559 Study
questions 560 Suggested readings 560

Chapter 17 Industrial microbiology 562

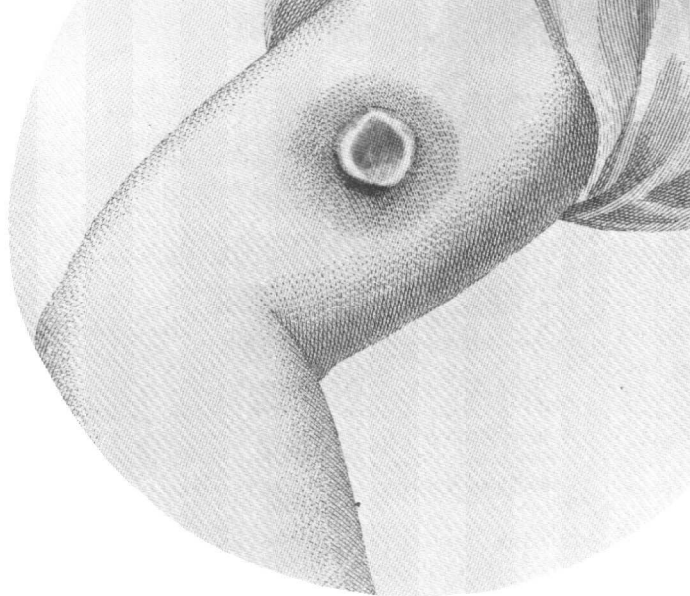
17.1 Industrial fermentation 562 STERILIZATION AERATION
RUNNING THE FERMENTATION 17.2 Yeasts in industry 567
BAKERS' YEAST FOOD AND FEED YEAST 17.3 Alcohol and alcoholic
beverages 571 WINE BREWING DISTILLED ALCOHOLIC BEVERAGES
INDUSTRIAL ALCOHOL 17.4 Antibiotic fermentation 578
17.5 Vitamins and amino acids 581 VITAMINS AMINO ACIDS
17.6 Microbial bioconversion 582 HORMONE PRODUCTION
17.7 Enzyme production by microorganisms 583
17.8 Vinegar 584 ACETIC ACID BACTERIA VINEGAR PRODUCTION
METHODS 17.9 Citric acid and other fermentation
products 586 17.10 Food from microorganisms 586
ALGAE BACTERIA FUNGI Summary 589 Study
questions 590 Suggested readings 590

Appendix 592

Glossary 596

Index 602

Outline of the classification of procaryotic microorganisms



In health and in disease, the activities of microorganisms greatly affect human life. Whether in country or city, tropics, midlatitudes, or the arctic, human beings are continually influenced by microbes. The science that deals with the study of microorganisms is called *microbiology* and is a branch of biology parallel to *botany*, the study of plants, and *zoology*, the study of animals. However, the procedures and practices by which microorganisms are studied are quite different from those used to study plants and animals, and it is for this reason that microbiology has developed as a science independent of botany and zoology. The goal of the microbiologist is to understand the beneficial and harmful activities of microorganisms and through this understanding to devise ways that benefits may be increased and damages curtailed. Microbiologists have been successful in achieving this goal, and microbiology has played a major role in the advancement of human health and welfare.

Microbiology may be the most applied of the biological sciences. At the same time, it is one of the most basic of the biological sciences, because microorganisms have provided the most suitable experimental materials for studies on the nature of life itself, studies now classified under the heading of *molecular biology*. Molecular biology has developed into an independent science, but microbiology as an applied science has remained intact and is no less important now than it was before the rise of molecular biology. One apprecia-

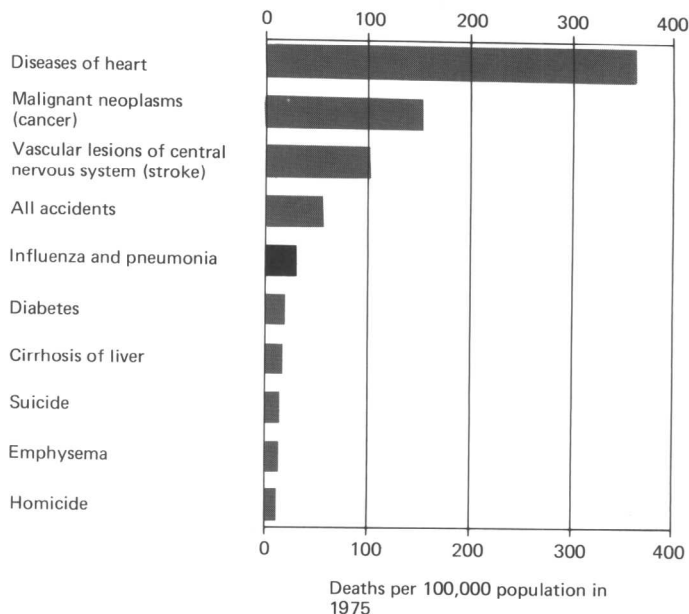
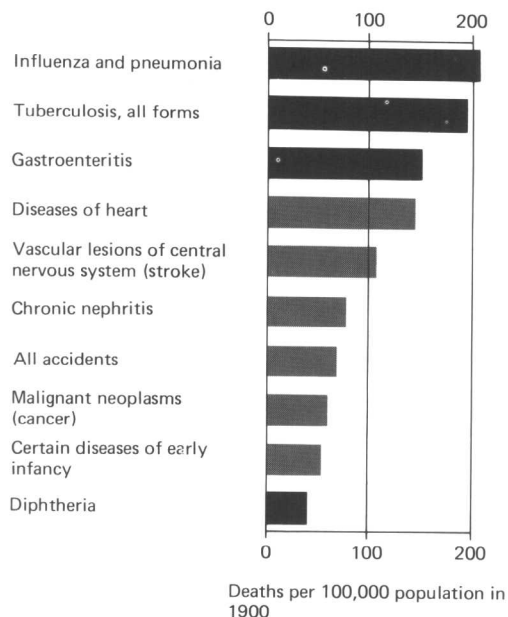


FIGURE 1.1
Death rates for the 10 leading causes of death: 1900 and 1975. Infectious diseases were the leading causes of death in 1900, whereas today they are much less important. From *U.S. Public Health Service Publ. No. 600* (revised 1967) and *Statistical Abstract of the United States*, 1975.

tion of the importance of microbiology for human health is shown by the statistics in Figure 1.1, which compares death rates in the United States in 1900 and 1975. In 1900, the major causes of death were all infectious diseases; currently, infectious diseases are of only minor importance. Control of infectious disease has come as a result of our vast scientific understanding of disease processes. Microbiology had its beginnings in these studies of disease.

In this chapter, we introduce the subject of microbiology through the presentation of a series of brief historical essays. Most of these sections concern studies that were done, primarily in the nineteenth century, to understand and control infectious disease. However, the striving to control infectious disease was not the only impetus for the development of microbiology. We also find that some interesting and important advances were made through studies on food and agricultural problems. And one of the most significant advances, the discovery of microorganisms themselves, occurred as a result of basic research done without any preconceived practical goal, but merely because of an interest in using microscopes to see the very small.

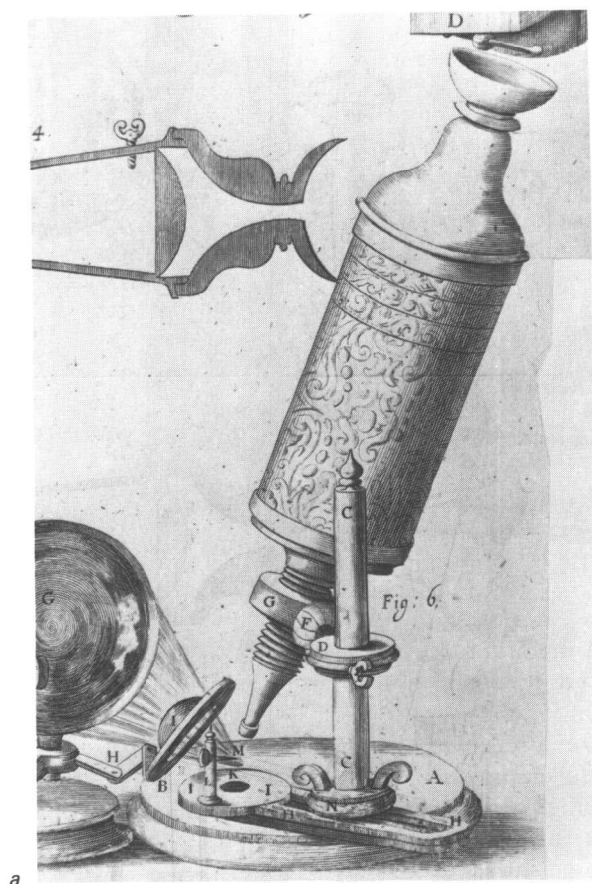
Although the existence of creatures too small to be seen with the eye had long been suspected, their discovery was linked to the invention of the microscope. Robert Hooke, using elegantly ornate micro-

1.1 The discovery of microorganisms

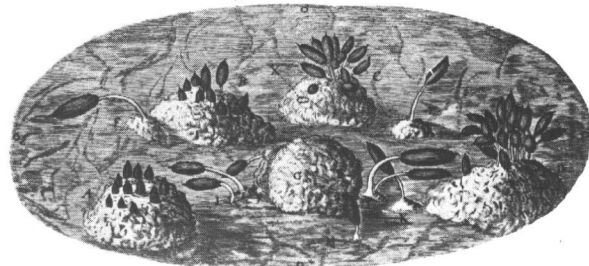
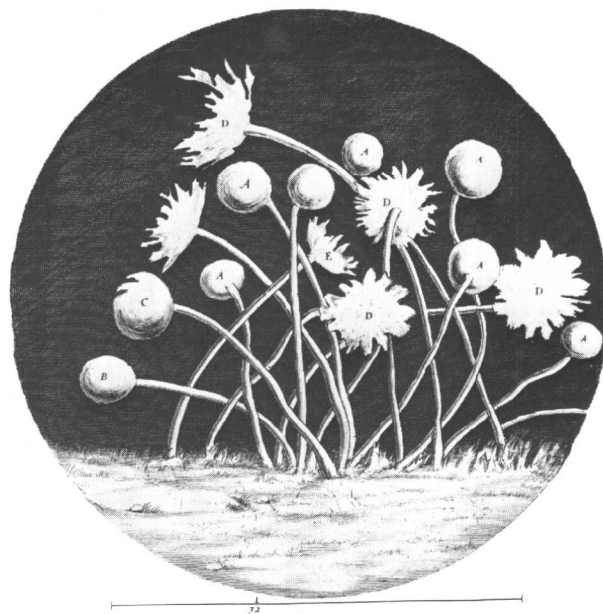
FIGURE 1.2

The early microscopic observation of a microorganism by Robert Hooke. *a* Robert Hooke's microscope, as illustrated in his great book, *Micrographia*, published in 1665. This is a compound microscope having two lenses, one near the eye and the other near the object. *b* Hooke's drawing of a blue mold growing on the surface of leather; the round structures contain spores of the mold.

scopes (Figure 1.2*a*), described the fruiting structures of molds in 1664 (Figure 1.2*b*), but the first person to see microorganisms in any detail was the Dutch amateur microscope builder Antoni van Leeuwenhoek, who used simple microscopes of his own construction (Figure 1.3). Leeuwenhoek's microscopes were extremely crude by today's standards, but by careful manipulation and focusing he was able to see organisms as small as bacteria. He reported his observations in a series of letters to the Royal Society of London, which published them in English translation. Drawings of some of Leeuwenhoek's "wee animalcules" are shown in Figure 1.4. His observations were confirmed by other workers, but progress in understanding the nature of these tiny organisms came slowly. Only in the nineteenth century did improved microscopes become available and widely distributed. At all stages of its history, the science of microbiology has taken the greatest steps forward when better microscopes have been developed, for these enable scientists to penetrate ever deeper into the mysteries of the cell.



a



b

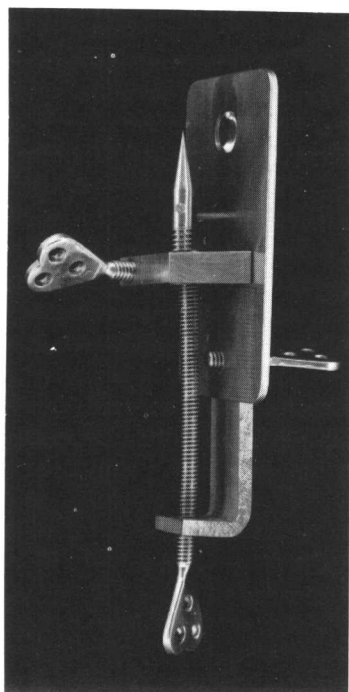
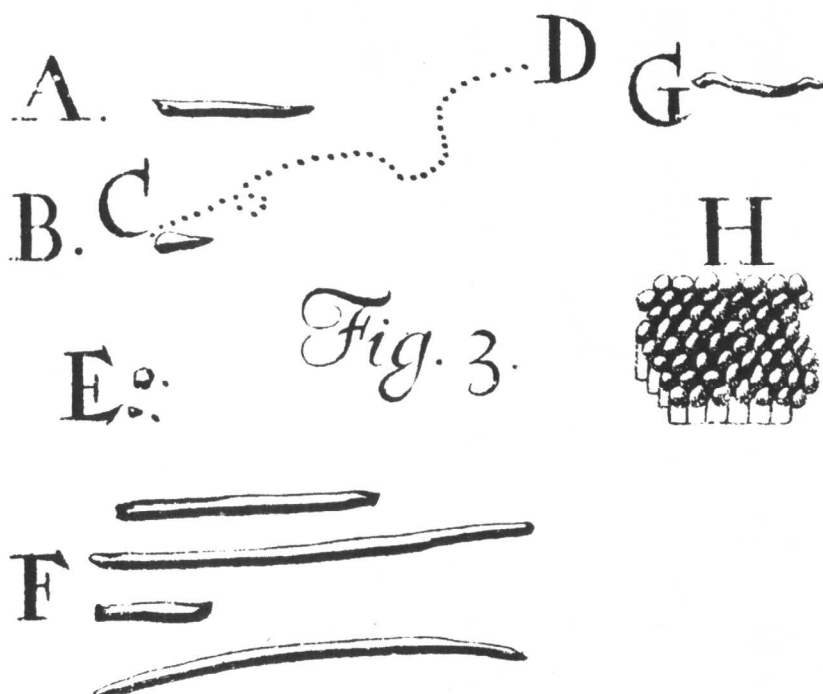


FIGURE 1.3

A replica of the microscope Leeuwenhoek used. The object to be viewed was placed on the pointed tip at the end of the screw and was moved back and forth by turning the screw. This is a simple microscope, composed of only a single lens. Although a simple microscope theoretically provides less resolution than a compound microscope such as Hooke's (Figure 1.2a), actually Leeuwenhoek was a superb lensmaker, and his microscopes resolved better than Hooke's.

FIGURE 1.4

Leeuwenhoek's drawings of bacteria, published in 1684. Even from these crude drawings we can recognize several kinds of common bacteria. Those lettered A, C, F, and G are rod-shaped; E, spherical or coccus-shaped; H, coccus-shaped bacteria in packets. From A. van Leeuwenhoek, *Phil. Trans. Roy. Soc., London*, **14**, 568, 1684.



Microbiology did not develop as a science until the latter part of the nineteenth century. This long delay occurred because, in addition to microscopy, certain other basic techniques for the study of microorganisms needed to be devised. In the nineteenth century, investigation of two perplexing questions led to the development of these techniques and laid the foundation of microbiological science: (1) Does spontaneous generation occur? (2) What is the nature of contagious disease? These two questions were studied simultane-

ously, and sometimes the same people worked on both. By the end of the century, both questions were answered, and microbiology was firmly established as a distinct and growing field of science.

1.2 Spontaneous generation

The basic idea of spontaneous generation can easily be understood. If food is allowed to stand for some time, it putrefies, and when the putrefied material is examined microscopically, it is found to be teeming with bacteria. Where do these bacteria come from, since they are not seen in fresh food? Some people said they developed from seeds or germs that had entered the food from the air, whereas others said that they arose spontaneously.

Spontaneous generation would mean that life could arise from something nonliving, and many people could not imagine something so complex as a living cell arising spontaneously from dead materials. The most powerful opponent of spontaneous generation was the French chemist Louis Pasteur, whose work on this problem was the most exacting and convincing. Pasteur first showed that there were structures present in air that closely resembled the microorganisms seen in putrefying materials. He did this by passing air through guncotton filters, the fibers of which stop solid particles. After the guncotton was dissolved in a mixture of alcohol and ether, the particles that it trapped fell to the bottom of the liquid and were examined on a microscope slide. Pasteur found that in ordinary air there exists constantly a variety of solid structures ranging in size from 0.01 millimeter (mm) to more than 1.0 mm. Many of these structures resembled the spores of common molds, the cysts of protozoa, and various other microbial cells. As many as 20 to 30 of them were found in 15 liters of ordinary air, and they could not be distinguished from the organisms found in much larger numbers in putrefying materials. Pasteur concluded, therefore, that the organisms found in putrefying materials originated from the organized bodies present in the air, which are constantly being deposited on all objects. If this conclusion was correct, it meant that food treated to destroy all the living organisms contaminating it would not putrefy. In fact, Nicholas Appert had already devised a method for food preservation based on heat treatment (see Section 1.5) but did not understand the principle upon which his method worked.

Pasteur used heat to eliminate contaminants, since many workers had shown that if a nutrient infusion was sealed in a glass flask and heated to boiling, it never putrefied. The proponents of spontaneous generation had criticized such experiments by declaring that fresh air was necessary for spontaneous generation and that the air inside the sealed flask was affected in some way by heating so that it would no longer support spontaneous generation. Pasteur skirted this objection simply and brilliantly by constructing a swan-necked