third edition

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A HUMAN PERSPECTIVE

Roberts

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Eugene W. Nester
University of Washington

Denise G. Anderson
University of Washington

C. Evans Roberts, Jr.
University of Washington

Nancy N. Pearsall

Martha T. Nester

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About the front cover: Complex patterns shown during growth of bacterial colonies result from cooperative effects and chemical communication among the bacteria. On the front cover, you see a chiral pattern developed by a colony of *Paenibacillus dendritiformis* grown on a soft thin agar substrate.
Photo provided by E. Ben Jacob, grown by E. Braines, photography by S. Avikam.

About the back cover: Multicellular organization of bacteria revealed by the regular appearance of differentiated cell groups in colonies. The three colonies at the top right contain *Escherichia coli* cells that turn blue when they produce the enzyme beta-galactosidase. The colony on the left contains *Chromobacterium violaceum* cells that can produce a purple pigment.
Photos provided by James A. Shapiro, University of Chicago.

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We dedicate this book to our students; we hope it helps to enrich their lives and to make them better informed citizens,

to our families whose patience and endurance made completion of this project a reality,

to Anne Nongthanat Panarak Roberts in recognition of her invaluable help, patience, and understanding,

to our colleagues for continuing encouragement and advice.

Eugene Nester

Eugene (Gene) Nester did his undergraduate work at Cornell University and received his Ph.D. in Microbiology from Case Western University. He then did postdoctoral work in the Department of Genetics at Stanford University with Joshua Lederberg. Since 1962, Gene has been a faculty member in the Department of Microbiology at the University of Washington. Gene's research has focused on gene transfer systems in bacteria. His laboratory demonstrated that *Agrobacterium* transfers DNA into plant cells, the basis for the disease, crown gall. He continues to study this unique system of gene transfer which has become a corner stone of plant biotechnology.

In 1990, Gene Nester was awarded the inaugural Australia Prize along with an Australian and a German scientist for their work on *Agrobacterium* transformation of plants. In 1991, he was awarded the Cetus Prize in Biotechnology by the American Society of Microbiology. He has been elected to Fellowship in the National Academy of Sciences, the American Academy for the Advancement of Science, the American Academy of Microbiology, and the National Academy of Sciences in India. Throughout his career, Gene has been actively involved with the American Society for Microbiology and currently serves as Chair of the Board of Governors of the American Academy of Microbiology.

In addition to his research activities, Gene has taught an introductory microbiology course for students in the allied health sciences for many years. He wrote the original version of the present text, *Microbiology: Molecules, Microbes and Man*, with Evans Roberts and Nancy Pearsall more than 25 years ago because they felt no suitable text was available for this group of students. The original text pioneered the organ system approach to the study of infectious disease.

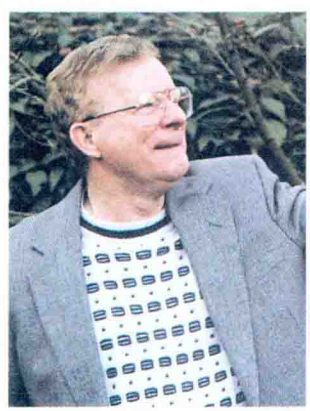
Gene enjoys traveling, museum hopping, and the study and collecting of Northwest Coast Indian Art. He and his wife, Martha, live on Lake Washington with a seldom used sailboat and their dog, Otis. Their two children and four grandchildren live in the Seattle area.

Denise Anderson

Denise Anderson is a Senior Lecturer in the Department of Microbiology at the University of Washington, where she teaches a variety of courses including general microbiology, recombinant DNA techniques, medical bacteriology laboratory, and medical mycology/parasitology laboratory. Equipped with a diverse educational background, including undergraduate work in nutrition and graduate work in food science and in microbiology, she first discovered a passion for teaching when she taught microbiology laboratory courses as part of her graduate training. Her enthusiastic teaching style, fueled by regular doses of Seattle's famous caffeine, receives high reviews by her students.

Outside of academic life, Denise relaxes in the Phinney Ridge neighborhood of Seattle, where she lives with her husband, Richard Moore, two dogs, and two cats, none of which are very well trained. When not planning lectures, grading papers, or writing textbook chapters, she can usually be found chatting with the neighbors, fighting the weeds in her garden, or enjoying a fermented beverage at the local pub.

Evans Roberts, Jr.



Evans Roberts was a marginally motivated mathematics student at Haverford College when a chance encounter landed him a summer job at the Marine Biological Laboratory in Woods Hole, Massachusetts. There, interaction with leading scientists awakened his interest in biology and medicine. After completing his undergraduate work in mathematics, he studied for his M.D. at Columbia University, completed an internship at the University of Rochester School of Medicine

and Dentistry, and held a Residency in Medicine at the University of Washington. Further, he received a fellowship in Infectious Disease with Dr. William M. M. Kirby and fulfilled a traineeship in Diagnostic Microbiology with Dr. John Sherris.

Subsequently, Dr. Roberts has taught microbiology, directed diagnostic microbiology laboratories, worked on hospital infection control committees, and helped in a refugee camp for Karen people in northern Thailand. He has had extensive experience in the practice of medicine as it relates to infectious diseases. He is certified both by the American Board of Microbiology and the Academy of Family Physicians.

Evans Roberts worked with Gene Nester in the early development of *Microbiology: A Human Perspective*. His professional publications concern susceptibility testing as a guide to treatment of infectious diseases, Whipple's disease, Group A streptococcal epidemiology, use of fluorescent antibody in diagnosis, bacteriocin typing, antimicrobial resistance of tuberculosis and gonorrhea, viral encephalitis, and rabies. Dr. Roberts has traveled extensively around the world. For relaxation he enjoys hiking and gardening, especially the cultivation of flowers and exotic tropical fruits.

Nancy Pearsall

Nancy Neville Pearsall attended the College of William and Mary, the University of Virginia, and the University of Washington School of Medicine, where she earned M.S. and Ph.D degrees in the areas of immunology and medical microbiology. Her research has included work on cell-mediated immunity, immunity to candidiasis, and immune responses to urinary tract infections.

Nancy's love of teaching led to writing a number of textbooks in immunology and also medical microbiology for medical students, and in microbiology for college students. The affiliation of Nester, Roberts, and Pearsall in teaching microbiology courses and writing textbooks for the courses spans more than two decades. She has also coauthored a monograph, *The Macrophage*, and studied the role of macrophages in the response to tissue transplants, as well as to infectious agents. She has served on the editorial board of several scientific journals and as a consultant to the National Institutes of Health.

Dr. Pearsall was a faculty member in the Department of Microbiology and Immunology at the University of Washington, and served for 10 years as Professor and Head of the Department of Pathology and Microbiology in the School of Medicine at the University of Zambia, part of the time as a Fulbright Professor. While in Zambia, she also helped establish a program allowing postgraduate doctors to be trained within the country of Zambia, rather than having to go overseas to specialize. She has two sons, two daughters-in-law, four grandchildren, two cats, and a springer spaniel. Huge bald eagle neighbors that fish and soar nearby and Stellar blue jays that come for breakfast every day help make her northwestern United States home a perfect substitute for the excellent animal-viewing safaris of Zambia, Zimbabwe, Botswana, Kenya, and other countries of southern and central Africa.

Martha Nester

Martha Nester received an undergraduate degree in biology from Oberlin College and a Master's degree in education from Stanford University. She has worked in university research laboratories and has taught elementary school. She currently works in an environmental education program at the Seattle Audubon Society. Martha has worked with her husband, Gene, for more than 35 years on microbiology textbook projects, at first informally as an editor and sounding board, and then in the last 22 years as one of the authors of *Microbiology: A Human Perspective*. Martha's favorite activities include spending time with their four grandchildren, all of whom live in the Seattle area. She also enjoys playing the cello with a number of musical groups in the Seattle area.

This is an exciting, enjoyable yet challenging time to be teaching and learning about microbiology. Almost every day a newspaper article describes the discovery of microbes in an ecological niche thought to be inhospitable to life, the sequencing of another microbial genome, or the death of an individual from a rare infectious disease. Anyone even glancing at the front page can't help but realize that microorganisms are very important in our daily lives. With the announcements of the many scientific advances being made about the microbial world, there also come many vehement arguments that also are played out in the popular press. Are plants that contain genes of microorganisms safe to eat? Is it wise to put antimicrobial agents in soaps and animal feed? What is the likelihood of getting AIDS from a person infected with HIV? What are the chances of finding life on Mars? This book presents what we to believe are the most important facts and concepts about the microbial world and the important role its members play in our daily lives.

An important consideration in revising this textbook was the diversity of interests among students who take an introductory microbiology course today. As always, many students are taking microbiology as a prerequisite for nursing, pharmacy, and dental programs. A suitable textbook must provide a solid foundation in health-related aspects of microbiology, including coverage of medically important bacteria, antimicrobial medications, and immunization. There is also an increasing number of students who take microbiology as a step in the pursuit of other fields, including biotechnology, food science and ecology. For these students, topics such as recombinant DNA techniques, fermentation processes and microbial diversity are essential. Microbiology is also becoming more popular as an elective for biology students, who are particularly interested in topics that highlight the relevance of microorganisms to shaping the biological world. Because of the wide range of career goals and interests of students, we have made a particular effort to broaden the scope of the previous editions, providing a more balanced approach, yet retaining our strength in medical microbiology.

Diversity in the student population is manifested not only in the array of career goals, but also in educational backgrounds. For some, microbiology may be their first college-level science course; for others microbiology builds on an already strong background in biology and chemistry. To address this broad range of student backgrounds, we have incorporated learning aids that will facilitate review for some advanced students, and will be a tremendous support to those who are seeing this material for the first time. We recognize that the number of terms in microbiology is almost enough to constitute a new language for beginning students. Therefore, we have defined key terms when they are introduced and include a comprehensive glossary. A pronunciation key is provided for names of microorganisms. We make frequent use of cross references that direct students to sections with a more thorough explanation of a concept. We recognize that a textbook, no matter how exciting the subject material, is not a novel. Few students will read the text from cover to cover and few instructors will include all of the topics covered in their course. Accordingly, we have used judicious redundancy to help present each major topic as a complete unit. We have avoided the chatty, superficial style of writing in favor of clarity and conciseness. The text is not "watered down" but rather provides students the depth of coverage needed to fully understand and appreciate the role of microorganisms in the biological sciences and human affairs.

Preparing a textbook that satisfies the needs of such a broad range of needs and interests is a daunting task, but also extremely rewarding. We hope you will find that the approach and structure of this edition presents a modern and balanced view of microbiology in our world today, acknowledging the profound and essential impact that microbes have on our lives.

What's New in This Edition?

No element of the book was left unexamined in this revision. Although previous and current users will recognize familiar features such as the Glimpse of History and the unparalleled coverage of medical microbiology, there are many new elements to explore. Some reorganization has occurred and each chapter contains material that appears for the first time in this edition. New learning aids have been incorporated such as critical thinking questions and illustrated tables. Many new topics such as quorum sensing and edible vaccines are included, and many familiar topics such as prokaryotic classification and horizontal gene transfer are presented in a more modern context.

Organization

Major changes in organization include:

1. The Table of Contents is now presented in 5 parts, with separate parts devoted to Microorganisms and Humans (Chapters 15–21) and Infectious Diseases (Chapters 22–29).
2. Control of Microbial Growth (Chapter 5) now immediately follows Dynamics of Prokaryotic Growth (Chapter 4).

3. Due to their importance in global health issues, coverage of arthropods and parasitic worms has been moved from an appendix and integrated into the text coverage where appropriate. These appear within distinct sections so that they still may be skipped in the interest of time.
4. Coverage of Respiratory System Infections now appears in a single chapter (Chapter 23) and coverage of Alimentary System Infections also appears in a single chapter (Chapter 24) so that common elements within the systems may be consolidated.
5. A "super" structure has been incorporated into lengthy chapters with more than one major topic so that students can identify discrete topics and instructors can make more directed assignments. For example in Chapter 3, Microscopy and Cell Structure, there are super-sections covering Microscopy and Cell Morphology, The Structure of the Prokaryotic Cell, and The Eukaryotic Cell.
6. Coverage of infectious diseases is indicated with yellow highlighting on the corners of pages. We hope this will facilitate its use in courses that use this material as a reference section.

Updates

With such rapid and sometimes surprising growth in the field of microbiology, new topics are found throughout the text. Moreover, familiar topics have been expanded with the addition of new information and insights as well as presented in new contexts made possible by advances in molecular biology. Recognizing the newly emerging significance of microbiology in the scientific community, each chapter ends with an essay (Future Challenges) presenting an issue of human concern facing us now or in the near future that will be tackled and possibly solved by the microbiologists of tomorrow. Epidemiological statistics have been updated. A partial list of new and updated topics follows.

- Antimicrobial resistance and gene transfer
- Overuse and misuse of germicidal chemicals
- Genomics
- Nucleotide array technology, ribotyping and other modern molecular methods
- Development of new vaccines
- New products of genetic engineering
- Quorum sensing
- Biofilms in ecology, medicine and applied microbiology
- Molecular methods to study microorganisms in nature
- Horizontal gene transfer and implications in microbial evolution
- Microbial life in the universe
- Ribosomal RNA and classification of microorganisms
- Role of viruses in cancer
- Nosocomial infections
- Emerging and re-emerging diseases
- Eradification of diseases such as measles and polio
- Updates on HIV infections and AIDS worldwide

Learning Aids

In order for students to succeed in their study of microbiology, they must be able to understand the material presented, utilize the text as a tool for learning, and enjoy reading the text. Therefore, we have continued use of many of the learning aids of previous editions and added some new ones to this edition to make the study of microbiology efficient and enjoyable. Many of these are shown in the Visual Preview included in this preface.

1. The art program has been completely revised to facilitate learning. New summary figures allow efficient review of complex systems and processes such as metabolic pathways or immune responses. More explanation appears within figures so that students can do not have to track events in a lengthy figure legend. Figures are more closely integrated with the text through boldface text references to parts and references to steps clearly identified within the text and the figure. Finally, all figures now benefit from attention to strict color coding and use of consistent icons to aid student comprehension.
2. Brief essays of human interest and contemporary relevance appear throughout the text. Each chapter opens with a Glimpse of History and closes with Future Challenges. Within a chapter, a human perspective is provided in the Perspective essays. Chapters on infectious disease contain a realistic Case Presentation.
3. New Microchecks provide opportunity to review each major section and test factual knowledge through review questions as well as offer practice in valuable critical thinking skills (through the blue questions).
4. Cross references with page numbers are provided at the ends of paragraphs mentioning concepts that are presented in more depth elsewhere in the text.
5. Figure and table references appear in boldface type throughout the text so that the context for figures and tables is easy to locate on the page.
6. Many new tables that summarize terms and concepts have been added to this edition.

   Tables outlining the major parameters of each disease appear in the chapters on infectious disease (Chapters 22–29); major diseases are also supported by a Disease Summary table that includes a visual presentation of the course of the infection.
7. Chapter summaries clearly indicate the key points under each major heading. Key figure references and table references appear in blue type. Key terms appear in boldface.
8. Each chapter still ends with Review Questions that encourage students to recap chapter content. New to this edition are Multiple Choice Questions, Applications Questions and Critical Thinking Questions. Multiple Choice questions provide self-testing; answers are available in Appendix 3. Students can apply their knowledge to real-life issues in the Applications. Critical Thinking questions, written by Robert Allen, a leading expert in critical thinking, provide practice in analyzing and using information in ways that will benefit students in any discipline. See the essay by Robert Allen in this preface.
9. A full glossary appears at the back of the book along with a pronunciation guide for names of microorganisms (Appendix 5) and appendices that provide help with

To the Student:

Included at the end of each chapter are critical thinking exercises that provide practice for applying the concepts and information included in the chapter. These exercises extend well beyond the correct recall of information or "looking up the answer." They require you to utilize critical thinking skills such as interpreting data and experimental results, predicting outcomes when conditions are changed, proposing and evaluating experimental designs, and establishing sound arguments and lines of reasoning. In other words, the emphasis is on skill development and application.

In each exercise, you should develop a logical argument that is based on information in the chapter and sound reasoning, not on opinion. The strength of your argument and reasoning will depend on appropriate concept application and structuring your argument so that it clearly leads to your conclusion and/or interpretation.

A few general guidelines for completing the exercises will be helpful:

1. Know what the question is asking. Does the question ask for a prediction? an interpretation? an experimental analysis?
2. What information is needed to solve the exercise? Now is the time for you to go back through the chapter, if necessary, to review concepts and information. Be sure to apply appropriate information to the problem.
3. What new information is provided in the exercise? How does this exercise differ from examples included in the chapter? Decide how this new information fits with and extends information in the chapter.
4. Draw a diagram or outline of the exercise. This will help organize your thoughts and insure understanding of the relationships in the exercise. It will also indicate the structure of your logic leading to your solution.

For most students, these exercises are difficult, especially at first. But as with any skill, ability and skill will improve with practice. Do not be discouraged with early difficulties; consistent effort and practice will lead to significant improvement.

Robert Allen

mathematics (Appendix 1), metabolic pathways (Appendix 2), and classification of microorganisms (Appendix 4).

Chapter Highlights

Chapter 1

Humans and the Microbial World Presents a more balanced view of the importance of microorganisms as well as the present and future challenges facing microbiologists. Includes multicellular parasites as members of the microbial world.

Chapter 2

The Molecules of Life Incorporates more biological relevance in coverage of chemistry. New sections on water chemistry and pH.

Chapter 3

Microscopy and Cell Structure Divided into three major sections - Microscopy and Cell Morphology, The Structure of the Prokaryotic Cell, and The Eukaryotic Cell. New emphasis on practical applications of various types of microscopes and staining techniques, updated coverage of transport mechanisms, expanded coverage of eukaryotic anatomy relevant to microbial infection processes. Many stunning new micrographs.

Chapter 4

Dynamics of Prokaryotic Growth New or expanded coverage of stock cultures, most probable number method, nutritional diversity, colony growth, and growth of biofilms in nature.

Chapter 5

Control of Microbial Growth Organization reflects the extent of use of a method rather than the traditional division into physical and chemical methods. Covers the factors included in choosing a control method, including associated risks and benefits.

Chapter 6

Metabolism: Fueling Cell Growth Completely revised chapter with new integrated art program and supportive summary tables. Initial overview of the fundamental principles of metabolism is followed by a deeper discussion of metabolic pathways; organization allows even beginning students to see the forest through the trees.

Chapter 7

The Blueprint of Life, From DNA to Protein The impact of genomics demands that today's students understand how cells extract and utilize information encoded in their DNA. Expansion of discussions on mechanisms make the processes of replication, transcription and translation easier to understand. Completely new art program reviewed for clarity and accuracy. Regulation now includes signal transduction, quorum sensing, and phase variation. New coverage of genomics.

Chapter 8

Bacterial Genetics Updated to include relevance of gene transfer in the spread of antibiotic resistance. Completely new art program continues clarity and style of Chapter 7. Divided into two major sections—Gene Mutation and Mechanisms of Gene Transfer.

Chapter 9

Biotechnology and Recombinant DNA Students become equipped to truly understand today's science with 1) a new discussion of DNA sequencing methods and 2) an expanded discussion of PCR that clarifies how it generates a fragment of a discrete size. Updated and relevant discussion of modern techniques including nucleotide array technology. Art program continues color and icon coding established in Chapters 7 and 8.

Chapter 10

Classification and Identification of Prokaryotes Chapter opens with identification which is the aspect of taxonomy that students will most likely experience. Routine phenotypic methods are covered, and building on the foundations laid in Chapter 9, current genotypic methods, including 16S rDNA sequencing and ribotyping are described. Phenotypic and genotypic methods of classification include the impact of 16S rDNA sequencing.

Chapter 11

The Diversity of Prokaryotic Organisms Organization and focus has been radically revised to highlight the extraordinary diversity of prokaryotes rather than their classification. Major sections

presenting more than 75 genera include Metabolic Diversity and Ecophysiology. For those incorporating classification schemes into their course, Appendix 4 includes the index of the latest edition of *Bergey's Manual of Determinative Bacteriology* which is now based on phylogeny rather than upon phenotype. Many stunning new micrographs portray microbial diversity.

Chapter 12

The Eukaryotic Members of the Microbial World New groupings of algae, protozoa, and fungi are presented based upon rRNA data. New discussion of arthropod vectors and the helminth parasites.

Chapter 13

Viruses of Bacteria Reorganization presents the general principles of virology followed by biology of bacteriophage, including several new groups.

Chapter 14

Viruses of Animals and Plants Now includes methods for studying viruses. Many new tables and summary figures, including comparisons of phage and animal viruses. Updated coverage on the role of viruses in cancer. Expanded coverage of prions and viroids.

Chapter 15

Nonspecific Immunity New overview of cells and tissues involved host defense supported by completely new art program. Updated coverage of cytokines. Phagocytosis now covered before inflammation.

Chapter 16

Specific Immunity Completely revised art program helps student to follow elements from Chapter 15 through discussion of specific immunity and to a final integrative overview figure. New summary tables. Revised and updated presentation of T-cell dependent and T-cell independent antigens, antibody diversity, and immunological tolerance.

Chapter 17

Applications of Immune Responses Antibody-mediated and cell-mediated immune responses are now included in Chapter 16. New section on quantifying antigen-antibody reactions, including principle of serial dilutions. New section on tests used in cellular immunology. Updated and expanded information on vaccines and immunization procedures, including current progress in the development of new vaccines.

Chapter 18

Immunologic Disorders New art program in continuity with preceding chapters on immunology. New section on transplantation immunity, expanded treatment of autoimmune diseases.

Chapter 19

Host-Microbe Interactions New overview with supporting summary tables introduces terms and concepts used in the study of infectious diseases. Updated coverage of A-B toxins and pathogenicity islands. New sections on 1) establishing the cause of an infectious disease, including discussion of Molecular Postulates as well as Koch's Postulates, 2) modes of transmission of infectious agents, and 3) pathogenic effects of viruses and other nonbacterial agents.

Chapter 20

Epidemiology New overview section on the principles of epidemiology. Coverage of nosocomial diseases has been expanded. New section on trends in disease, including emerging diseases. New heading structure adds clarity.

Chapter 21

Antimicrobial Medications New overview introduces the important concepts of antimicrobial medications. Discussion of penicillin family expanded to provide one in-depth example. Expanded coverage of mechanisms and transfer of antimicrobial resistance.

Chapter 22

Skin Infections Updated discussion and figures on Lyme disease, expanded material on acne. Common names of diseases are emphasized as well as clinical terminology. Illustrated disease summaries are presented for Lyme disease, chickenpox, measles and rubella.

Chapter 23

Respiratory System Infections Major sections include Infections of the Upper Respiratory System and Infections of the Lower Respiratory System. Updated revision of figures showing action of diphtheria and pertussis toxins, updated coverage of hantavirus pulmonary syndrome. Illustrated disease summaries are presented for strep throat, diphtheria, tuberculosis, and influenza.

Chapter 24

Alimentary System Infections Major sections include Infections of the Upper Alimentary System and Infections of the Lower Alimentary System. Improved illustration of system anatomy. New figures showing mode of action of cholera toxin, pathogenesis of shigellosis, and hepatitis A distribution. Revised figure on hepatitis B replication. Diseases caused by parasitic worms are included, with illustrations of life cycles and course of disease. Illustrated disease summaries are presented for cholera and *E. coli* disease.

Chapter 25

Genitourinary Infections Updates and new discussion on controlling sexually transmitted diseases. New photos showing symptoms of syphilis. New sections on non-venereal genital tract infections, pubic lice, and scabies. Illustrated disease summaries are presented for leptospirosis, gonorrhea, and syphilis.

Chapter 26

Nervous System Infections New figures on the causes of meningitis, viral encephalitis, polio, and the natural cycle of the Lacrosse virus. New discussion on prospects for the eradication of polio. Illustrated disease summaries are provided for meningococcal meningitis and listeriosis.

Chapter 27

Wound Infections New figures on "flesh-eating" streptococcal disease, cat scratch disease, and the mode of action of tetanus toxin. Illustrated disease summaries include lockjaw and gas gangrene.

Chapter 28

Blood and Lymphatic Infections New coverage of the blood fluke (*Schistosoma*), and the infection hypothesis as a contributing

cause of arteriosclerosis. New or revised figures on Gram : negative sepsis, distribution of tularemia, plague-infected fleas, infectious mononucleosis, and the malaria life cycle. Illustrated disease summaries include brucellosis and plague.

Chapter 29

HIV Disease and Complications of Immunodeficiency Extensively updated coverage throughout including cellular targets of HIV, global epidemiology of AIDS, effect of new treatments such as HAART, and the relationship between viral load and mortality.

Chapter 30

Environmental Microbiology Revised introductory section on the principles of microbial ecology. New section on bacteria in low-nutrient environments. Section on aquatic environments now immediately follows a completely revised section on terrestrial environments, including an overview discussion of soil.

Chapter 31

Water and Waste Treatment Updated coverage of health effects associated with waterborne organisms. Revised discussion of large-scale sewage treatment methods with new overview illustration.

Chapter 32

Food Microbiology Presentation of fermented foods has been reorganized to emphasize the microbial processes used to make food products—lactic acid fermentation by bacteria, alcohol fermentation by yeast, and changes due to mold growth. Although at the end of the text, this chapter can be a perfect follow-up to coverage of growth and metabolism.

Supplements

McGraw-Hill has developed an extensive teaching and learning package to accompany *Microbiology: A Human Perspective, third edition* that will provide unparalleled support for both students and instructors. Supplementary material appears in print versions, on CD-ROM, and on the Web. Check out some of the items available.

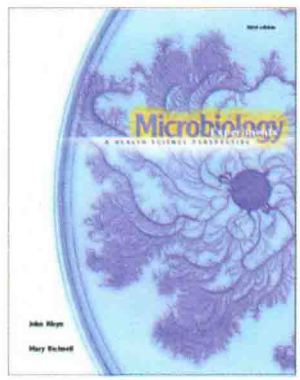
For the Student

Microbes in Motion Interactive CD-ROM This interactive CD-ROM for both Windows and Mac brings microbiology to life through interactive screens, video, audio, animations, and hyperlinking. This easy to use tutorial can go from the classroom to the resource center to the student's own personal computer. Ideal for self-quizzing, class preparation, or review of microbiological concepts.

Hyperclinic CD-ROM Students will have fun with this interactive CD-ROM while learning valuable concepts and gaining practical experience in clinical microbiology. Packed with over 100 case studies and over 200 pathogens supported with audio, video, and interactive screens, students will gain confidence as they take on the role of the professionals. Available Fall 2001.

Student Study Guide This valuable student resource written by Rick Corbett and Michael Lema of Midlands Technical College goes beyond the standard multiple choice and true-false self-quizzing. The authors have provided a wealth of study assets to help students truly master the material. In addition to unique learning activities, it includes key concepts, vocabulary review, self-tests, and more.

Laboratory Manual The third edition of *Microbiology Experiments: A Health Science Perspective* by John Kleyn and Mary Bicknell has been prepared to directly support the text (although it may be used with other microbiology textbooks). The laboratory manual features health-oriented experiments and endeavors also to reflect the goals and safety regulation guidelines of the American Society for Microbiologists. The class-tested exercises are modular and do not require a great deal of time either in lab or in preparation. Equipment and materials for the labs, including the laboratory manual itself, are inexpensive. Finally, all experiments are safe—they do not call for use of pathogens or human samples.



New to this edition is a series of engaging student projects that introduce some more intriguing members of the microbial world and expand the breadth of the manual beyond health-related topics. New experiments introduce modern techniques in biotechnology such as use of restriction enzymes and use of a computer database to identify sequence information. Five new appendices have been added to provide background in basic technique and practice problems. A new *Preparator's Manual* including answers to exercises, tips for successful experiments, lists of microbial cultures with sources and storage information, formulae and sources for stains and reagents, directions and recipes for preparing culture media, and sources of supplies is available to instructors for this edition.

For the Instructor

Transparencies A set of 200 images from the textbook are enhanced for classroom projection and available to adopters of the third edition of *Microbiology: A Human Perspective.*

Visual Resource Library This valuable CD-ROM contains all of the images from the textbook as well as the tables that appear in the textbook. This presentation software allows you to create your own multimedia presentations or export images into other programs. Images may be sorted by a number of criteria, and may be viewed in groups using the Small Gallery view.

Projection Slides Slide sets are available that show clinical examples of diseases or examples of microbial specimens.

Instructor's Manual and Test Item File Prepared by Michael Lema and Rick Corbett of Midlands Technical College, this valuable resource provides approximately 2,000 test items including multiple choice questions coded for level of difficulty, plus matching, true-false, and critical thinking questions. The manual also includes Learning Objectives keyed to the Student Study Guide, correlations to the multimedia and Web resources available with

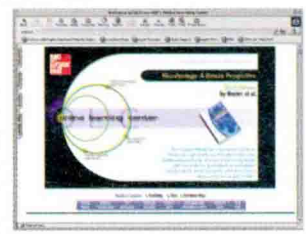
the text, answers to questions in the text, and support for teaching using a critical thinking approach.

Computerized Test Bank This helpful computerized testing and classroom management software from Microtest provides a sortable database of objective questions from the Test Item File for preparing exams. Available for Windows or Mac, it also includes an easy-to-use grade-recording program.

PageOut, PageOut Lite, McGraw-Hill Course Solutions Designed specifically to help you with your individual course needs, these products and services will assist you in integrating your syllabus with *Microbiology: A Human Perspective, third edition* state-of-the-art media tools. Create your own course-specific web page supported by McGraw-Hill's extensive electronic resources, set up a class message board or chat room online, provide online testing opportunities for your students, and more! For further information on these features, visit the Nester Web site at www.mhhe.com/nester.

Multimedia Resources

Online Learning Center Through the Nester 2001 Online Learning Center, everything you need for effective, interactive teaching and learning is at your fingertips. Moreover, this vast McGraw-Hill resource is easily loaded into course management systems such as Web CT or Blackboard.



Some of the online features you will find to support your use of *Microbiology: A Human Perspective, third edition* include:

For the Student:

- Additional multiple choice questions in a self-quizzing interactive format
- Electronic flash cards to review key vocabulary
- Study Outlines
- Tips for Solving Critical Thinking exercises
- Student Tutorial Service

For the Instructor:

- All of the images and tables from the text in an uploadable format for classroom presentation
- Correlation guides for use of all resources available with the text and to the ASM Guidelines
- Answers to text questions
- Course Consultant service to answer your specific questions about using McGraw-Hill resources with your syllabus
- Tips for teaching using Critical Thinking exercises

Plus

- An interactive Time Line detailing events and highlighting personalities critical to the development of the science of microbiology
- A supplementary section on clinical and diagnostic microbiology including additional Case Presentations and other resources
- Web exercises encouraging practice of use of the Web to gather and evaluate information
- Further Reading and Web Links to explore topics in microbiology more extensively

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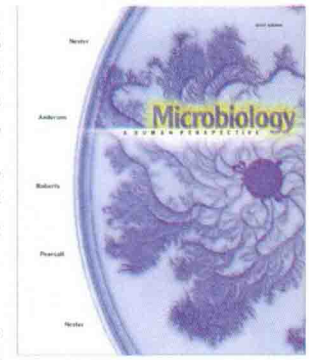
Interactive E-Source

The Interactive E-Source is an exciting student resource that combines McGraw-Hill print, media, study and web-based materials into one easy-to-use CD-ROM. This CD-ROM provides cutting edge technology that accommodates all learning styles, and complements the printed text. It provides a truly non-linear experience by using video, art, web-based, and other course materials to help students organize their study. Features of the Interactive E-Source include:



All narrative, art and photos, plus expertly crafted animations and video are included in the interlinked HTML files of the full textbook and study guide. Students can perform non-linear searches as well as retrieve any media content relevant to a topic.

Targeted web links supported by a powerful search engine encourage focused web research.

An annotation function allows students to enhance their study by personalizing e-Source material with their own notes and comments. A customized binder allows students to extract information and customize materials for future reference. The highlighting function allows students to quickly identify important concepts as they review their materials.

A special Read feature converts written text to audio, enabling students to listen to important concepts and hear the proper pronunciation of key terms and names.

Available Fall, 2001.

Reviewers of the Third Edition

We offer our sincere appreciation to the many gracious and expert professionals who helped us with this revision by offering helpful suggestions. In addition to thanking those individuals listed here who carefully reviewed revised chapters, we also thank those who responded to our informal surveys, those who viewed illustrations as they were rendered and revised, those who solicited feedback for us from their students, those who participated in regional focus groups, and those participants who chose not to be identified. All of you have contributed significantly to this work and we thank you.

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Barry Anderson, Portland Community College
Delia Anderson, University of Southern Mississippi
Rao Ayyagari, Lindenwood College
Al Brown, Auburn University
Dan Brown, Sante Fe Community College
Anne Camper, Montana State University
Daniel Caprioglio, University of Southern Colorado
Elizabeth Carrington, Tarrant County Junior College
Bret Clark, Newberry College
John Clausz, Carroll College
William Coleman, University of Hartford
Rick Corbett, Midlands Technical College
Donna Daugherty, Floyd College
Michael Davis, Central Connecticut State University
Ted Drouin, University of Alberta
David Filmer, Purdue University
S. Marvin Friedman, Hunter College, City University of New York
Juliet Fuhrman, Tufts University
Joseph Gauthier, University of Alabama at Birmingham
David Giron, Wright State University
Terry Giugni, Chaffey College
Diane Godin, Richland Community College
Steve Greenwald, Gordon College
Dana Haldeman, Community College of Southern Nevada
James Helliger, Cancer Research Institute of New England
Dawn Holsapple, Schenectady County Community College
David Hurley, South Dakota State University
Suzanne Huth, Louisiana Tech University
Suzanne Kelly, Scottsdale Community College
Harry Kestler, Lorain County Community College
Christopher Kirk, University of Michigan Medical Center
Ed Leadbetter, University of Connecticut
Michael Lockhart, Truman State University
Andrea Mastro, Pennsylvania State University
Trudy McKee, Thomas Jefferson Medical College
Blair McMillan, Madison Area Technical College
Catherine McVay, Texas Tech University Health Sciences Center
Brian Merkel, University of Wisconsin at Green Bay
Robert Moldenhauer, St. Clair County Community College
Thomas Montie, University of Tennessee
Douglas Oba, Brigham Young University at Hawaii
Mark Peppler, University of Alberta
Bobbie Pettriess, Wichita State University
Barbara Poole, Bossier Parish Community College
Laraine Powers, East Tennessee State University
Fred Rosenberg, California Lutheran University
Harry Rowen, University of Nebraska at Omaha
Doug Schelhaas, University of Mary, North Dakota
Wendy Schlucter, University of New Orleans
Thomas Schmidt, Michigan State University
Brian Shmaefsky, Kingwood College
Sara Silverstone, State University of New York at Brockport
Ann Smith, University of Maryland
Jim Smith, Emory University
Kathy Smith, Emory University
Cynthia Sommer, University of Wisconsin at Milwaukee
Angela Spence, Southwest Missouri State College
Christine Tachibana, University of Washington
Marcelo Tolmasky, California State University at Fullerton
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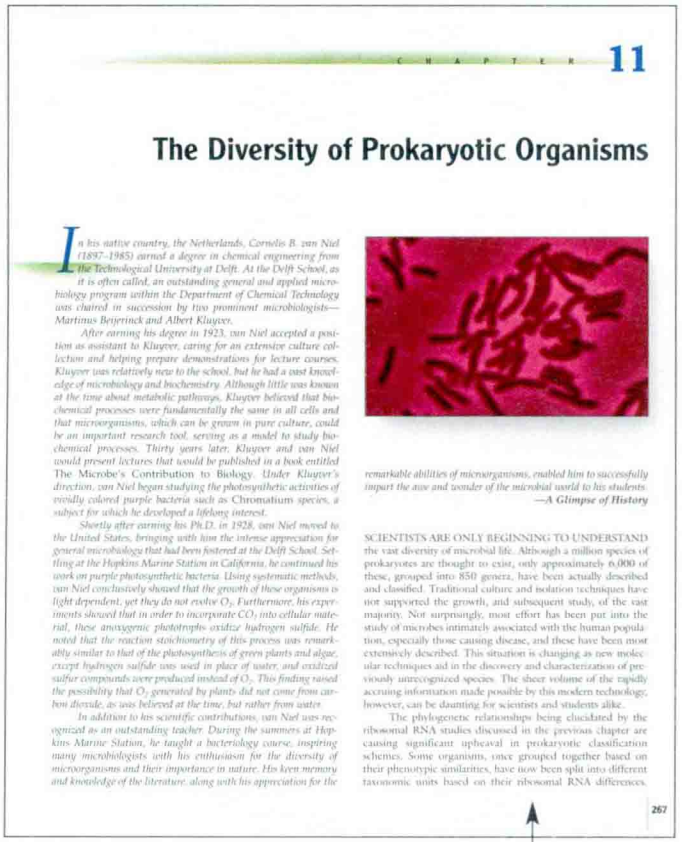
Additionally, we would like to thank Kathy Naylor who developed, created, and sketched the new and revised figures that appear in this edition. Her care and talent have transformed our acclaimed art program into one that we believe is truly exceptional. We thank Robert Allen and Brian Shmaefsky for their valuable contributions of critical thinking questions and applications. We are also grateful for the skillful assistance of the McGraw-Hill staff, including Jim Smith, our editor, Connie Mueller and John Leland, our photo editors, Rick Noel, our designer, and Stacy Patch and Lori Welsh, our print and multimedia supplements coordinators. Special appreciation goes to Marilyn Rothenberger, our project manager, who directed this project through the complexities of the publishing process while maintaining good humor along with the highest standards for accuracy and quality.

We hope very much that this text will be interesting and educational for students and a help to their instructors. We would appreciate any comments and suggestions from our readers.

Eugene Nester
Denise Anderson
C. Evans Roberts, Jr.
Nancy Pearsall
Martha Nester

Visual Preview



CHAPTER 11

The Diversity of Prokaryotic Organisms

In his native country, the Netherlands, Cornelis B. van Niel (1897–1985) earned a degree in chemical engineering from the Technological University at Delft. At the Delft School, as it is often called, an outstanding general and applied microbiology program within the Department of Chemical Technology was chaired in succession by two prominent microbiologists—Martinus Beijerinck and Albert Kluyver.

After earning his degree in 1923, van Niel accepted a position as assistant to Kluyver, caring for an extensive culture collection and helping prepare demonstrations for lecture courses. Kluyver was relatively new to the school, but he had a vast knowledge of microbiology and biochemistry. Although little was known at the time about metabolic pathways, Kluyver believed that biochemical processes were fundamentally the same in all cells and that microorganisms, which can be grown in pure culture, could be an important research tool, serving as a model to study biochemical processes. Thirty years later, Kluyver and van Niel would present lectures that would be published in a book entitled The Microbe's Contribution to Biology. *Under Kluyver's direction, van Niel began studying the photosynthetic activities of vividly colored purple bacteria such as* Chromatium *species, a subject for which he developed a lifelong interest.*

Shortly after earning his Ph.D. in 1928, van Niel moved to the United States, bringing with him the intense appreciation for general microbiology that had been fostered at the Delft School. Settling at the Hopkins Marine Station in California, he continued his work on purple photosynthetic bacteria. Using systematic methods, van Niel conclusively showed that the growth of these organisms is light dependent, yet they do not evolve O_2. Furthermore, his experiments showed that in order to incorporate CO_2 into cellular material, these anoxygenic phototrophs oxidize hydrogen sulfide. He noted that the reaction stoichiometry of this process was remarkably similar to that of the photosynthesis of green plants and algae, except hydrogen sulfide was used in place of water, and oxidized sulfur compounds were produced instead of O_2. This finding raised the possibility that O_2 generated by plants did not come from carbon dioxide, as was believed at the time, but rather from water.

In addition to his scientific contributions, van Niel was recognized as an outstanding teacher. During the summers at Hopkins Marine Station, he taught a bacteriology course, inspiring many microbiologists with his enthusiasm for the diversity of microorganisms and their importance in nature. His keen memory and knowledge of the literature, along with his appreciation for the remarkable abilities of microorganisms, enabled him to successfully impart the awe and wonder of the microbial world to his students.

—A Glimpse of History

SCIENTISTS ARE ONLY BEGINNING TO UNDERSTAND the vast diversity of microbial life. Although a million species of prokaryotes are thought to exist, only approximately 6,000 of these, grouped into 850 genera, have been actually described and classified. Traditional culture and isolation techniques have not supported the growth, and subsequent study, of the vast majority. Not surprisingly, most effort has been put into the study of microbes intimately associated with the human population, especially those causing disease, and these have been most extensively described. This situation is changing as new molecular techniques aid in the discovery and characterization of previously unrecognized species. The sheer volume of the rapidly accruing information made possible by this modern technology, however, can be daunting for scientists and students alike.

The phylogenetic relationships being elucidated by the ribosomal RNA studies discussed in the previous chapter are causing significant upheaval in prokaryotic classification schemes. Some organisms, once grouped together based on their phenotypic similarities, have now been split into different taxonomic units based on their ribosomal RNA differences.

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Glimpse of History

Each chapter opens with an engaging story about the men and women who pioneered the field of microbiology.

Learn of the heartbreaks, triumphs, and strokes of luck that produced the subject you study today.

Future Challenges

Each chapter ends with a pending challenge facing microbiologists and future microbiologists.

See how learning to share this planet more effectively with the multitude of astonishing microorganisms will shape our lifestyles and our world of tomorrow.

294 Chapter 11 The Diversity of Prokaryotic Organisms

Figure 11.33 **Typical Habitat of *Sulfolobus*** Sulfur hot spring in Yellowstone National Park.

Thermophilic Extreme Acidophiles

Members of two genera, *Thermoplasma* and *Picrophilus*, are notable for their preference of growing in extremely acidic, hot environments. *Thermoplasma* species grow optimally at pH 2; in fact, *T. acidophilum* lyses at neutral pH. It was originally isolated from coal refuse piles. *Picrophilus* species tolerate conditions that are even more acidic, growing optimally at a pH below 1. Two species have been isolated in Japan from acidic areas in regions that exude sulfurous gases.

MICROCHECK 11.9

Archaea typically inhabit extreme environments that are otherwise devoid of life. These include conditions of high salinity, heat, acidity, and alkalinity.

- Why do seawater ponds sometimes turn pink as the water evaporates?
- At which relative depth in a sulfur hot spring would a sulfur reducer likely be found? How about a sulfur oxidizer?
- What characteristic of the methanogens makes it logical to discuss them with the Bacteria rather than the other Archaea?

FUTURE CHALLENGES

Astrobiology: The Search for Life on Other Planets

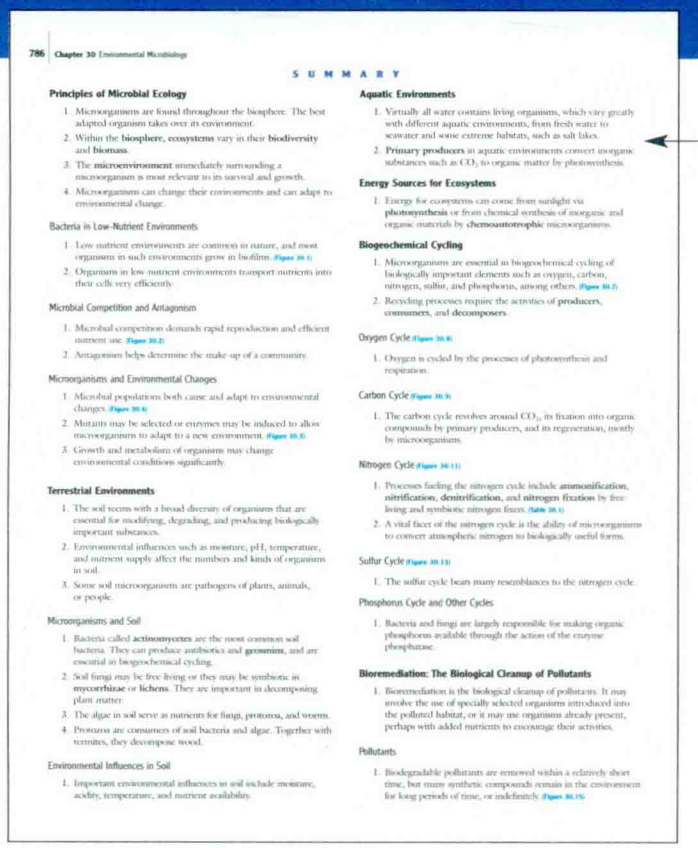
If life as we know it exists on other planets, one form it will take will likely be microbial. The task, then, is to figure out how to find and detect such extraterrestrial microorganisms.

Considering that we still know relatively little about the microbial life on our own planet, coupled with the extreme difficulty of obtaining or testing extraterrestrial samples, this is a daunting challenge with many as yet unanswered questions. For example, what is the most likely source of life on other planets? What is the best way to preserve specimens for study on earth? What will be the culture requirements to grow such organisms? **Astrobiology**, *the study of life in the universe, is a new field that is bringing together scientists from a wide range of disciplines, including microbiology, geology, astronomy, biology, and chemistry, to begin answering some of these questions. The goal is to determine the origin, evolution, distribution, and destiny of life in the universe. These Astrobiologists are also given the task of developing lightweight, dependable, and meaningful testing devices to be used in future space missions.*

Astrobiologists believe that within our solar system, life would most likely be found either on Europa, a moon of Jupiter, or on Mars. This is because Europa and Mars appear to have, or have had, water, which is crucial for all known forms of life. Europa has an icy crust, beneath which may be liquid water or even a liquid ocean. Mars is the planet that is closest to Earth, and it has the most similar environment. Photographs suggest that flowing water once existed there. Besides missions to both these bodies, NASA also has future plans to return material from both a comet and an asteroid.

To prepare for researching life on other planets, microbiologists have turned to some of the most extreme environments here on Earth. These include glaciers and ice shelves, hot springs, deserts, volcanoes, deep ocean hydrothermal vents, and subterranean features such as caves. Because select microorganisms can survive in these environs, which are analogous to conditions expected on other planets, they are good testing grounds for the technology to be used on future missions.

The next few pages show you the tools found throughout the text to help you in your study of microbiology.



786 Chapter 30 Environmental Microbiology

SUMMARY

Principles of Microbial Ecology

1. Microorganisms are found throughout the biosphere. The best adapted organism takes over its environment.
2. Within the **biosphere**, **ecosystems** vary in their **biodiversity** and **biomass**.
3. The **microenvironment** immediately surrounding a microorganism is most relevant to its survival and growth.
4. Microorganisms can change their environments and can adapt to environmental change.

Bacteria in Low-Nutrient Environments

1. Low-nutrient environments are common in nature, and most organisms in such environments grow as biofilms. (Figure 30.1)
2. Organisms in low-nutrient environments transport nutrients into their cells very efficiently.

Microbial Competition and Antagonism

1. Microbial competition demands rapid reproduction and efficient nutrient use. (Figure 30.2)
2. Antagonism helps determine the make-up of a community.

Microorganisms and Environmental Changes

1. Microbial populations both cause and adapt to environmental changes. (Figure 30.4)
2. Mutants may be selected or enzymes may be induced to allow microorganisms to adapt to a new environment. (Figure 30.3)
3. Growth and metabolism of organisms may change environmental conditions significantly.

Terrestrial Environments

1. The soil teems with a broad diversity of organisms that are essential for modifying, degrading, and producing biologically important substances.
2. Environmental influences such as moisture, pH, temperature, and nutrient supply affect the numbers and kinds of organisms in soil.
3. Some soil microorganisms are pathogens of plants, animals, or people.

Microorganisms and Soil

1. Bacteria called **actinomycetes** are the most common soil bacteria. They can produce antibiotics and **geosmins**, and are essential in biogeochemical cycling.
2. Soil fungi may be free-living or they may be symbiotic in **mycorrhizae** or **lichens**. They are important in decomposing plant matter.
3. The algae in soil serve as nutrients for fungi, protozoa, and worms.
4. Protozoa are consumers of soil bacteria and algae. Together with termites, they decompose wood.

Environmental Influences in Soil

1. Important environmental influences in soil include moisture, acidity, temperature, and nutrient availability.

Aquatic Environments

1. Virtually all water contains living organisms, which vary greatly with different aquatic environments, from fresh water to seawater and some extreme habitats, such as salt lakes.
2. **Primary producers** in aquatic environments convert inorganic substances such as CO_2 to organic matter by photosynthesis.

Energy Sources for Ecosystems

1. Energy for ecosystems can come from sunlight via **photosynthesis** or from chemical synthesis of inorganic and organic materials by **chemoautotrophic** microorganisms.

Biogeochemical Cycling

1. Microorganisms are essential in biogeochemical cycling of biologically important elements such as oxygen, carbon, nitrogen, sulfur, and phosphorus, among others. (Figure 30.7)
2. Recycling processes require the activities of **producers**, **consumers**, and **decomposers**.

Oxygen Cycle (Figure 30.8)

1. Oxygen is cycled by the processes of photosynthesis and respiration.

Carbon Cycle (Figure 30.9)

1. The carbon cycle revolves around CO_2, its fixation into organic compounds by primary producers, and its regeneration, mostly by microorganisms.

Nitrogen Cycle (Figure 30.11)

1. Processes fueling the nitrogen cycle include **ammonification**, **nitrification**, **denitrification**, and **nitrogen fixation** by free-living and symbiotic nitrogen fixers. (Table 30.1)
2. A vital facet of the nitrogen cycle is the ability of microorganisms to convert atmospheric nitrogen to biologically useful forms.

Sulfur Cycle (Figure 30.13)

1. The sulfur cycle bears many resemblances to the nitrogen cycle.

Phosphorus Cycle and Other Cycles

1. Bacteria and fungi are largely responsible for making organic phosphorus available through the action of the enzyme phosphatase.

Bioremediation: The Biological Cleanup of Pollutants

1. Bioremediation is the biological cleanup of pollutants. It may involve the use of specially selected organisms introduced into the polluted habitat, or it may use organisms already present, perhaps with added nutrients to encourage their activities.

Pollutants

1. Biodegradable pollutants are removed within a relatively short time, but many synthetic compounds remain in the environment for long periods of time, or indefinitely. (Figure 30.15)

Chapter Summary

Important points are listed under each major heading.

Key figure references and table references are highlighted in blue.

Key terms appear in boldface type.

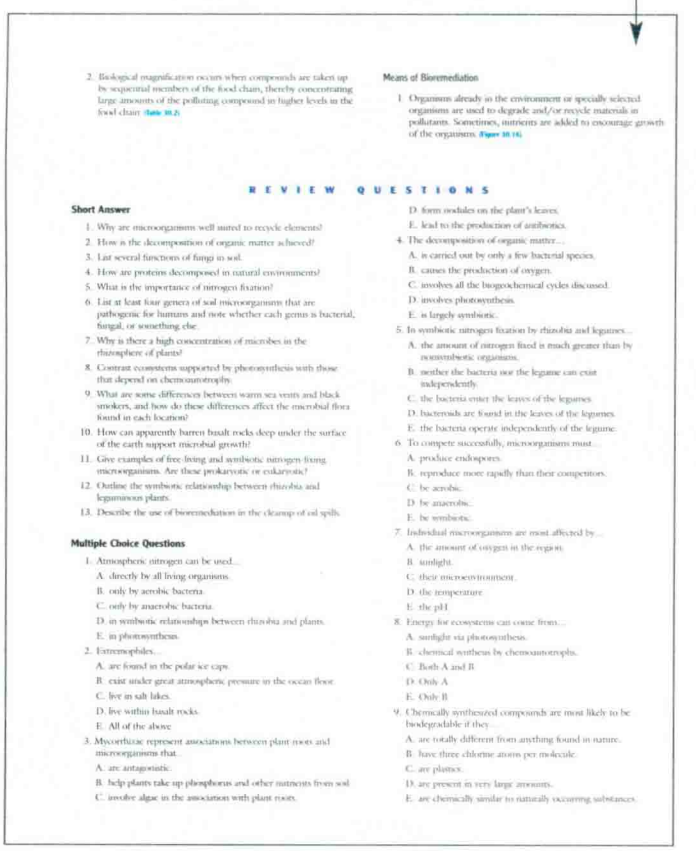
End-of-Chapter Review

Short Answer Questions review major chapter concepts.

Multiple Choice Questions allow self-testing; answers are provided in Appendix 3.

Applications provide an opportunity to use knowledge of microbiology to solve real-world problems.

Critical Thinking Questions encourage practice in analysis and problem-solving that can be used in the study of any subject.



2. Biological magnification occurs when compounds are taken up by sequential members of the food chain, thereby concentrating large amounts of the pollutant compound in higher levels in the food chain. (Table 30.2)

Means of Bioremediation

1. Organisms already in the environment or specially selected organisms are used to degrade and/or recycle materials in pollutants. Sometimes, nutrients are added to encourage growth of the organisms. (Figure 30.16)

REVIEW QUESTIONS

Short Answer

1. Why are microorganisms well suited to recycle elements?
2. How is the decomposition of organic matter achieved?
3. List several functions of fungi in soil.
4. How are proteins decomposed in natural environments?
5. What is the importance of nitrogen fixation?
6. List at least four genera of soil microorganisms that are pathogenic for humans and note whether each genus is bacterial, fungal, or something else.
7. Why is there a high concentration of microbes in the rhizosphere of plants?
8. Contrast ecosystems supported by photosynthesis with those that depend on chemoautotrophy.
9. What are some differences between warm sea vents and black smokers, and how do these differences affect the microbial flora found in each location?
10. How can apparently barren basalt rocks deep under the surface of the earth support microbial growth?
11. Give examples of free-living and symbiotic nitrogen-fixing microorganisms. Are these prokaryotic or eukaryotic?
12. Outline the symbiotic relationship between rhizobia and leguminous plants.
13. Describe the use of bioremediation in the cleanup of oil spills.

Multiple Choice Questions

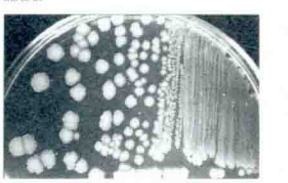
1. Atmospheric nitrogen can be used...
   A. directly by all living organisms.
   B. only by aerobic bacteria.
   C. only by anaerobic bacteria.
   D. in symbiotic relationships between rhizobia and plants.
   E. in photosynthesis.
2. Extremophiles...
   A. are found in the polar ice caps.
   B. exist under great atmospheric pressure in the ocean floor.
   C. live in salt lakes.
   D. live within basalt rocks.
   E. All of the above
3. Mycorrhizae represent associations between plant roots and microorganisms that...
   A. are antagonistic.
   B. help plants take up phosphorus and other nutrients from soil.
   C. involve algae in the association with plant roots.
   D. form nodules on the plant's leaves.
   E. lead to the production of antibiotics.
4. The decomposition of organic matter...
   A. is carried out by only a few bacterial species.
   B. causes the production of oxygen.
   C. involves all the biogeochemical cycles discussed.
   D. involves photosynthesis.
   E. is largely symbiotic.
5. In symbiotic nitrogen fixation by rhizobia and legumes...
   A. the amount of nitrogen fixed is much greater than by nonsymbiotic organisms.
   B. neither the bacteria nor the legume can exist independently.
   C. the bacteria enter the leaves of the legumes.
   D. bacteroids are found in the leaves of the legumes.
   E. the bacteria operate independently of the legume.
6. To compete successfully, microorganisms must...
   A. produce endospores.
   B. reproduce more rapidly than their competitors.
   C. be aerobic.
   D. be anaerobic.
   E. be symbiotic.
7. Individual microorganisms are most affected by...
   A. the amount of oxygen in the region.
   B. sunlight.
   C. their microenvironment.
   D. the temperature.
   E. the pH
8. Energy for ecosystems can come from...
   A. sunlight via photosynthesis.
   B. chemical synthesis by chemoautotrophs.
   C. Both A and B
   D. Only A
   E. Only B
9. Chemically synthesized compounds are most likely to be biodegradable if they...
   A. are totally different from anything found in nature.
   B. have three chlorine atoms per molecule.
   C. are plastics.
   D. are present in very large amounts.
   E. are chemically similar to naturally occurring substances.
10. Numbers of living organisms in an environment can be estimated by all of the following techniques, *except*...
    A. measurement of ATP in the sample.
    B. nucleic acid probes.
    C. Gram staining.
    D. staining with dyes that only stain living cells.
    E. A and D

Applications

1. A farmer who was growing soybeans, a type of legume, saw an Internet site advertising an agricultural product for safely killing soil bacteria. The ad claimed that soil bacteria were responsible for most crop losses. The farmer called the agricultural extension office at a local university for advice. Explain what the extension office crop adviser most likely told the farmer about the usefulness of the product.
2. Recent reports suggest that human activities, such as the generous use of nitrogen fertilizers, have doubled the rate at which elemental nitrogen is fixed, raising concerns of environmental overload of nitrogen. What problems could arise from too much fixed nitrogen, and what could be done about this situation?
3. Nearly every summer, a huge area of oxygen-depleted, almost lifeless ocean spreads off the coast of Louisiana into the Gulf of Mexico. Scientists claim that this "dead zone" is the result of nitrogen- and phosphorous-containing fertilizer used in farmland along the Mississippi River. Fertilizer washes down the river, into the Gulf of Mexico, and nourishes the increased growth of algae and tiny organisms that feed on the algae. Two questions can be asked about this effect:
   a. How can increased algae and other organisms deplete oxygen from the surface layers of the water?
   b. Algae live only near the surface, where sunlight is available. Why would oxygen be depleted far below the surface?

Critical Thinking

1. A student argued that if soil particles were all the same size and all the same composition, then only one kind of microorganism would be found in the soil. What was the student's probable reasoning? How would you criticize the student's argument?
2. Large populations of bacteria are found living almost 3 km underground. Most of these are autotrophs and derive their nutrients and energy from inorganic chemicals in the immediate environment. Surprisingly, many other bacterial species are found that require organic material as a nutrient and energy source. Since organic material will not be carried from the surface to such depths, where can these bacteria obtain the necessary organic material?
3. Each colony of microorganisms growing on an agar plate arises from a single cell (see photo). Colonies growing close together are much smaller than those that are well separated. Why would this be so?



4. An entrepreneur found an economically feasible way of collecting large amounts of sulfur from underwater hot vents in the Pacific Ocean. The sulfur will be harvested from the microorganisms found in the vent areas. A group of ecologists argued that the project would destroy the fragile ecosystem by depleting it of usable sulfur. The entrepreneur argued that the environment would not be harmed because the vents produce an unlimited source of sulfur for the clams and tube worms in the area. Explain who is correct in their assessment.
5. Describe the kind of life forms one would expect to find on Mars or the moon, given what we know about conditions there.

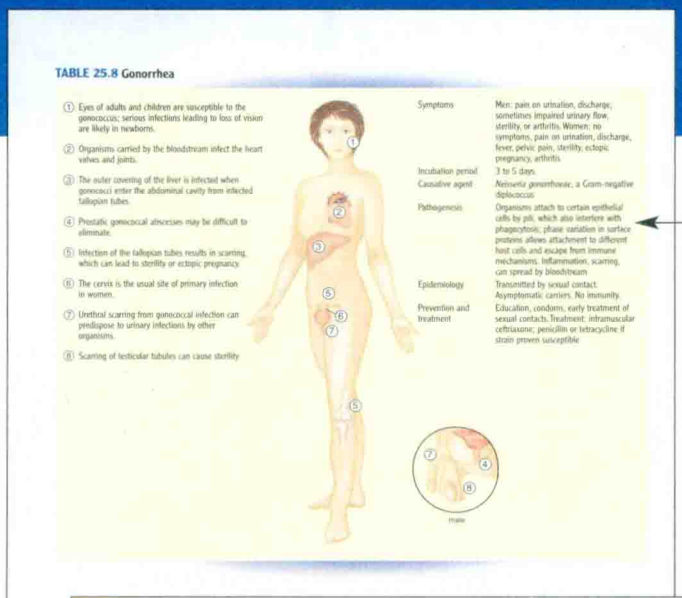


TABLE 25.8 Gonorrhea

① Eyes of adults and children are susceptible to the gonococcus; serious infections leading to loss of vision are likely in newborns.

② Organisms carried by the bloodstream infect the heart valves and joints.

③ The outer covering of the liver is infected when gonococci enter the abdominal cavity from infected fallopian tubes.

④ Prostatic gonococcal abscesses may be difficult to eliminate.

⑤ Infection of the fallopian tubes results in scarring, which can lead to sterility or ectopic pregnancy.

⑥ The cervix is the usual site of primary infection in women.

⑦ Urethral scarring from gonococcal infection can predispose to urinary infections by other organisms.

⑧ Scarring of testicular tubules can cause sterility.

Symptoms	Men: pain on urination, discharge; sometimes impaired urinary flow, sterility, or arthritis. Women: no symptoms, pain on urination, discharge, fever, pelvic pain, sterility, ectopic pregnancy, arthritis
Incubation period	3 to 5 days
Causative agent	*Neisseria gonorrhoeae*, a Gram-negative diplococcus
Pathogenesis	Organisms attach to certain epithelial cells by pili, which also interfere with phagocytosis; phase variation in surface proteins allows attachment to different host cells and escape from immune mechanisms. Inflammation, scarring, can spread by bloodstream
Epidemiology	Transmitted by sexual contact. Asymptomatic carriers. No immunity.
Prevention and treatment	Education, condoms, early treatment of sexual contacts. Treatment: intramuscular ceftriaxone; penicillin or tetracycline if strain proven susceptible

Disease Summaries

Major diseases are represented with a summary table and an outline of pathogenesis keyed to a human figure showing the entry and exit of the pathogen as well as the course of the infection.

Infectious Disease Coverage

Diseases are organized by human body system with background anatomy and physiology.

Each disease is presented systematically and predictably including Symptoms, Causative Agents, Pathogenesis, Epidemiology, and Prevention and Treatment.

Each disease is summarized in a table.

Each chapter includes a Case Presentation of a realistic clinical situation.

Chapters on infectious diseases are highlighted with yellow shading for easy reference.

Additional Case Presentations and Clinical Reference material is available on the Nester Web Site.

CASE PRESENTATION

The patient was a 24-year-old woman, a surgical nurse, seen in the clinic for evaluation of a needle puncture wound to the hand. Earlier in the day, while assisting in a frantic attempt to revive a man with cardiac arrest, she sustained a deep puncture wound to her right palm from a needle that had accidentally dropped into the bed clothes. The needle was visibly contaminated with blood. She immediately washed her hand thoroughly with soap and water, applied an antiseptic, and dressed the puncture site with a bone adhesive bandage.

She was married, with one 14-month-old child. There was no history of blood transfusion or injected-drug abuse. She had donated blood the previous month, and it was not rejected. Her tetanus immunization was up to date, but she had not been immunized against hepatitis B.

Two days after the clinic visit, tests for antibody in the cardiac arrest patient's blood revealed that he had a chronic viral infection.

1. What were the main diagnostic considerations?
2. What risk of infection did the patient face?
3. What measures could be taken to reduce the risk? How much time could expire before preventive measures became ineffective?
4. What was the nurse's prognosis?

Discussion

1. The viruses of concern are hepatitis B virus (HBV), human immunodeficiency virus (HIV), and hepatitis C virus (HCV). Each of these could be transmitted to the nurse by a needle stick and cause serious illness.
2. There are an estimated 750,000 to 1 million carriers of HBV in the United States. They typically have large amounts of circulating infectious virus, so that even a tiny amount of their blood can transmit the disease. The risk of infection from a needle puncture wound when the blood originates from a hepatitis B virus carrier is estimated to be 10% to 35%. The AIDS-causing human immunodeficiency virus (HIV) infects approximately 1 million Americans. The blood of these persons is also potentially infectious, but the risk of transmission by a needle stick is considerably lower than the risk for hepatitis B, averaging about 0.4%. The lower risk results from smaller amounts of circulating infectious virus in HIV-infected individuals. The risk is probably higher early in HIV disease, during the acute infection, and later, when AIDS develops, because much higher levels of circulating infectious virus are then present.

   Hepatitis C virus transmission by blood accounts for most cases of post-transfusion hepatitis. Transmission from surgeon to patient has been documented, presumably by the multiple pricks from surgical needles that often penetrate the surgeons' gloves during major surgery. The risk of transmission by needle stick from an HCV-positive individual is about 1.8%. The number of new hepatitis C virus infections in the United States each year has been estimated at between 150,000 and 170,000, but the mode of transmission is unknown in most cases.

   Other viruses, such as cytomegalovirus (CMV) and Epstein-Barr virus (EBV), can be transmitted by blood. The risk from a needle stick injury is unknown but is probably much lower than from the viruses already mentioned. Obviously, all blood should be considered potentially infectious.
3. In the case of needle puncture wounds that expose a person to HBV, hepatitis B immune globulin (HBIG) is given as soon as possible after the wound occurs. HBIG is gamma globulin obtained from individuals that have a high titer of antibody against HBV. At the same time, active immunization is started with hepatitis B vaccine. These measures must be initiated within 7 days of the injury to be effective. This nurse, as with all persons at high risk of blood exposure, should have already been immunized with hepatitis B vaccine; then, no other preventive measures would need to be taken.

   Those exposed to HIV by needle punctures should be given zidovudine (AZT), plus one or more other anti-HIV medications, immediately and for 4 weeks. There is probably little protective effect if therapy is delayed beyond 2 hours.

   There is no proven preventive measure for HCV exposure. Approaches similar to those for HBV may become available in the future.
4. Preventive measures for hepatitis B exposure are highly effective, reducing the risk of infection by 75% or more. Also, the already relatively low risk from needle puncture wound for HIV exposure can probably be reduced by 75% to 80% with preventive medication. The patient's prognosis for remaining free of infection was good. The small chance of becoming infected and the long incubation period of these diseases, however, add up to considerable worry. Every effort should be made to avoid needle puncture wounds in the first place.

Human Bites

Wounds caused from human bites, striking the teeth of another person, or resulting from objects that have been in a person's mouth are common and can result in very serious infections. Rarely, diseases such as syphilis, tuberculosis, and hepatitis B are transmitted this way. Much more commonly, it is the normal mouth flora that cause trouble.

Symptoms

The wound may appear insignificant at first but then becomes painful and swells massively. Discharged pus often has a foul smell. Most of the wounds are on the extensor surface on the hand, and here the swelling may soon involve the palm also, and movement of some or all of the fingers becomes difficult or impossible.

Causative Agents

Stains and cultures usually show members of the normal mouth flora, including anaerobic streptococci, fusiforms, spirochetes, and *Bacteroides* sp., often in association with *Staphylococcus aureus*.

Pathogenesis

The crushing nature of bite wounds provides suitable conditions for anaerobic bacteria to establish infection. Although most members of the mouth flora are harmless alone, together they produce an impressive number of toxins and destructive enzymes. These include leukocidin, collagenase, hyaluronidase, ribonuclease, various proteinases, neuraminidase, and enzymes that destroy complement and antibody. Capsules of some species inhibit phagocytosis. Facultatively anaerobic organisms reduce available oxygen and thus encourage the growth of anaerobes. The result of all these factors is a **synergistic infection**, meaning that the sum effect of all the organisms acting together is greater than sum of their individual effects. Irreversible destruction of tissues such as tendons and permanent loss of function can be the result. ■**facultative anaerobes, p. XXX**

Epidemiology

Most of the serious human bite infections occur in association with violent confrontations related to alcohol ingestion, or during forcible restraint, as in law enforcement and in mental institutions. The risk is greatly increased when the biting individual has poor mouth care and extensive dental disease. Bites by little children are usually inconsequential.

Prevention and Treatment

Prevention involves avoiding situations that lead to uncivilized behavior such as biting and hitting. Prompt cleansing of wounds followed by application of an antiseptic are advised, and most important is immediate medical attention if there is any suspicion of developing infection. Treatment of infected wounds consists of opening the infected area widely with a scalpel, washing the wound thoroughly with sterile fluid, and removing dirt and dead tissue. The choice of antibacterial medication includes one effective against anaerobes.

The main features of human bite wound infections are presented in **table 27.10**.

MICROCHECK 27.4

A single species of Gram-negative, encapsulated, facultatively anaerobic rods, *Pasteurella multocida*, can infect bite wounds caused by a number of different animals, notably cats. Cat bites and scratches can also transmit *Bartonella henselae*, cause of cat scratch disease, characterized typically by local lymph node enlargement, but this disease may involve other parts of the body. Streptobacillary rat bite fever, acquired from bites of rats and mice, and animals that prey on them, is marked by fever that comes and goes and a rash. The causative bacterium, *Streptobacillus moniliformis*, spontaneously develops L forms. Human bite infections can be dangerous because certain members of the mouth flora with little invasive ability when growing alone can invade and destroy tissue when growing together.

- What Gram-negative organism commonly infects wounds caused by animal bites?
- What is the most common cause of chronic localized lymph node enlargement in young children?
- What unusual kind of variant occurs spontaneously in *Streptobacillus moniliformis* cultures?
- Why would normal mouth flora be a most common cause of systemic human bite infections than the causative agents of syphilis, tuberculosis, and hepatitis B, which can also be transmitted by human bites?

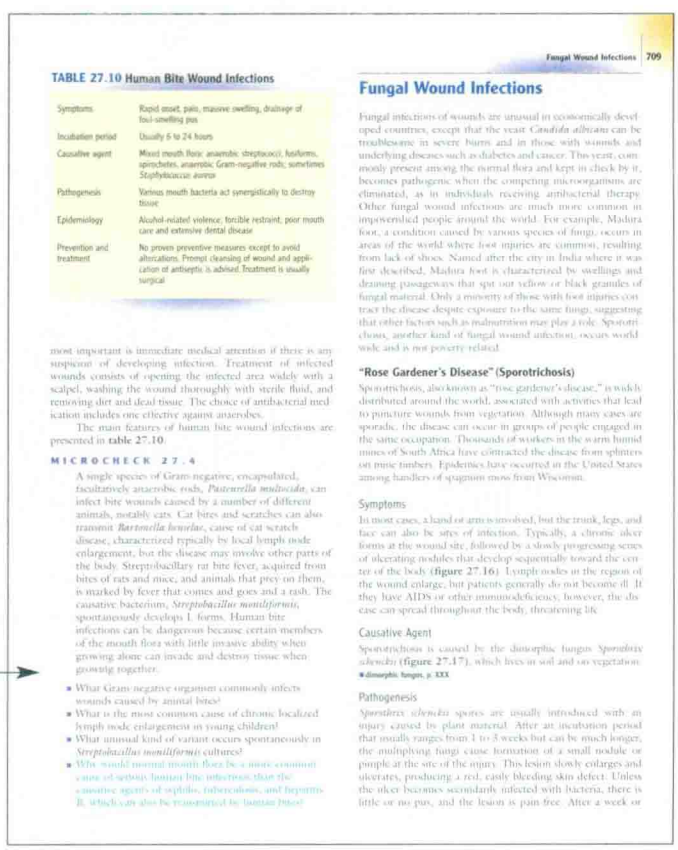


TABLE 27.10 Human Bite Wound Infections

Symptoms	Rapid onset, pain, massive swelling, drainage of foul-smelling pus
Incubation period	Usually 6 to 24 hours
Causative agent	Mixed mouth flora: anaerobic streptococci, fusiforms, spirochetes, anaerobic Gram-negative rods; sometimes *Staphylococcus aureus*
Pathogenesis	Various mouth bacteria act synergistically to destroy tissue
Epidemiology	Alcohol-related violence, forcible restraint, poor mouth care and extensive dental disease
Prevention and treatment	No proven preventive measures except to avoid altercations. Prompt cleansing of wound and application of antiseptic is advised. Treatment is usually surgical

Fungal Wound Infections

Fungal infections of wounds are unusual in economically developed countries, except that the yeast *Candida albicans* can be troublesome in severe burns and in those with wounds and underlying diseases such as diabetes and cancer. This yeast, commonly present among the normal flora and kept in check by it, becomes pathogenic when the competing microorganisms are eliminated, as in individuals receiving antibacterial therapy. Other fungal wound infections are much more common in impoverished people around the world. For example, Madura foot, a condition caused by various species of fungi, occurs in areas of the world where foot injuries are common, resulting from lack of shoes. Named after the city in India where it was first described, Madura foot is characterized by swellings and draining passageways that spit out yellow or black granules of fungal material. Only a minority of those with foot injuries contract the disease despite exposure to the same fungi, suggesting that other factors such as malnutrition may play a role. Sporotrichosis, another kind of fungal wound infection, occurs worldwide and is not poverty related.

"Rose Gardener's Disease" (Sporotrichosis)

Sporotrichosis, also known as "rose gardener's disease," is widely distributed around the world, associated with activities that lead to puncture wounds from vegetation. Although many cases are sporadic, the disease can occur in groups of people engaged in the same occupation. Thousands of workers in the warm humid mines of South Africa have contracted the disease from splinters on mine timbers. Epidemics have occurred in the United States among handlers of sphagnum moss from Wisconsin.

Symptoms

In most cases, a hand or arm is involved, but the trunk, legs, and face can also be sites of infection. Typically, a chronic ulcer forms at the wound site, followed by a slowly progressing series of ulcerating nodules that develop sequentially toward the center of the body (**figure 27.16**). Lymph nodes in the region of the wound enlarge, but patients generally do not become ill. If they have AIDS or other immunodeficiency, however, the disease can spread throughout the body, threatening life.

Causative Agent

Sporotrichosis is caused by the dimorphic fungus *Sporothrix schenckii* (**figure 27.17**), which lives in soil and on vegetation. ■**dimorphic fungus, p. XXX**

Pathogenesis

Sporothrix schenckii spores are usually introduced with an injury caused by plant material. After an incubation period that usually ranges from 1 to 8 weeks but can be much longer, the multiplying fungi cause formation of a small nodule or pimple at the site of the injury. This lesion slowly enlarges and ulcerates, producing a red, easily bleeding skin defect. Unless the ulcer becomes secondarily infected with bacteria, there is little or no pus, and the lesion is pain free. After a week or

Definitions

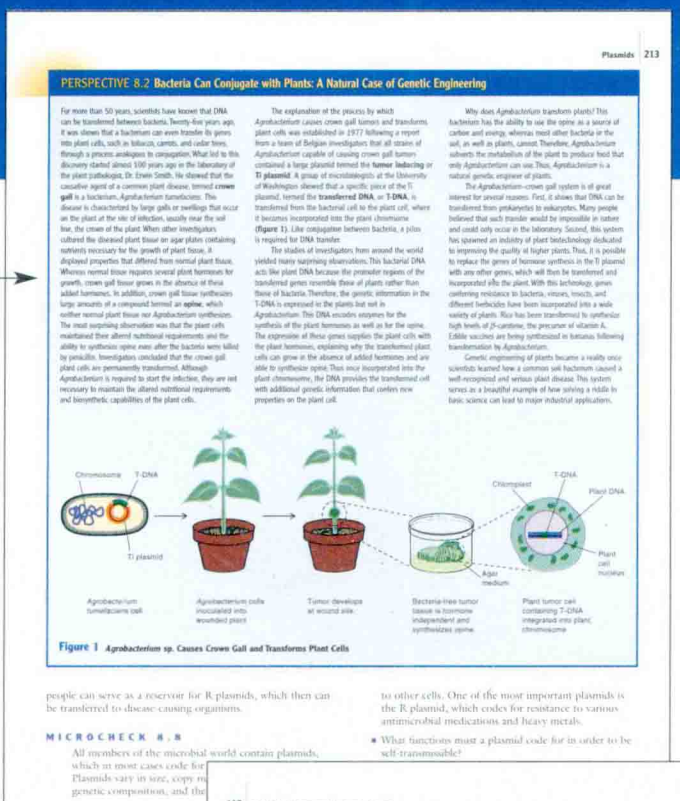
Key terms appear in boldface type, are defined when introduced and may be found in the glossary.

Cross References

Page numbers direct students to sections elsewhere in the text with additional background to support the concepts mentioned within a paragraph.

Perspective Boxes

Perspective boxes introduce a "human" perspective by showing how microorganisms and their products influence our lives in a myriad of different ways.



Plasmids 213

PERSPECTIVE 8.2 Bacteria Can Conjugate with Plants: A Natural Case of Genetic Engineering

For more than 50 years, scientists have known that DNA can be transferred between bacteria. Twenty-five years ago, it was shown that a bacterium can even transfer its genes into plant cells, such as tobacco, carrots, and cedar trees, through a process analogous to conjugation. What led to this discovery started almost 100 years ago in the laboratory of the plant pathologist, Dr. Erwin Smith. He showed that the causative agent of a common plant disease, termed **crown gall** is a bacterium, *Agrobacterium tumefaciens*. This disease is characterized by large galls or swellings that occur on the plant at the site of infection, usually near the soil line, the crown of the plant. When other investigators cultured the diseased plant tissue on agar plates containing nutrients necessary for the growth of plant tissue, it displayed properties that differed from normal plant tissue. Whereas normal tissue requires several plant hormones for growth, crown gall tissue grows in the absence of these added hormones. In addition, crown gall tissue synthesizes large amounts of a compound termed an **opine**, which neither normal plant tissue nor *Agrobacterium* synthesizes. The most surprising observation was that the plant cells maintained their altered nutritional requirements and the ability to synthesize opine even after the bacteria were killed by penicillin. Investigators concluded that the crown gall plant cells are permanently transformed. Although *Agrobacterium* is required to start the infection, they are not necessary to maintain the altered nutritional requirements and biosynthetic capabilities of the plant cells.

The explanation of the process by which *Agrobacterium* causes crown gall tumors and transforms plant cells was established in 1977 following a report from a team of Belgian investigators that all strains of *Agrobacterium* capable of causing crown gall tumors contained a large plasmid termed the **tumor inducing** or **Ti plasmid**. A group of microbiologists at the University of Washington showed that a specific piece of the Ti plasmid, termed the **transferred DNA**, or **T-DNA**, is transferred from the bacterial cell to the plant cell, where it becomes incorporated into the plant chromosome (**figure 1**). Like conjugation between bacteria, a pilus is required for DNA transfer.

The studies of investigators from around the world yielded many surprising observations. This bacterial DNA acts like plant DNA because the promoter regions of the transferred genes resemble those of plants rather than those of bacteria. Therefore, the genetic information in the T-DNA is expressed in the plants but not in *Agrobacterium*. This DNA encodes enzymes for the synthesis of the plant hormones as well as for the opine. The expression of these genes supplies the plant cells with the plant hormones, explaining why the transformed plant cells can grow in the absence of added hormones and are able to synthesize opine. Thus once incorporated into the plant chromosome, the DNA provides the transformed cell with additional genetic information that confers new properties on the plant cell.

Why does *Agrobacterium* transform plants? This bacterium has the ability to use the opine as a source of carbon and energy, whereas most other bacteria in the soil, as well as plants, cannot. Therefore, *Agrobacterium* subverts the metabolism of the plant to produce food that only *Agrobacterium* can use. Thus, *Agrobacterium* is a natural genetic engineer of plants.

The *Agrobacterium*–crown gall system is of great interest for several reasons. First, it shows that DNA can be transferred from prokaryotes to eukaryotes. Many people believed that such transfer would be impossible in nature and could only occur in the laboratory. Second, this system has spawned an industry of plant biotechnology dedicated to improving the quality of higher plants. Thus, it is possible to replace the genes of hormone synthesis in the Ti plasmid with any other genes, which will then be transferred and incorporated into the plant. With this technology, genes conferring resistance to bacteria, viruses, insects, and different herbicides have been incorporated into a wide variety of plants. Rice has been transformed to synthesize high levels of β-carotene, the precursor of vitamin A. Edible vaccines are being synthesized in bananas following transformation by *Agrobacterium*.

Genetic engineering of plants became a reality once scientists learned how a common soil bacterium caused a well-recognized and serious plant disease. This system serves as a beautiful example of how solving a riddle in basic science can lead to major industrial applications.

Figure 1 *Agrobacterium* sp. Causes Crown Gall and Transforms Plant Cells

people can serve as a reservoir for R plasmids, which then can be transferred to disease-causing organisms.

MICROCHECK 8.8

All members of the microbial world contain plasmids, which in most cases code for
Plasmids vary in size, copy n
genetic composition, and th

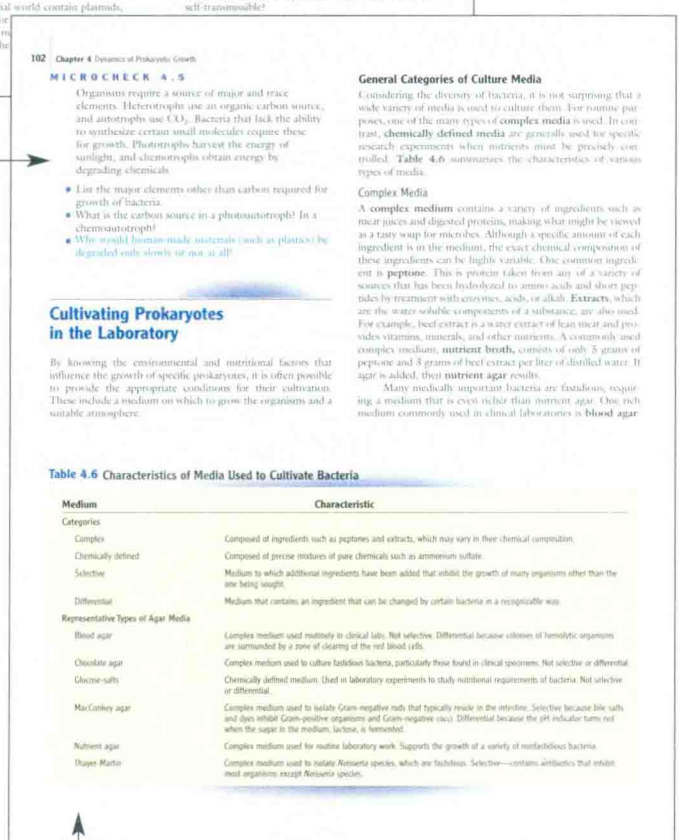
to other cells. One of the most important plasmids is the R plasmid, which codes for resistance to various antimicrobial medications and heavy metals.

- What functions must a plasmid code for in order to be self-transmissible?

Microchecks

Major sections end with a short "Microcheck" that summarizes the major concepts in that section.

Microchecks also offer several review questions to assess your understanding of the preceding material. Finally there is an opportunity to sharpen your critical thinking skills with the questions in blue.



102 Chapter 4 Dynamics of Prokaryotic Growth

MICROCHECK 4.5

Organisms require a source of major and trace elements. Heterotrophs use an organic carbon source, and autotrophs use CO_2. Bacteria that lack the ability to synthesize certain small molecules require these for growth. Phototrophs harvest the energy of sunlight, and chemotrophs obtain energy by degrading chemicals.

- List the major elements other than carbon required for growth of bacteria.
- What is the carbon source in a photoautotroph? In a chemoautotroph?
- Why would human-made materials (such as plastics) be degraded only slowly or not at all?

Cultivating Prokaryotes in the Laboratory

By knowing the environmental and nutritional factors that influence the growth of specific prokaryotes, it is often possible to provide the appropriate conditions for their cultivation. These include a medium on which to grow the organisms and a suitable atmosphere.

General Categories of Culture Media

Considering the diversity of bacteria, it is not surprising that a wide variety of media is used to culture them. For routine purposes, one of the many types of **complex media** is used. In contrast, **chemically defined media** are generally used for specific research experiments when nutrients must be precisely controlled. **Table 4.6** summarizes the characteristics of various types of media.

Complex Media

A **complex medium** contains a variety of ingredients such as meat juices and digested proteins, making what might be viewed as a tasty soup for microbes. Although a specific amount of each ingredient is in the medium, the exact chemical composition of these ingredients can be highly variable. One common ingredient is **peptone**. This is protein taken from any of a variety of sources that has been hydrolyzed to amino acids and short peptides by treatment with enzymes, acids, or alkali. **Extracts**, which are the water-soluble components of a substance, are also used. For example, beef extract is a water extract of lean meat and provides vitamins, minerals, and other nutrients. A commonly used complex medium, **nutrient broth**, consists of only 5 grams of peptone and 3 grams of beef extract per liter of distilled water. If agar is added, then **nutrient agar** results.

Many medically important bacteria are fastidious, requiring a medium that is even richer than nutrient agar. One rich medium commonly used in clinical laboratories is **blood agar**

Table 4.6 Characteristics of Media Used to Cultivate Bacteria

Medium	Characteristic
Categories	
Complex	Composed of ingredients such as peptones and extracts, which may vary in their chemical composition.
Chemically defined	Composed of precise mixtures of pure chemicals such as ammonium sulfate.
Selective	Medium to which additional ingredients have been added that inhibit the growth of many organisms other than the one being sought.
Differential	Medium that contains an ingredient that can be changed by certain bacteria in a recognizable way.
Representative Types of Agar Media	
Blood agar	Complex medium used routinely in clinical labs. Not selective. Differential because colonies of hemolytic organisms are surrounded by a zone of clearing of the red blood cells.
Chocolate agar	Complex medium used to culture fastidious bacteria, particularly those found in clinical specimens. Not selective or differential.
Glucose-salts	Chemically defined medium. Used in laboratory experiments to study nutritional requirements of bacteria. Not selective or differential.
MacConkey agar	Complex medium used to isolate Gram-negative rods that typically reside in the intestine. Selective because bile salts and dyes inhibit Gram-positive organisms and Gram-negative cocci. Differential because the pH indicator turns red when the sugar in the medium, lactose, is fermented.
Nutrient agar	Complex medium used for routine laboratory work. Supports the growth of a variety of nonfastidious bacteria.
Thayer-Martin	Complex medium used to isolate *Neisseria* species, which are fastidious. Selective—contains antibiotics that inhibit most organisms except *Neisseria* species.

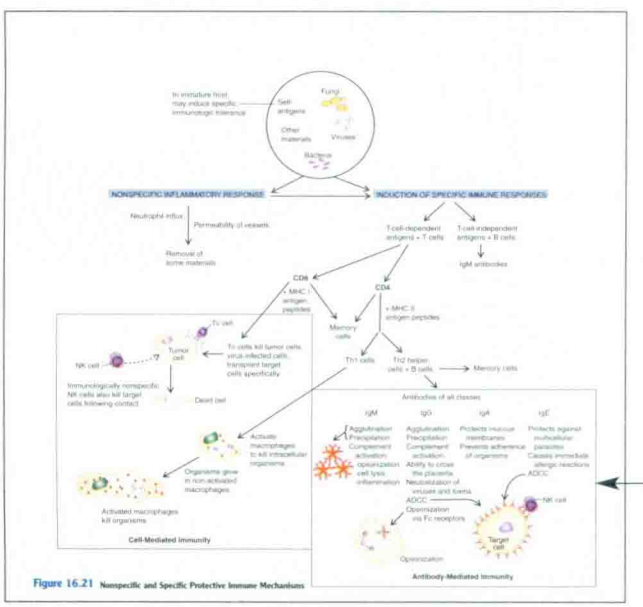


Figure 16.21 Nonspecific and Specific Protective Immune Mechanisms

Summary Figures and Tables

Many new figures and tables have been added to this edition that summarize complex information in a concise presentation.

All figure and table references appear in bold type within the text for easy correlation between text and visual support elements.