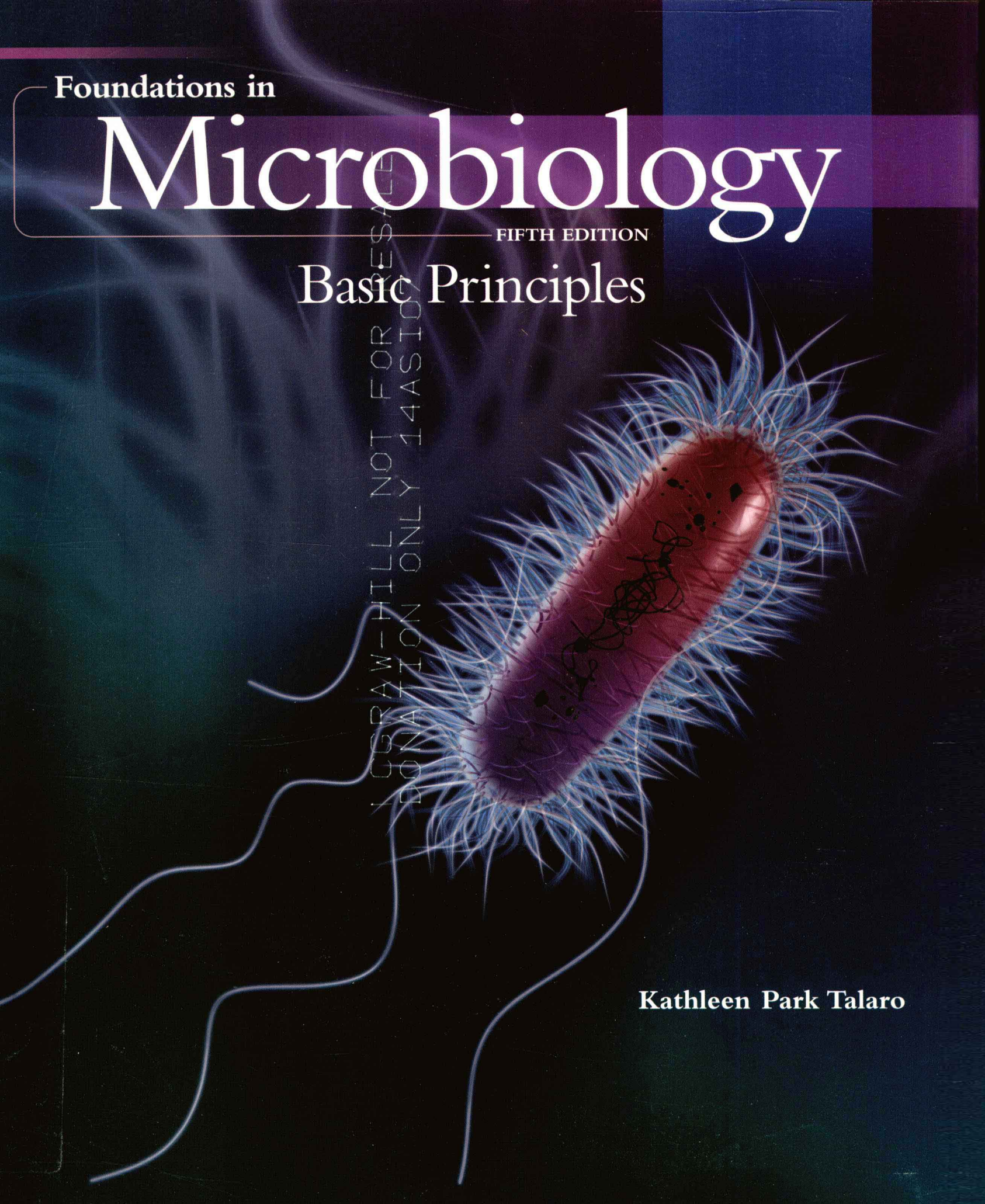
Foundations in

Microbiology

FIFTH EDITION

Basic Principles



Kathleen Park Talaro

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Basic Principles

Kathleen Park Talaro
Pasadena City College

Mc Graw Hill Higher Education

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FOUNDATIONS IN MICROBIOLOGY: BASIC PRINCIPLES, FIFTH EDITION

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Cover image The unusual cover image may give the impression of a fanciful painting, but it is actually a three-dimensional sculpture of a single cell of *Escherichia coli* (0157:H7), displaying its fine fringe of fimbriae and its dangling flagella. This model is from an exhibit at the American Museum of Natural History in Washington, D.C. that surveys the importance of microorganisms as disease agents. The pathogenic *E. coli* attaches to the intestine using its fimbriae, and from there launches a systemic infection that damages the blood cells and kidney. Visit the Talaro Online Learning Center at www.mhhe.com/talaro5 to access an excellent website that allows you to explore this image and many others like it.

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Subjects as complex as microbiology would be much more daunting to students if not for the contributions of thousands of dedicated college professors from all over the world. These advocates tirelessly and deftly lead you through the many esoteric areas of this subject. Along the way, they bring their own personal insights, tone, and vision of what microbiology means to them and what it can mean to you. They strive with much devotion and hard work to facilitate your learning and understanding, mentor, prepare labs, develop study guides and websites, grade, tutor, and advise. In this spirit, I would like to pay a special tribute to my own first microbiology professors—Dr. Dorothy Faris and Dr. Francis Jarvis—emeritus professors at Idaho State University in Pocatello, Idaho. I was in awe of their impressive command of the subject matter, the scope of their research and contributions to the discipline, and the enthusiasm and love for the subject that just stood out. They helped shape my early science experiences and encouraged me to continue my studies. I can think of no better role models than they were.

About the Author

Kathleen Park Talaro

Kathleen Park Talaro is a microbiologist, author, illustrator, photographer, and educator at Pasadena City College. Professor Talaro developed a keen interest in biology and microbiology as a child. From her earliest days on a farm in Blackfoot, Idaho, she was drawn naturally to science and to observing the living world. Her curiosity extended to plants, insects, amphibians, and farm animals, but it was the amazing idea of the tiny creatures swimming around in her father's fishpond that totally captured her attention.

Kathy began her college education at Idaho State University in Pocatello. She found a niche that fit her particular abilities and interests, spending part of her time as a scientific illustrator for one of her professors and part as a biology lab assistant. After graduation with a B.S. in biology, she entered graduate school at Arizona State University, majoring in physiological ecology. During her graduate studies she also participated in two research expeditions to British Columbia with the Scripps Institution of Oceanography. Excited by the diversity and career opportunities available in California, she moved to Pasadena and began working as a microbiologist at Pasadena City College. Kathy continued to expand her background, first finishing a Masters degree at Occidental College, and later taking additional specialized coursework in microbiology at California Institute of Technology and California State University.

If there is one continuing theme reverberating through Kathy's experiences, it is the love of education and teaching. She has been teaching allied health microbiology and major's biology courses for nearly 25 years. "It is so exciting to watch the students develop their early awareness of microorganisms—when they first come face-to-face with the reality of them on their hands, in the air, in their food, and, of course, nearly everywhere. At first, they obsess a little bit about 'germs' and hand washing, but in time, I see the light in their eyes as they begin to understand and apply what they have learned in a sophisticated way. My students come back to visit after going on to professional schools and emphasize the life-changing effect this learning and knowledge of the microscopic realm has had on them."

Professor Talaro is a member of the American Society for Microbiology and the American Association for the Advancement of Science. She keeps active in self-study and research, and continues to attend workshops and conferences to remain current in her field. Her special interests are general medical microbiology and biotechnology. She has been actively involved in science outreach programs for young people by teaching Saturday workshops in microbiology and DNA technology to high school and junior high students.

Preface

A SAMPLING OF CLIPS FROM HEADLINE STORIES AFTER 9/11/01

"The FBI and U.S. Postal Service are offering a $2.5 million reward for information that helps solve the case labeled "Amerithrax." Investigators have interviewed more than 5,000 people and spent more than $13 million on scientific testing."

"In June, the FBI drained and searched a pond in Frederick, Md., but found no evidence. Frederick is the home of the Army Medical Research Institute of Infectious Diseases, one of the nation's main anthrax research centers."

"Five people died, all from inhalation anthrax, between Oct. 5 and Nov. 21, 2001. Seventeen others were sickened by inhalation or cutaneous anthrax. At least three of those are postal workers who continue to recover and have not returned to work."

"The consequences of a successful biological attack, especially if the infection were readily communicable, could far exceed those of a chemical or even a nuclear event," the medical council said. Given the ease of travel and increasing globalization, an outbreak anywhere in the world could be a threat to all nations."

"Smallpox, anthrax, bubonic plague—a smart terrorist could use any of these deadly diseases to wreak havoc on thousands or even millions of Americans. Yet there aren't enough antibiotics and vaccines in stockpile, public-health facilities can't handle a "surge," and most law enforcement agencies have no idea how to cope with a crisis. "I do not believe it is a question of whether a lone terrorist or terrorist group will use infectious disease agents to kill unsuspecting citizens; I'm convinced it's really just a question of when and where."

Microbiology in a New Age

In the fall of 2001, at about the time the previous edition of this textbook was going to press, shattering events occurred that have swept microbiology into the spotlight with a vengeance. The possibility of using microorganisms as weapons was no longer mere speculation. One effect of these revelations has been a heightened awareness of microorganisms unlike any in past memory, especially among the students in my classes. On many occasions, my colleagues and I have had to spend a significant portion of class time in discussions relating to this topic, separating fact from fiction, and expanding on the latest potential "threat" from news reports. Many sessions were spent answering questions such as *"What is anthrax and how is it treated? How could smallpox come back after all these years? Are the vaccines for preventing infections safe? What is the chance I can get SARS, or how did West Nile Valley Fever get to North America?"* Giving voice to these concerns has been a bittersweet educational experience. Of course, it has been gratifying to observe the high level of interest in this subject and to be able to use real life circumstances to teach basic concepts—for example, how to sterilize mail to destroy anthrax spores, the kind of treatments available for biological agents, or exploring the epidemiology of the "pathogen of the week." My other, conflicting, reaction has involved the unfortunate and somewhat overblown fears about microbes these happenings have instilled in many people. More than ever before these small, ubiquitous, mostly beneficial organisms are the subjects of misunderstanding and anxiety.

At such an extraordinary time, there is a serious need for useful, accurate information about microorganisms and their activities, so the public can operate from a basis of knowledge and understanding rather than fear or rumor. Part of this education must help maintain a balanced view of the infectious nature of microbes alongside their undeniable importance in the functioning of the earth. This has been our primary goal for the past four editions, and we have undertaken this fifth revision from that same point of view. Once again, we want our students—all of you—to come away from a course of study prepared for any personal or professional challenges, to develop in your thinking from the unknown to the known, and to be the voices of reason during trying times.

As you will see, microbiology is a complex interdisciplinary subject that covers a broad scope of information, from the basic biology of cells and their function to the roles of microbes in the global ecosystem, in industrial production, and—yes—in disease. It truly does offer something for everyone, whether your purpose is to prepare for a health profession, to gain skills for technical work, to become informed about practical applications in your daily life, or to improve your knowledge of these smallest inhabitants of the biological world.

Emphases and Changes in the Fifth Edition

We have been fortunate to have the assistance of four able specialists for this edition—three microbiologists and one physician—to support what had previously been the responsibility of just the author. These contributors include:

Barry Chess, my fellow instructor at Pasadena City College
Charles Wright of Baltimore County Community College
Marjorie Kelly Cowan of Miami University of Ohio
Steve Hecht of Grand Valley State University

They have shared the daunting task of overseeing many of the miniscule details that all revisions require. I have welcomed their help in writing new sections and feature boxes, suggesting ideas for new and improved figures, editing and updating text, and refreshing chapter overviews, summaries, and questions. Although this textbook has always been a labor of love, I found this collaboration beneficial, and it has released me to concentrate on content and illustrations without having to pore over every word.

As in previous revisions, we have strived to retain basic content that is the foundation of microbiology while introducing pertinent new developments in the many fields that are part of this science. Our aims can be summarized as:

- to keep the book readable and accurate for a wide range of student levels and abilities
- to introduce topics in a logical order so that early concepts and terms can be used as a foundation for later ones
- to use illustrations, maps, flow charts, analogies, and tables to improve assimilation of information by students with different learning styles
- to make difficult concepts accessible and understandable
- to provide a background for practical applications
- to inspire lifelong learning in the subject
- to incite excitement and awe of this dynamic science

IMPROVED ART PROGRAM

A significant element in any science textbook is the visual program. We set our sights anew on fine-tuning the appearance and readability of the artwork and photographs.

- Every figure in the text has been reviewed, and at least 60% of them have been revised or completely redone.
- Consistency in presentation has been imposed so that elements are presented in the same manner from chapter to chapter.
- Whenever feasible, we have moved the legends into the figure itself and placed them close to the step being described.
- We have also simplified certain illustrations that were too crowded and improved the accuracy and flow of others.
- Special attention has been given to the number and accuracy of labels on art and photographs.
- Many hours have been spent searching for top-notch photographs, some of which were supplied by the author.
- Since many users have commented on their appreciation of illustrated tables and flow charts, we have developed several new ones.

STREAMLINING PRESENTATIONS

The breadth of this discipline makes covering it something of a juggling act. Foremost, it is necessary to sufficiently cover the great variety of topics in microbiology. It is also critical to include ample descriptive background to go with the illustrations. On the other hand, we must also acknowledge that this book is generally used for a one-semester course, and that students' time for reading is not unlimited. Given these concerns:

- We have tightened the content by editing, rewording, simplifying, and removing non-essential detail, without cutting important concepts.
- Being mindful to not minimize important concepts some boxes have been removed or re-positioned in the text flow, and some reference material has been moved to the appendix.
- All initial references to figures, tables, and boxes have been boldfaced, and important sequential ideas or concepts have been numbered or bulleted within the text.
- In recognition of the serious nature of bioterrorism, we have included new boxes and sections on this topic as well as on emerging diseases.

Other alterations to streamline the chapters include compressed chapter overviews and more abbreviated summaries. Our extensive review questions have been well received, and so we have retained the three types of questions as in previous editions. Most chapters have additional questions, including several that involve analysis of figures. As in the past, much attention has been paid to vocabulary and pronunciation, and we have added new terms to the glossary.

USING THE INTERNET

In my own Internet searches over the past two years, I have discovered hundreds of excellent websites that cover topics in a pertinent and relevant manner. A computer connected to the World Wide Web can offer dynamic experiences that a textbook cannot. It can display animations, videos, and interactive graphics, quizzes, and case studies that enhance and extend your textbook readings. Since this science advances so rapidly, events that happen tomorrow cannot possibly be found in your textbook. Also, some of these websites were located only after long searches, and I felt that if someone didn't point the readers towards them, they would remain obscure.

- Specific websites that I have found particularly useful and instructive are listed at the chapter level on the Online Learning Center at www.mhhe.com/talaro5.
- Suggestions for exercises you can use with these URL addresses are presented at the end of each chapter.
- Keep in mind that this textbook has its own dedicated website with text-specific activities and study aids that are available at www.mhhe.com/talaro5.

Teaching and Learning Supplements

McGraw-Hill offers various tools and teaching products to support the fifth edition of *Foundations in Microbiology.* Students can order supplemental study materials by contacting your local bookstore. Instructors can obtain teaching aids by calling the Customer Service

Department at 800-338-3987, visiting our Microbiology website at www.mhhe.com, or contacting your local McGraw-Hill sales representative.

Digital Content Manager This multimedia collection of visual resources allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually-based tests and quizzes, dynamic course website content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped by chapter within the following easy-to-use folders.

Active Art Library Key figures are saved in manipulable layers that can be isolated and customized to meet the needs of the lecture environment.

Animations Library Numerous full-color animations of key microbiology processes are provided. Harness the visual impact of processes in motion by importing these files into classroom presentations or course websites.

Art Libraries Full-color digital files of all illustrations in the book can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. These images are also pre-inserted into blank PowerPoint slides for ease of use.

Photo Libraries Digital files of instructionally significant photographs from the text can be reproduced for multiple classroom uses.

PowerPoint Lectures Ready-made presentations that combine art and lecture notes have been specifically written to cover each chapter of the text. Use the PowerPoint lectures as they are, or tailor them to reflect your preferred lecture topics and sequences.

Tables Library Every table that appears in the text is provided in electronic form. You can quickly preview images and incorporate them into PowerPoint or other presentation programs to create your own multimedia presentations. You can also remove and replace labels to suit your own preferences in terminology or level of detail.

INSTRUCTOR TESTING AND RESOURCE CD-ROM

This cross-platform CD-ROM provides a wealth of resources for the instructor. Supplements featured on this CD-ROM include a computerized test bank utilizing Brownstone Diploma testing software to quickly create customized exams. This user-friendly program allows instructors to search for questions by topic, format, or difficulty level; edit existing questions or add new ones; and scramble questions and answer keys for multiple versions of the same test.

Word files of the test bank are included for those instructors who prefer to work outside of the test generator software.

TRANSPARENCIES

McGraw-Hill provides 450 color ***Overhead Transparencies*** of text line art and numerous photos.

COURSE DELIVERY SYSTEMS

With help from our partners, **WebCT, Blackboard, TopClass, eCollege,** and other course management systems, professors can take complete control over their course content. These course cartridges also provide online testing and powerful student tracking features.

FOR THE STUDENT

Online Learning Center www.mhhe.com/talaro5
The OLC offers an extensive array of learning and teaching tools. The site includes quizzes for each chapter, links to websites related to each chapter, interactive activities, and case studies.

Student Study Guide by Nancy Boury, Iowa State University
The author provides study objectives, chapter overviews, test-taking strategies, crossword puzzles, multiple-choice questions, critical thinking questions, matching exercises, and pathway mapping problems to reinforce the concepts in each section of the text. Answers to the objective questions are included.

HyperClinic 2 CD-ROM by Lewis Tomalty and Gloria Delisle
Evaluate realistic case studies that include a patient history and description of signs and symptoms. Students can either analyze the results of physician-ordered clinical tests to reach a diagnosis or evaluate a case study scenario and then decide which clinical samples should be taken and which diagnostic tests should be run. More than 200 pathogens are profiled, 105 case studies presented, and 46 diagnostic tests covered. PC compatible.

Microbes in Motion 3 CD-ROM
This interactive, easy-to-use general microbiology CD-ROM helps students actively explore and understand microbial structure and function through audio, video, animations, illustrations, and text. 18 books cover topics from microbial genetics to vaccines. Mac and Windows compatible.

A Message to Students

Most of you are probably taking this course as a prerequisite to a health science program such as nursing, dental hygiene, medicine, pharmacy, or physical therapy. Because you are preparing for a career in a profession that involves interactions with patients, you will be concerned with infection control and precautions, which in turn requires you to think about microbes and how to manage them. This means you must not only be knowledgeable about the characteristics of bacteria, viruses, and other microbes, their metabolism, and primary niches in the world, but you must have a grasp of disease transmission, the infectious process, disinfection procedures, and drug treatments. You will also need to understand how the immune system interacts with microorganisms and the effects of immunization. All of these areas bring their own vocabulary and language—much of it new to you—and mastering it will require time, motivation, and preparation.

TIPS ON LEARNING TO GAIN UNDERSTANDING

The challenge of this type of technical course is, "How can I best learn this information in a way to be successful in the course as well as retain it for the future?"

To begin, probably the most important consideration is how the college and instructor have organized your course. Since there is more information than could be covered in the usual course, your instructor will select what he/she wants to emphasize and construct a reading and problem assignment that corresponds to lectures and discussion sessions. Many instructors have a detailed syllabus or study guide that directs the class to the specific content areas and vocabulary words. Others may have their own website to distribute assignments and even sample exams. Whatever materials are provided, this should be your primary guide in preparing for study.

The next consideration involves your own learning style and what works best for you. To be successful, you must commit essential concepts and terminology to memory. A quick list of how we retain information comes from Edgar Dale, who prioritizes the pyramid of learning as follows: We remember about:

10% of what we read
20% of what we hear
30% of what we see
50% of what we see and hear
70% of what we discuss with others
80% of what we experience personally
95% of what we teach to someone else

It should be obvious from this list that there are many ways to go about assimilating information, but mainly, you need to use all of your senses—to read, to write, draw diagrams, do lab work, take exams, and study with others. This means you must spend the time not just to read the book but also to write down notes as you go along. It means that you attend lecture and discussion sessions to listen to your instructors or teaching assistants explain the material. Notes taken during lecture can be rewritten or outlined to organize the main points. This begins the process of laying down memory. You should discuss concepts with others—perhaps a tutor or study group—and even take on the role of the teacher-presenter part of the time. It is with these kinds of interactions that you will not just rote memorize words but *understand* the ideas and be able to apply them later.

A substantial way to experience the material personally is to give yourself examinations. You may use the exams in the text, study guide, or make up your own. One strategy for self-quizzing is to make a set of flash cards that goes with your notes (which is in itself a great learning exercise). Then you can use the cards to assess what you know one concept or vocabulary word at a time. A beneficial side effect of this technique is that you are getting in the frame of mind for taking an exam, which is how most of your evaluations will be given.

Another big factor in learning is the frequency of studying. It is far more effective to spend an hour or so each day for two weeks than a 14-hour cramming session on one weekend. The brain cannot commit information to memory nonstop—it needs to refresh itself. If you approach the subject in small bites and remain connected with the terminology and topics, over time you will find it all fitting together. Then the day before an exam, all you have to do is review.

FEATURES OF THE TEXT HELP YOU STUDY

This textbook has several features that facilitate learning.

Chapter Overviews are quick statements about chapter content to show you the main concepts in the chapter.

Chapter Capsule with Key Terms contain key words and concepts together in outline form. They also make for a useful guide to review the material.

Chapter Checkpoints serve as a quick "snapshot" review of the main points of a section.

End of chapter questions are varied to give you experience in answering different types of exam questions. At the end of chapter 1, there is a description of how these questions are meant to be answered. Multiple choice questions can be used to quickly test yourself on what you know (answers are in the appendix). They are chosen from random information in the text, and it is likely that if you get them correct, you have adequate preparation. The same is true for the matching questions.

The **concept questions** require more in-depth knowledge and will demand that you write several sentences or even paragraphs to show your mastery of a given idea.

The **critical-thinking questions** are "brain teasers" that give you some problem solving experience after you have learned the basics of a certain concept. Many of them involve case studies, models, interpretations of graphs, comparisons, and lab exercises. They give you experience in applying microbiology to real life situations.

In the final analysis, the process of learning comes down to self-motivation. There is a big difference between having to memorize something to get by and really wanting to know and understand it. We feel strongly about the inherent value and fascination of microbiology. It is up to you to become emotionally involved in it yourself and get caught up in the wonder of learning about this new world. Therein is the key to most success and achievement, no matter what your final goals. And though it is true that mastering the subject matter in this textbook can be challenging, it can certainly be accomplished by any students with a "can do" attitude. Millions of students who have already succeeded will attest to this fact.

IN RECOGNITION AND TRIBUTE

Once again, the team from McGraw-Hill has outdone itself in providing first-rate support throughout this revision. In addition to the valuable services of four new contributors, I am delighted to have Jean Sims Fornango once again as my senior developmental editor. Jean is truly a modern "Renaissance woman," skilled in all areas of publishing, well versed in the arts and sciences, and an all-around inspiration. I can always count on Jean to place things in perspective, to offer great insights, to help make decisions that keep the textbook moving in the right direction. She is the epitome of grace under pressure. Another publishing gem is Rose Koos, reprising her role as the production editor for this project. As involved as the author and developmental editor are in keeping the book project on track, the production editor must have her finger on the pulse of literally "everything." She must tackle the overwhelming task of overseeing the finest details that go into the finished product—from a little typo to a paging problem to an illustration run amok—all the while remaining cool, calm, and collected. I

would like to recognize our Senior Sponsoring Editor, Patrick Reidy, who has been a strong supporter of expanding our illustration program and trying new ways of presenting the material and figures.

Other members of the team deserving special mention include Carrie Burger, an experienced and able photo editor; Karen Pugliano, the photo researcher, who negotiated expertly for the very best photographs available. I would like to credit Wayne Harms for using his distinct touch to create an elegant book and cover design. No tribute would be complete without praising the valuable contributions of our publisher, Marty Lange, and our Marketing Manager, Tami Petsche. Many kudos to the folks out in the trenches, those sales representatives who handle the huge responsibility of presenting this textbook to college instructors. You are an integral part of this publishing team and we would be working in a vacuum without you.

I also wish to thank my colleagues in the Natural Science Division at Pasadena City College for their continued encouragement and interest. I want to make special mention of our Dean, Dr. Bruce Carter. He has been instrumental in allowing me to adjust my schedule to work on the text, and has assisted in the upgrading of the microbiology lab to make it a first class place to teach science. I also want to thank Barry Chess, Tom Belzer, and John Stantzos for their friendship and long time support for this project. Last but certainly not least in my heart and mind are my students, who come to the subject eager to learn and prepared to experience the marvelous world of microbiology.

To paraphrase Blanche Dubois, I do "count on the kindness of reviewers" to provide a critical eye and give suggestions for changes and improvements. Thus, I want to salute the new team of reviewers that helped with this edition. I have been a reviewer myself, so I know that it is not an easy job to evaluate another person's work critically yet constructively. I can always rely on them to see things that I have missed or to share their own classroom experiences on how a certain figure or treatment works in the everyday world. This collaboration has been instrumental in shaping the finished product. At this tenth anniversary of *Foundations,* I wish to express my gratefulness for all of the students and instructors who have used the book and written personal comments to me over the years. You have made the many years I have spent in developing this book worthwhile.

This textbook has been thoroughly inspected by the author, editors, reviewers, and contributors, and we have tried to make it as error-free as possible. Since no process is 100% accurate, some errors can still be missed, so we would appreciate any feedback from readers who find typos, missing labels, or omissions, or errors in content. I may be reached by email at ktalaro@aol.com or at www.mcgraw-hill.com.

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Foundations for Success

Improved Art Program

- 60% of images have been revised
- Increased consistency in figure presentation
- Legends placed within figures
- Improved accuracy

Fourth Edition

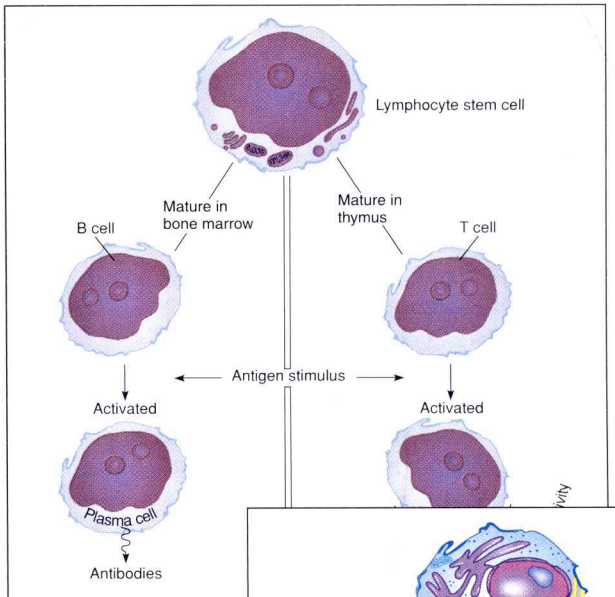

FIGURE 14.11
Summary of the general (lymphocytes, which are t reactions. B cells and T diverge into two cell lines. cannot differentiate them o large nucleus—cytoplasm

Fifth Edition

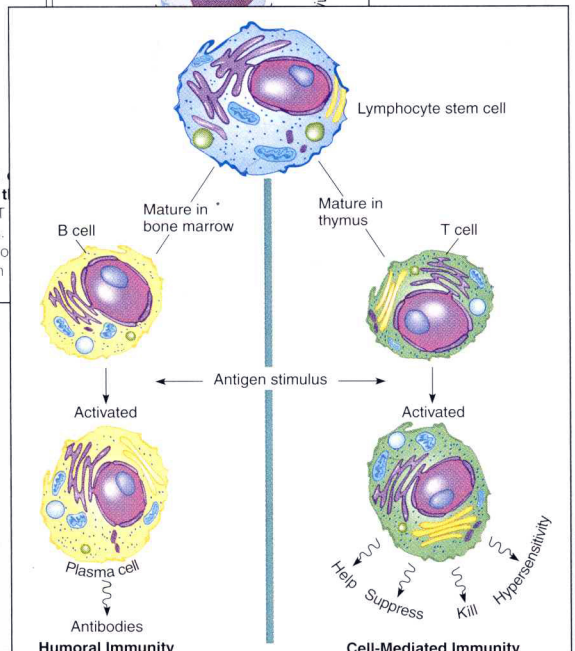

FIGURE 14.10
Summary of the general development and functions of lymphocytes, which are the cornerstone of specific immune reactions. B cells and T cells arise from the same stem cell but later diverge into two cell lines. Their appearances are similar, and one cannot differentiate them on the basis of staining. Note the relatively large nucleus—cytoplasm ratio and the lack of granules.

(a) The finest level of lymphatic circulation begins with blind capillaries that pick up fluid, white blood cells, and microbes or other foreign matter from the surrounding tissues and transport this liquid mixture (lymph) away from the extremities via a system of small ducts.

(b) The ducts carry lymph into a circuit of larger ducts that ultimately flow into clusters of specialized filtering organs, the lymph nodes.

(c) The center diagram shows a section through a lymph node to reveal the afferent ducts draining into sinuses that house several types of white blood cells, primarily T lymphocytes, B lymphocytes, macrophages, and dendritic cells. Here, foreign material is filtered out, processed, and becomes the focus of various immune responses.

(d) Lymph continues to trickle from the lymph nodes via efferent ducts into a system of larger drainage vessels, which ultimately connect with large veins near the heart. In this way, cells and products of immunity continually enter the regular circulation.

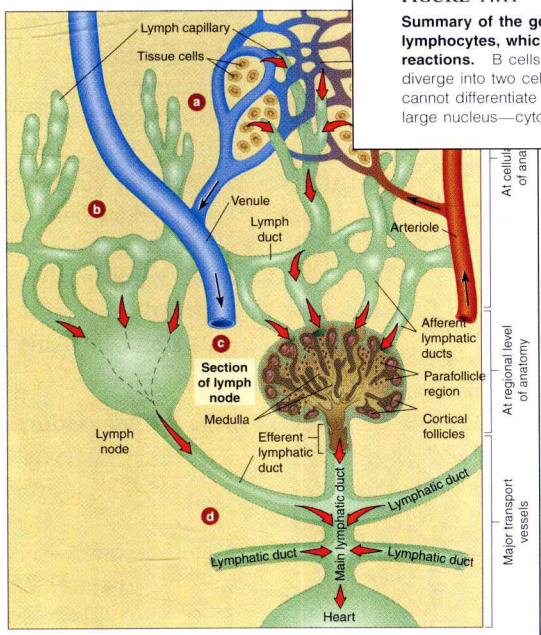

FIGURE 14.13
Scheme of circulation in the lymphatic vessels and lymph nodes.

Art Program

- Integration of top-notch photographs
- Several new illustrated tables and flow charts have been added throughout the text

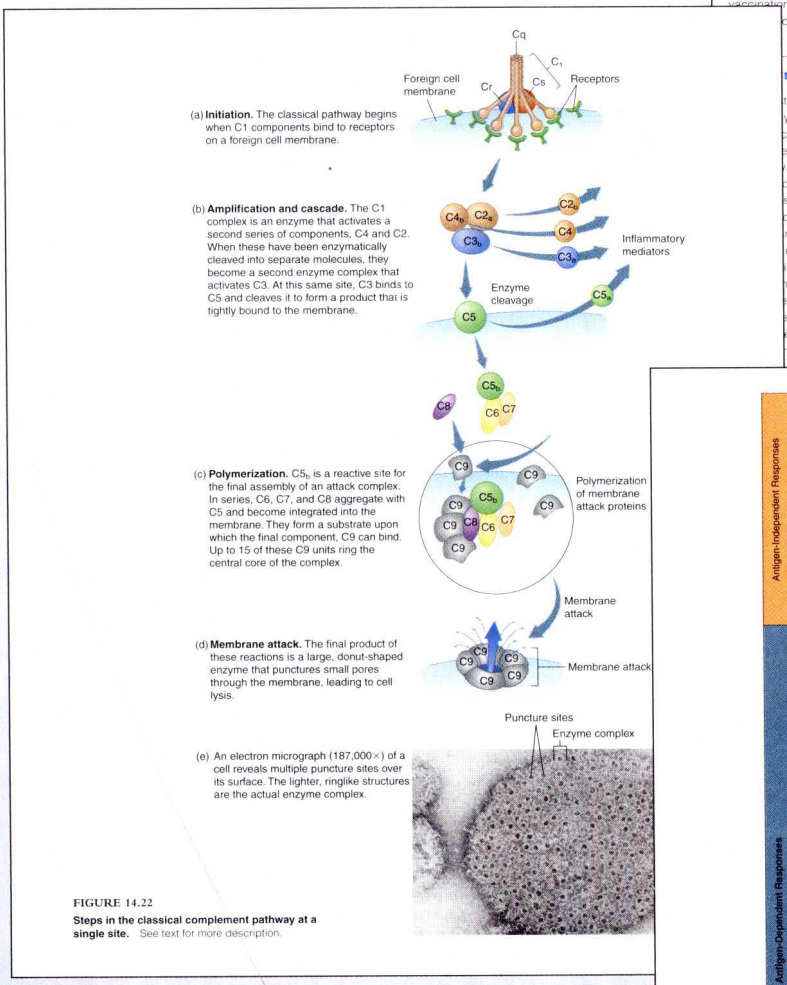

FIGURE 14.22
Steps in the classical complement pathway at a single site. See text for more description.

CHAPTER 15

The Acquisition of Specific Immunity and Its Applications

An immune system huddle. The large central dendritic cell communicates with a team of smaller T lymphocytes, giving the signal for the next play. From this

he primary focus of this chapter is the remarkable system of lymphocytes that are responsible for specific, acquired immunities. In our more detailed examination, we will discover the complex adaptations for defense against microbes, cancer, and toxic substances. This background will prepare you for coverage of vaccination, immune testing, allergy, and immune deficiency in chapd 17.

r Overview

t specific host defenses are derived from a dual system of ytes that are genetically programmed to react with foreign ces (antigens) found in microbes and other organisms. lls carry glycoprotein receptors that dictate their specificity and

ocytes have antibody receptors, T lymphocytes have T-cell s, and macrophages have histocompatibility receptors such as d HLA.

nd T cells arise in the bone marrow, where they proliferate and extreme variations in the expression of receptor genes. iation of lymphocytes creates billions of genetically different at each have a unique specificity for antigen.

lls reach final maturity in special bone marrow sites, and the ach final maturity in the thymus gland.

es of lymphocytes home (migrate) to separate sites in lymphoid here they serve as a constant source of immune cells primed to

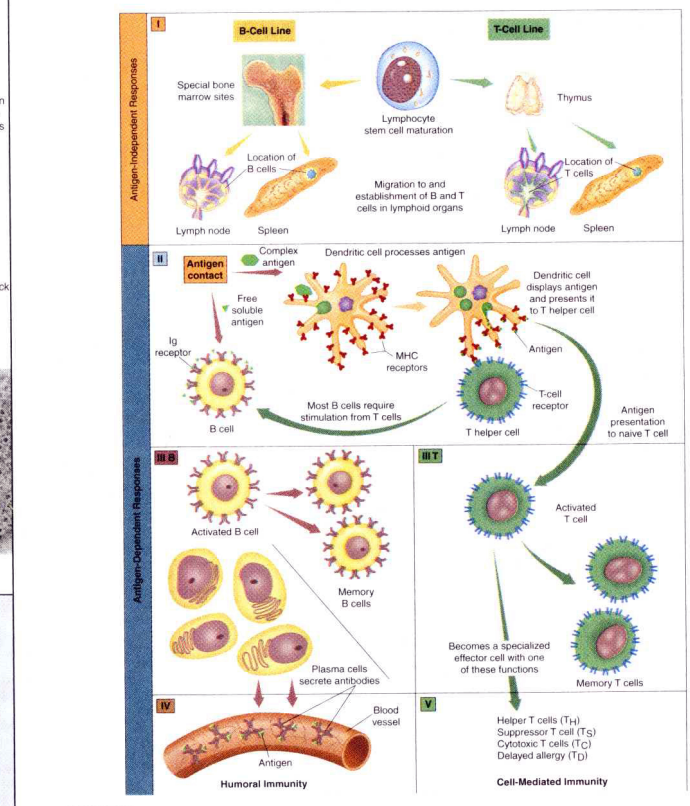

FIGURE 15.1
Overview of the stages of lymphocyte development and function. **I.** Development of B- and T-lymphocyte specificity and migration to lymphoid organs. **II.** Antigen processing by macrophage and presentation to lymphocytes, assistance to B cells by T cells. **III B** and **III T.** Lymphocyte activation, clonal expansion, and formation of memory B and T cells. **IV.** Humoral immunity, B-cell line produces antibodies to react with the original antigen. **V.** Cell-mediated immunity. Activated T cells perform various functions, depending on the signal and type of antigen. Details of these processesare covered in each corresponding section heading

Features that Facilitate Learning

Overviews Chapters open with a vignette that states the relevance of the chapter focus and a bulleted list that outlines the main themes of the chapter.

Chapter Checkpoints serve as quick "snapshot" reviews of the main themes of each major section of a chapter.

Chapter Capsule Summaries contain key words and concepts together in outline form. The capsules help students review the most important information in each chapter.

CHAPTER 11

Physical and Chemical Control of Microbes

The natural condition of humanity is to share surroundings with a large, diverse population of microorganisms. The complete exclusion of microbes from the environment is not only impossible but of questionable value. In many instances, however, our health and comfort can depend on the ability to destroy, inhibit, and remove microbes in the habitats we share. These techniques, also known as antimicrobial control, are very broad in scope. They include routine activities such as cleaning, refrigeration, and cooking. They are also of central importance in the medical, dental, and commercial settings to prevent infection and spoilage, and to ensure the safety of food, water, and other products. Both this chapter and chapter 12 will survey important aspects of microbial control.

Chapter Overview

- The control of microbes in the environment is a constant concern of health care and industry since microbes are the cause of infection and food spoilage, among other undesirable events.
- Antimicrobial control is accomplished using both physical techniques and chemical agents to destroy, remove, or reduce microbes in a given area.
- Many factors must be contemplated when choosing an antimicrobial technique, including the material being treated, the type of microbes involved, the microbial load, and the time available for treatment.
- Antimicrobial agents damage microbes by disrupting the structure of the cell wall or cell membrane, preventing synthesis of nucleic acids (DNA and RNA), or altering the function of cellular proteins.
- Microbicidal agents kill microbes by inflicting nonreversible damage to the cell. Microbistatic agents temporarily inhibit the reproduction of microbes but do not inflict irreversible damage. Mechanical antimicrobial agents physically remove microbes from materials but do not necessarily kill or inhibit them.
- Heat is the most important physical agent in microbial control and can be delivered in both moist (steam sterilization, pasteurization) and dry (incinerators, Bunsen burners) forms.
- Radiation exposes materials to high energy waves that can enter and

A look down the cleaning products aisle of most any store will confirm our preoccupation (some would say obsession) with microbial control.

Controlling Microorganisms

Much of the time in our daily existence, we take for granted tap water that is drinkable, food that is not spoiled, shelves full of products to eradicate "germs," and drugs to treat infections. Controlling our degree of exposure to potentially harmful microbes is a monumen-

CHAPTER CHECKPOINTS

Chemical agents of microbial control are classified by their physical state and chemical nature.

Chemical agents can be either microbicidal or microbistatic. They are also classified as high-, medium-, or low-level germicides.

Factors that determine the effectiveness of a chemical agent include the type and numbers of microbes involved, the material involved, the strength of the agent, and the exposure time.

Halogens are effective chemical agents at both microbicidal and microbistatic levels. Chlorine compounds disinfect water, food, and industrial equipment. Iodine is used as either free iodine or iodophor to disinfect water and equipment. Iodophors are also used as antiseptic agents.

Phenols are strongly microbicidal agents used in general disinfection. Milder phenol compounds, the bisphenols, are also used as antiseptics.

Alcohols dissolve membrane lipids and destroy cell proteins. Their action depends upon their concentration, but they are generally only microbistatic.

Hydrogen peroxide is a versatile microbicide that can be used as an antiseptic for wounds and a disinfectant for utensils. A high concentration is an effective sporicide.

Surfactants are of two types: detergents and soaps. They reduce cell membrane surface tension, causing membrane rupture. Cationic detergents, or quats, are low-level germicides limited by the amount of organic matter present and the microbial load.

Aldehydes are potent sterilizing agents and high-level disinfectants that irreversibly disrupt microbial enzymes.

Ethylene oxide and chlorine dioxide are gaseous sterilants that work by alkylating protein and DNA.

CHAPTER CAPSULE WITH KEY TERMS

I. **Physical methods for controlling microorganisms**
  A. Moist heat denatures proteins and DNA while destroying membranes.
    1. **Sterilization: Autoclaves** utilize steam under pressure to sterilize heat resistant materials while intermittent sterilization can be used to sterilize more delicate items.
    2. **Disinfection:** Pasteurization subjects liquids to temperatures below 100°C and is used to lower the microbial load in liquids. Boiling water can be used to destroy vegetative pathogens in the home.
  B. Dry heat, using higher temperatures than moist heat, can also be used to sterilize.
    1. **Incineration** can be carried out using a Bunsen burner or incinerator. Temperatures range between 600°C and 1800°C.
    2. **Dry ovens** coagulate proteins at temperatures of 15° to 180°C.
  C. Cold temperatures are microbistatic, with refrigeration (0° to 15°C) and freezing (below 0°C) commonly used to preserve food, media and cultures.
  D. Drying and desiccation lead to (often temporary) metabolic inhibition by reducing water in the cell.
  E. Radiation: Energy in the form of radiation is a method of **cold sterilization,** which works by introducing mutations into the DNA of target cells.
    1. **Ionizing radiation,** such as Gamma rays and X-rays, has deep penetrating power and works by causing breaks in the DNA of target organisms.
    2. **Nonionizing radiation** uses **ultraviolet waves** with very little penetrating power and works by creating dimers between adjacent pyrimidines, which interferes with replication.
  F. Filtration involves the physical removal of microbes by passing a gas or liquid though a fine filter and can be used to sterilize air as well as heat sensitive liquids.

II. **Chemical Control of Microorganisms**
  A. Chemicals are divided into **disinfectants, antiseptics, sterilants, sanitizers** and **degermers** based on their level of effectiveness and the surfaces to which they are applied.
  B. Antimicrobic chemicals are found as solids, gases and liquids. Liquids can be either aqueous (water based) or tinctures (alcohol based).
  C. Halogens are chemicals based on elements from group VII of the periodic table.
    1. **Chlorine** is used as chlorine gas, hypochlorites and chloramines. All work by disrupting disulfide bonds and, given adequate time, are sporicidal.
    2. **Iodine** is found both as free iodine (I_2) and iodophors (iodine bound to organic polymers such as soaps). Iodine has a mode of action similar to chlorine and is also sporicidal given enough time.
  D. Phenolics are chemicals based on phenol that work by disrupting cell membranes and precipitating proteins. They are bactericidal, fungicidal and viricidal, but not sporicidal.
    1. Although phenol is now considered too toxic to be used in most circumstances, phenolic compounds (Lysol, Triclosan) are commonly used as, or added to, home and hospital disinfectants.
  E. Chlorhexidine (Hibiclens, Hibitane) is a surfactant and protein denaturant with broad microbicidal properties, although it is not sporicidal. Solutions of chlorhexidine are used as skin degerming agents for preoperative scrubs, skin cleaning and burns.
  F. Ethyl and isopropyl alcohol, in concentrations of 50% to 90%, are useful for microbial control. Alcohols act as **surfactants,** dissolving membrane lipids and coagulating proteins of vegetative bacterial cells and fungi. They are not sporicidal.
  G. Hydrogen peroxide produces highly reactive hydroxyl-free radicals that damage protein and DNA while also decomposing to O_2 gas, which is toxic to anaerobes. Strong solutions of H_2O_2 are sporicidal.
  H. Detergents and soaps
    1. Cationic detergents known as **quaternary ammonium compounds** (quats) act as surfactants that alter the membrane permeability of some bacteria and fungi. They are not sporicidal.
    2. Soaps have little microbicidal activity but rather function by removing grease and soil that contain microbes.

The Learning System

End of Chapter Questions are varied to give students experience in answering different types of questions; Multiple Choice Questions; Concept Questions; and Critical-Thinking Questions.

MULTIPLE-CHOICE QUESTIONS

1. A microbicidal agent has what effect?
   a. sterilizes
   b. inhibits microorganisms
   c. is toxic to human cells
   d. destroys microorganisms
2. Microbial control methods that kill ____ are able to sterilize.
   a. viruses
   b. the tubercle bacillus
   c. endospores
   d. cysts
3. Any process that destroys the non-spore-forming contaminants on inanimate objects is
   a. antisepsis
   b. disinfection
   c. sterilization
   d. degermation
4. Sanitization is a process by which
   a. the microbial load on objects is reduced
   b. objects are made sterile with chemicals
   c. utensils are scrubbed
   d. skin is debrided
5. An example of an agent that lowers the surface tension of cells is
   a. phenol
   b. chlorine
   c. alcohol
   d. formalin
6. High temperatures ____ and low temperatures ____ .
   a. sterilize, disinfect
   b. kill cells, inhibit cell growth
   c. denature proteins, burst cells
   d. speed up metabolism, slow down metabolism
7. The temperature-pressure combination for an autoclave is
   a. 100°C and 4 psi
   b. 121°C and 15 psi
   c. 131°C and 9 psi
   d. 115°C and 3 psi
8. Microbe(s) that is/are the target(s) of pasteurization include:
   a. *Clostridium botulinum*
   b. *Mycobacterium* species
   c. *Salmonella* species
   d. both b and c
9. Ionizing radiation removes ____ from atoms.
   a. protons
   b. waves
   c. electrons
   d. ions
10. The primary mode of action of nonionizing radiation is to
    a. produce superoxide ions
    b. make pyrimidine dimers
    c. denature proteins
    d. break disulfide bonds
11. The most versatile method of sterilizing heat-sensitive liquids is
    a. UV radiation
    b. exposure to ozone
    c. beta propiolactone
    d. filtration
12. ____ is the iodine antiseptic of choice for wound treatment.
    a. Eight percent tincture
    b. Five percent aqueous
    c. Iodophor
    d. Potassium iodide solution
13. A chemical with sporicidal properties is
    a. phenol
    b. alcohol
    c. quaternary ammonium compound
    d. glutaraldehyde
14. Silver nitrate is used
    a. in antisepsis of burns
    b. as a mouthwash
    c. to treat genital gonorrhea
    d. to disinfect water
15. Detergents are
    a. high-level germicides
    b. low-level germicides
    c. excellent antiseptics
    d. used in disinfecting surgical instruments
16. Which of the following is an approved sterilant?
    a. chlorhexidine
    b. betadyne
    c. ethylene oxide
    d. ethyl alcohol

CONCEPT QUESTIONS

1. Compare sterilization with disinfection and sanitization. Describe the relationship of the concepts of sepsis, asepsis, and antisepsis.
2. t of a tuberculocide.
   he effect of a pseudomonicide?
   static agent do?
3. ow the type of microorganisms present will ctiveness of exposure to antimicrobial agents. numbers of contaminants can influence the control them.
4. microbial death?
   dation of microbes not die instantaneously when imicrobial agent?
5. ial processes inhibited in the presence of matter?
6. Describe four modes of action of antimicrobial agents, and give a specific example of how each works.
7. a. Summarize the nature, mode of action, and effectiveness of moist and dry heat.
   b. Compare the effects of moist and dry heat on vegetative cells and spores.
   c. Explain the concepts of TDT and TDP, using examples. What are the minimum TDTs for vegetative cells and endospores?
8. How can the temperature of steam be raised above 100°C? Explain the relationship involved.
9. a. What do you see as a basic flaw in tyndallization?
   b. In boiling water devices?
   c. In incineration?
   d. In ultrasonic devices?

10. a. What are several microbial targets of pasteurization?
    b. What are the primary purposes of pasteurization?
    c. What is ultrapasteurization?
11. Explain why desiccation and cold are not reliable methods of disinfection.
12. a. What are some advantages of ionizing radiation as a method of control?
    b. Some disadvantages?
13. a. What is the precise mode of action of ultraviolet radiation?
    b. What are some disadvantages to its use?
14. What are the superior characteristics of iodophors over free iodine solutions?
15. a. What does it mean to lower the surface tension?
    b. What cell parts will be most affected by surface active agents?
16. a. Name one chemical for which the general rule that a higher concentration is more effective is *not* true.
    b. What is a sterilant?
    c. Name the principal sporicidal chemical agents.
17. Why is hydrogen peroxide solution so effective against anaerobes?
18. Give the uses and disadvantages of the heavy metal chemical agents, glutaraldehyde, and the sterilizing gases.
19. What does it mean to say that a chemical has an oligodynamic action?
20. a. Define cold sterilization.
    b. Name three totally different methods that qualify for this definition.

CRITICAL-THINKING QUESTIONS

1. What is wrong with this statement: "Prior to vaccination, the patient's skin was sterilized with alcohol"? What would be the more correct wording?
2. For each item on the following list, give a reasonable method of sterilization. You cannot use the same method more than three times; the method must sterilize, not just disinfect; and the method must not destroy the item or render it useless unless there is no other choice. After considering a workable method, think of a method that would not work. Note: Where an object containing something is given, you must sterilize everything (for example, both the jar and the Vaseline in it). Some examples of methods are autoclave, ethylene oxide gas, dry oven, and ionizing radiation.

room air	carcasses of cows with "mad cow" disease
blood in a syringe	inside of a refrigerator
serum	wine
a pot of soil	a jar of Vaseline
plastic Petri plates	fruit in plastic bags
heat-sensitive drugs	talcum powder
cloth dressings	milk
leather shoes from a thrift shop	orchid seeds
a cheese sandwich	metal instruments
human hair (for wigs)	mail contaminated with anthrax spores
a flask of nutrient agar	
an entire room (walls, floor, etc.)	
rubber gloves	
disposable syringes	

3. a. Graph the data on tables 11.3 and 11.4, plotting the time on the Y axis and the temperature on the X axis for three different organisms.
   b. Using pasteurization techniques as a model, compare the TDTs and explain the relationships between temperature and length of exposure.
   c. Is there any difference between the graph for a sporeformer and the graph for a non-sporeformer? Explain.
4. Can you think of situations in which the same microbe would be considered a serious contaminant in one case and completely harmless in another?
5. A supermarket/drugstore assignment: With a partner, look at the labels of 25 different products used to control microbes, and make a list of their active ingredients, their suggested uses, and information on toxicity and precautions.
6. Devise an experiment that will differentiate between bacteriocidal and bacteriostatic effects.
7. There is quite a bit of concern that chlorine used as a water purification chemical presents serious dangers. What alternative methods covered by this chapter could be used to purify water supplies and yet keep them safe from contamination?
8. The shelf-life and keeping qualities of fruit and other perishable foods are greatly enhanced through irradiation, saving industry and consumers billions of dollars. How would you personally feel about eating a piece of irradiated fruit? How about spices that had been sterilized with ETO?
9. The microbial levels in saliva are astronomical ($<10^6$ cells per ml, on average). What effect do you think a mouthwash can have against this high number? Comment on the claims made for such products.
10. Can you think of some innovations the health care community can use to deal with medical waste and its disposal that prevent infection but are ecologically sound?

INTERNET SEARCH TOPICS

1. Look for information on the Internet concerning triclosan-resistant bacteria. Based on what you find, do you think the widespread use of this antimicrobial is a good idea? Why or why not?
2. Find websites that discuss problems with sterilizing reusable medical instruments such as endoscopes and the types of diseases that can be transmitted with them.
3. Handwashing is one of our main protections to ensure good health and hygiene. Visit the student Online Learning Center at www.mhhe.com/talaro5. Go to chapter 11, Internet Search Topics, and log on to the available websites to research information, statistics, and other aspects of handwashing.

Internet Search Topics provide students with additional resources to investigate current topics in microbiology. The URL addresses are listed in each chapter of the Online Learning Center, www.mhhe.com/talaro5

Foundations in

Microbiology

FIFTH EDITION

Basic Principles

Brief Contents