教育部高等教育司推荐
国外优秀生命科学教学用书

Microbiology

微生物学 影印版

Fifth Edition

- Lansing M. Prescott
- John P. Harley
- Donald A. Klein

高等教育出版社
Higher Education Press
McGraw-Hill Companies

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Fifth Edition

Lansing M. Prescott
Augustana College

John P. Harley
Eastern Kentucky University

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Colorado State University

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Nobel Prizes Awarded for Research in Microbiology

Date	Scientist[a]	Research
1901	E. von Behring (GR)	Diphtheria antitoxin
1902	R. Ross (GB)	Cause and transmission of malaria
1905	R. Koch (GR)	Tuberculosis research
1907	C. Laveran (F)	Role of protozoa in disease
1908	P. Ehrlich (GR) E. Metchnikoff (R)	Work on immunity
1913	C. Richet (F)	Work on anaphylaxis
1919	J. Bordet (B)	Discoveries about immunity
1928	C. Nicolle (F)	Work on typhus fever
1930	K. Landsteiner (US)	Discovery of human blood groups
1939	G. Domagk (GR)	Antibacterial effect of prontosil
1945	A. Fleming (GB) E. B. Chain (GB) H. W. Florey (AU)	Discovery of penicillin and its therapeutic value
1951	M. Theiler (SA)	Development of yellow fever vaccine
1952	S. A. Waksman (US)	Discovery of streptomycin
1954	J. F. Enders (US) T. H. Weller (US) F. Robbins (US)	Cultivation of poliovirus in tissue culture
1957	D. Bovet (I)	Discovery of the first antihistamine
1958	G. W. Beadle (US) E. L. Tatum (US) J. Lederberg (US)	Microbial genetics
1959	S. Ochoa (US) A. Kornberg (US)	Discovery of enzymes catalyzing nucleic acid synthesis
1960	F. M. Burnet (AU) P. B. Medawar (GB)	Discovery of acquired immune tolerance to tissue transplants
1962	F. H. C. Crick (GB) J. D. Watson (US) M. Wilkins (GB)	Discoveries concerning the structure of DNA
1965	F. Jacob (F) A. Lwoff (F) J. Monod (F)	Discoveries about the regulation of genes
1966	F. P. Rous (US)	Discovery of cancer viruses
1968	R. W. Holley (US) H. G. Khorana (US) M. W. Nirenberg (US)	Deciphering of the genetic code
1969	M. Delbrück (US) A. D. Hershey (US) S. E. Luria (US)	Discoveries concerning viruses and viral infection of cells
1972	G. Edelman (US) R. Porter (GB)	Research on the structure of antibodies
1975	H. Temin (US) D. Baltimore (US) R. Dulbecco (US)	Discovery of RNA-dependent DNA synthesis by RNA tumor viruses; reproduction of DNA tumor viruses
1976	B. Blumberg (US) D. C. Gajdusek (US)	Mechanism for the origin and dissemination of hepatitis B virus; research on slow virus infections
1977	R. Yalow (US)	Development of the radioimmunoassay technique
1978	H. O. Smith (US) D. Nathans (US) W. Arber (SW)	Discovery of restriction enzymes and their application to the problems of molecular genetics
1980	B. Benacerraf (US) G. Snell (US) J. Dausset (F)	Discovery of the histocompatibility antigens
	P. Berg (US) W. Gilbert (US) & F. Sanger (GB)	Development of recombinant DNA technology (Berg); development of DNA sequencing techniques (Chemistry Prize)
1982	A. Klug (GB)	Development of crystallographic electron microscopy and the elucidation of the structure of viruses and other nucleic-acid–protein complexes (Chemistry Prize)
1984	C. Milstein (GB) G. J. F. Kohler (GR) N. K. Jerne (D)	Development of the technique for formation of monoclonal antibodies (Milstein & Kohler); theoretical work in immunology (Jerne)
1986	E. Ruska (GR)	Development of the transmission electron microscope (Physics Prize)
1987	S. Tonegawa (J)	The genetic principle for generation of antibody diversity
1988	J. Deisenhofer, R. Huber, and H. Michel (GR)	Crystallization and study of the photosynthetic reaction center from a bacterial membrane
	G. Elion (US) G. Hitchings (US)	Development of drugs for the treatment of cancer, malaria, and viral infections
1989	J. M. Bishop (US) H. E. Varmus (US)	Discovery of oncogenes
	S. Altman (US) T. R. Cech (US)	Discovery of catalytic RNA
1993	K. B. Mullis (US)	Invention of the polymerase chain reaction
	M. Smith (US)	Development of site-directed mutagenesis
	R. J. Roberts (US) P. A. Sharp (US)	Discovery of split genes
1996	P. C. Doherty (AU) R. M. Zinkernagel (SW)	Discovery of the mechanism by which T lymphocytes recognize virus-infected cells
1997	S. Prusiner (US)	Discovery of prions

[a]The Nobel laureates were citizens of the following countries: Australia (AU), Belgium (B), Denmark (D), France (F), Germany (GR), Great Britain (GB), Italy (I), Japan (J), Russia (R), South Africa (SA), Switzerland (SW), and the United States (US).

出 版 前 言

随着克隆羊的问世和人类基因组计划的完成，生命科学成为21世纪名副其实的领头学科，生物高新技术产业逐步成为高科技产业的核心。生物科技和生物产业的发展对世界科技、经济、政治和社会发展等方面产生着深刻的影响，这也是我国赶超世界发达国家生产力水平最有前途和希望的领域。生命科学与技术全方位的发展呼唤高等教育培养更多高水平的复合型科技人才。

为此，教育部在《关于加强高等学校本科教学工作　提高教学质量的若干意见》[教高（2001）4号文件]中提出，高等学校要大力提倡编写、引进和使用先进教材，其中信息科学、生命科学等发展迅速、国际通用性强、可比性强的学科和专业可以直接引进先进的、能反映学科发展前沿的原版教材。教育部高等教育司还于2001年11月向全国主要大学和出版社下发了“关于开展‘国外生命科学类优秀教学用书’推荐工作的通知”，有力推动了生命科学类教材的引进工作。

高等教育出版社对国外生命科学教材进行了充分的调研，并委托教育部高等学校生物科学与工程教学指导委员会的专家教授开展了“引进国外优秀生命科学教材及其教学辅助材料专项研究”，并就国内外同类教材进行了比较，提出了具体的引进教材书目。经过版权谈判，目前我社已经购买了 Pearson Education, McGraw-Hill, John Wiley & Sons, Blackwell Science, Thomson Learning, Cambridge University Press, Lippincott Williams & Wilkins 等出版的12种教材的影印权，学科领域涉及生物化学、细胞生物学、遗传学、微生物学、生态学、免疫学、神经科学、发育生物学、解剖学与生理学、分子生物学、普通生物学等。这些教材具有以下特点：（1）所选教材基本是近2年出版的，及时反映了学科发展的最新进展，在国际上使用广泛，具有权威性和时代感；（2）内容简明，篇幅适中，结构合理，兼具一定的深度和广度，适用范围广；（3）插图精美、丰富，既有很强的艺术性，又不失严谨的科学性，图文并茂，与正文相辅相成；（4）语言简练、流畅，十分适合非英语国家的学生阅读。其中9种已入选教育部高等教育司推荐“国外优秀生命科学教学用书”。

考虑到中国国情，为了让学生买得起，同时又能让学生看到原版书彩色精美的插图，我们在引进学生用原版教材时，一方面采用黑白影印，最大限度地降低定价，另一方面随书附赠含有原书彩色插图的光盘，以充分体现原教材的风格、特色，为读者提供方便。

引进国外优秀生命科学教学用书是我社一项长期的重点工作，因此，我们衷心希望广大专家教授和同学提出宝贵的意见和建议，如有更好的教材值得引进，请与高等教育出版社生命科学分社联系，联系电话：010-68344002，E-mail 地址：lifesciences-hep@x263.net。

高等教育出版社

2002年11月

国外优秀生命科学教学用书

（影印教材）

Biochemistry (2nd ed.)	生物化学
Cell and Molecular Biology (3rd ed.)	分子细胞生物学
Essentials of Genetics (4th ed.)	遗传学基础
Microbiology (5th ed.)	微生物学
Roitt's Essential Immunology (10th ed.)	Roitt 免疫学基础
Neuroscience：Exploring the Brain (2nd ed.)	神经科学
Essential Developmental Biology	发育生物学基础
Understanding Human Anatomy and Physiology (4th ed.)	人体解剖生理学
Gene Cloning and DNA Analysis (4th ed.)	基因克隆和 DNA 分析
Principles of Gene Manipulation(6th ed.)	基因操作原理
An Introduction to Genetic Engineering (2nd ed.)	遗传工程导论
Essential Biology	生物学导论

PREFACE

Books are the carriers of civilization. Without books, history is silent, literature dumb, science crippled, thought and speculation at a standstill. They are engines of change, windows on the world, lighthouses erected in a sea of time.
–Barbara Tuchman

Microbiology is an exceptionally broad discipline encompassing specialties as diverse as biochemistry, cell biology, genetics, taxonomy, pathogenic bacteriology, food and industrial microbiology, and ecology. A microbiologist must be acquainted with many biological disciplines and with all major groups of microorganisms: viruses, bacteria, fungi, algae, and protozoa. The key is balance. Students new to the subject need an introduction to the whole before concentrating on those parts of greatest interest to them. This text provides a balanced introduction to all major areas of microbiology for a variety of students. Because of this balance, the book is suitable for courses with orientations ranging from basic microbiology to medical and applied microbiology. Students preparing for careers in medicine, dentistry, nursing, and allied health professions will find the text just as useful as those aiming for careers in research, teaching, and industry. Two quarters/semesters each of biology and chemistry are assumed, and an overview of relevant chemistry is also provided in appendix I.

Organization and Approach

The book is organized flexibly so that chapters and topics may be arranged in almost any order. Each chapter has been made as self-contained as possible to promote this flexibility. Some topics are essential to microbiology and have been given more extensive treatment.

The book is divided into 11 parts. The first 6 parts introduce the foundations of microbiology: the development of microbiology, the structure of microorganisms, microbial growth and its control, metabolism, molecular biology and genetics, DNA technology and genomics, and the nature of viruses. Part Seven is a survey of the microbial world. In the fifth edition, the bacterial survey closely follows the general organization of the forthcoming second edition of *Bergey's Manual of Systematic Bacteriology.* Although principal attention is devoted to bacteria, eucaryotic microorganisms receive more than usual coverage. Fungi, algae, and protozoa are important in their own right. The introduction to their biology in chapters 25–27 is essential to understanding topics as diverse as clinical microbiology and microbial ecology. Part Eight focuses on the relationships of microorganisms to other organisms and the environment (microbial ecology). It also introduces aquatic and terrestrial microbiology. Chapter 28 presents the general principles underlying microbial ecology and environmental microbiology so that the subsequent chapters on aquatic and terrestrial habitats can be used without excessive redundancy. The chapter also describes various types of microbial interactions such as mutualism, protocooperation, commensalism, and predation that occur in the environment. Parts Nine and Ten are concerned with pathogenicity, resistance, and disease. The three chapters in Part Nine describe normal microbiota, nonspecific host resistance, the major aspects of the immune response, and medical immunology. Part Ten first covers such essential topics as microbial pathogenicity, antimicrobial chemotherapy, and epidemiology. Then chapters 38–40 survey the major human microbial diseases. The disease survey is primarily organized taxonomically on the chapter level; within each chapter diseases are covered according to their mode of transmission. This approach provides flexibility and allows the student easy access to information concerning any disease of interest. The survey is not a simple catalog of diseases; diseases are included because of their medical importance and their ability to illuminate the basic principles of disease and resistance. Part Eleven concludes the text with an introduction to food and industrial microbiology. Five appendices aid the student with a review of some basic chemical concepts and with extra information about important topics not completely covered in the text.

This text is designed to be an effective teaching tool. A text is only as easy for a student to use as it is easy to read. Readability has been enhanced by using a relatively simple, direct writing style, many section headings, and an organized outline format within each chapter. The level of difficulty has been carefully set with the target audience in mind. During preparation of the fifth edition, every sentence was carefully checked for clarity and revised when necessary. The American Society for Microbiology's *ASM Style Manual* conventions for nomenclature and abbreviations have been followed as consistently as possible.

The many new terms encountered in studying microbiology are a major stumbling block for students. This text lessens the problem by addressing and reinforcing a student's vocabulary development in three ways: (1) no new term is used without being clearly defined (often derivations also are given)—a student does not have to be familiar with the terminology of microbiology to use this text; (2) the most important terms are printed in boldface when first used; and (3) a very extensive, up-to-date, page-referenced glossary is included at the end of the text.

Because illustrations are critical to a student's learning and enjoyment of microbiology, all illustrations are full-color, and many excellent color photographs have been used. Color not only enhances the text's attractiveness but also increases each figure's teaching effectiveness. Considerable effort has gone into making the art as attractive and useful as possible. Much of the art in the

fourth edition has been revised and improved for use in the fifth edition. All new line art has been produced under the direct supervision of an art editor and the authors, and designed to illustrate and reinforce specific points in the text. Consequently every illustration is directly related to the narrative and specifically cited where appropriate. Great care has been taken to position illustrations as close as possible to the places where they are cited. Illustrations and captions have been reviewed for accuracy and clarity.

Themes in the Book

At least seven themes run through the text, though a particular one may be more obvious at some points than are others. These themes or emphases are the following:

1. The development of microbiology as a science
2. The nature and importance of the techniques used to isolate, culture, observe, and identify microorganisms
3. The control of microorganisms and reduction of their detrimental effects
4. The importance of molecular biology for microbiology
5. The medical significance of microbiology
6. The ways in which microorganisms interact with their environments and the practical consequences of these interactions
7. The influences that microorganisms and microbiological applications have on everyday life

These themes help unify the text and enhance continuity. The student should get a feeling for what microbiologists do and for how their activities affect society.

What's New in the Fifth Edition

Many substantial changes and improvements have been made in the fifth edition, including the following:

1. The general organization of the text has been modified to provide a more logical flow of topics and give greater emphasis to microbial ecology. Treatment of nucleic acid and protein synthesis has been moved to the genetics chapters to integrate the discussion of gene structure, replication, expression, and regulation. Recombinant DNA technology has been moved to a separate section, which also contains a new chapter on microbial genomics. The three-chapter introduction to microbial ecology now follows the survey of microbial diversity. This places it earlier in the text where basic principles of microbiology are introduced. Part Nine now contains a description of nonspecific host resistance as well as an introduction to the fundamentals of immunology. Symbiotic associations are discussed in the context of microbial ecology. The treatment of microbial pathogenesis has been expanded into a full chapter and placed with other medical topics in Part Ten.
2. Pedagogical aids have been expanded. A new Critical Thinking Questions section with two or more questions follows the Questions for Thought and Review. Section numbers have been given to all major chapter sections in order to make cross references more precise. The summary now contains boldfaced references to tables and figures that will be useful in reviewing the chapter.
3. New illustrations have been added to almost every chapter. In addition, all figures have been carefully reviewed by our art editor, and many have been revised to improve their appearance and usefulness.
4. All reference sections have been revised and updated.

Besides these broader changes in the text, every chapter has been updated and often substantially revised. Some of the more important improvements are the following:

Chapter 1—A box on molecular Koch's postulates and a new section on the future of microbiology have been added.

Chapter 2—Differential interference contrast microscopy and confocal microscopy are described.

Chapter 3—More details on the mechanism of flagellar motion are provided.

Chapter 5—Phosphate uptake and ABC transporters are described.

Chapter 6—The chapter has new material on starvation proteins, growth limitation by environmental factors, viable but nonculturable procaryotes, and quorum sensing.

Chapter 8—The discussions of metabolic regulation and control of enzyme activity have been combined with the introduction to energy and enzymes.

Chapter 9—The metabolic overview has been rewritten to aid in understanding. The sections on electron transport, oxidative phosphorylation, and anaerobic respiration have been updated and expanded.

Chapter 11—The chapter now focuses on nucleic acid and gene structure, mutations, and DNA repair. New material on DNA methylation has been added.

Chapter 12—Material on gene expression (transcription and protein synthesis) has been moved here and combined with an extensive discussion of the regulation of gene expression. New sections on global regulatory systems and two-component phosphorelay systems have been added.

Chapter 15—This new chapter provides a brief introduction to microbial genomics, including genome sequencing, bioinformatics, general characteristics of microbial genomes, and functional genomics.

Chapter 18—Virus taxonomy has been updated and new life cycle diagrams added.

Chapter 19—Material on polyphasic taxonomy and the effects of horizontal gene transfer on phylogenetic trees has been added. The introduction to the second edition of *Bergey's Manual* has been revised and updated.

Chapters 20–24—The procaryotic survey chapters have been further revised to conform to the forthcoming second edition of *Bergey's Manual.*

Chapter 28—This chapter, formerly chapter 40, has been substantially rewritten and now includes a treatment of symbiosis and microbial interactions (e.g., mutualism, protocooperation, commensalism, predation, amensalism, competition, etc.). A discussion of microbial movement

between ecosystems has been added, and the treatment of biofilms and microbial mats has been expanded.

Chapter 29—The chapter on microorganisms in aquatic environments has new material on such topics as oxygen fluxes in water, the microbial loop, *Thiomargarita namibiensis,* microorganisms in freshwater ice, and current drinking water standards.

Chapter 30—Microorganisms in cold moist area soils, desert soils, and geologically heated hyperthermal soils are discussed. The effects of nitrogen, phosphorus, and atmospheric gases on plants and soils are described more extensively. There is a new section on the subsurface biosphere.

Chapter 31—This reorganized chapter discusses normal microbiota and nonspecific resistance. An overview of host resistance; a discussion of the cells, tissues, and organs of the immune system; an introduction to the alternative and lectin complement pathways; and a summary of cytokine properties and functions have been included.

Chapter 32—All aspects of specific immunity have been moved to this chapter in order to provide a clearer and more coherent discussion. The chapter contains an overview of specific immunity, a discussion of antigens and antibodies, T-cell and B-cell biology, a discussion of the action of antibodies, the classical complement pathway, and a section on acquired immune tolerance. It ends with a summary of the role of antibodies and lymphocytes in resistance.

Chapter 33—The new chapter on medical immunology contains topics more directly related to the practical aspects of health and clinical microbiology: vaccines and immunizations, immune disorders, and in vitro antigen-antibody interactions. Previously these were scattered over three chapters. The treatment of vaccines has been greatly expanded.

Chapter 34—The treatment of microbial pathogenicity has been greatly enlarged and made into a separate chapter. Several topics have been expanded or added: regulation of bacterial virulence factors and pathogenicity islands, the mechanisms of exotoxin action, and microbial mechanisms for escaping host defenses.

Chapter 37—In the epidemiology chapter, the treatment of emerging diseases has been expanded. New sections on bioterrorism and the effect of global travel on health have been added.

Chapters 38–40—The disease survey chapters have been brought up-to-date, and bacterial diseases are now covered in one chapter rather than two. New material has been added on genital herpes, listeriosis, the use of clostridial toxins in therapy, and other topics. A new table describing common sexually transmitted diseases and their treatment is provided.

Chapter 41—New aspects of food microbiology include discussions of modified atmosphere packaging, algal toxins, bacteriocins as preservatives, new variant Creutzfeldt-Jakob disease, food poisoning by uncooked foods, new techniques in tracing outbreaks of food-related diseases, and the use of probiotics in the diet.

Chapter 42—The chapter on industrial microbiology and biotechnology has been revised to include current advances due to new molecular techniques. A section on developing and choosing microorganisms for use in industry has been added. Other topics that have been added or substantially revised include the synthesis of products for medical use, biodegradation of pesticides and other pollutants, the addition of microorganisms to the environment, and the use of microarray technology.

Aids to the Student

It is hard to overemphasize the importance of pedagogical aids for the student. Accuracy is most important, but if a text is not clear, readable, and attractive, up-to-dateness and accuracy are wasted because students will not read it. Students must be able to understand the material being presented, effectively use the text as a learning tool, and enjoy reading the book.

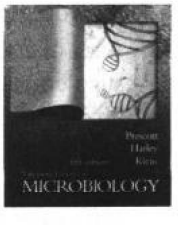
To be an effective teaching tool, a text must present the science of microbiology in a way that can be clearly taught and easily learned. Therefore many aids are included to make the task of learning more efficient and enjoyable. Following the preface a special section addressed to the student user reviews the principles of effective learning, including the SQ4R (survey, question, read, revise, record, and review) study technique. Specific chapter aids are described in the special Visual Preview section.

Besides the chapter aids the text also contains a glossary, an index, and five appendices. The extensive *glossary* defines the most important terms from each chapter and includes page references. Where desirable, phonetic pronunciations also are given. Most of the glossary definitions have not been taken directly from the text but have been rewritten to give the student further understanding of the item. To improve ease of use, the fifth edition has a large, detailed *index.* It has been carefully designed to make text material more accessible. The *appendices* aid the student with extra review of chemical principles and metabolic pathways and provide further details about the taxonomy of bacteria and viruses. To aid the student in following the rapidly changing field of procaryotic taxonomy, appendix III provides the classification of procaryotes according to the first edition of *Bergey's Manual of Systematic Bacteriology,* and appendix IV gives the classification used by the upcoming second edition of *Bergey's Manual.*

Supplementary Materials

Rich supplementary materials are available for students and instructors to assist learning and course management.

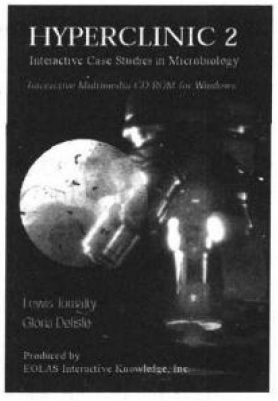
For the Student



1. A ***Student Study Guide*** by Linda Sherwood of Montana State University is a valuable resource that provides learning objectives, study outlines, learning activities, and self-testing material to help students master course content.
2. The ***Interactive E-TEXT*** available on CD-ROM in January 2002 includes all of *Microbiology,* Fifth Edition, as well as the

Student Study Guide in an interactive electronic format. The e-text includes animations and web links to enhance learning.

3. The third edition of ***Microbes in Motion*** by Gloria Delisle and Lewis Tomalty is an interactive CD-ROM that brings microbiology to life. A correlation guide on the CD links this exciting resource directly to your textbook. This easy to use tutorial can go from the classroom to the resource center to students' own personal computers. *Microbes in Motion* brings discovery back into the learning and education process through interactive screens, animations, video, audio, and hyperlinking questions. The applications of this CD-ROM are only as limited as your good ideas.
4. The second edition of ***Hyperclinic*** by Lewis Tomalty and Gloria Delisle is packed with over 100 case studies and over 200 pathogens supported with audio, video, and interactive screens. Students will have fun and gain confidence as they learn valuable concepts and gain practical experience in clinical microbiology.



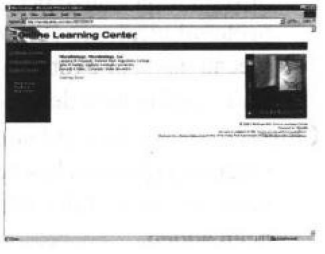
5. The fifth edition of ***Laboratory Exercises in Microbiology*** by John P. Harley and Lansing M. Prescott has been prepared to accompany the text. Like the text, the laboratory manual provides a balanced introduction to laboratory techniques and principles that are important in each area of microbiology. The class-tested exercises are modular and short so that an instructor can easily choose only those exercises that fit his or her course. The fifth edition contains recipes for all reagents and media. New exercises in biotechnology have been added to this edition. A new appendix provides practice in solving dilution problems.
6. A set of 305 ***Microbiology Study Cards*** prepared by Kent M. Van De Graaff, F. Brent Johnson, Brigham Young University, and Christopher H. Creek features complete descriptions of terms, clearly labeled drawings, clinical information on diseases, and much more.

For the Instructor

1. A ***Testing CD*** is offered free on request to adopters of the text. This cross-platform CD provides a database of over 2,500 objective questions for preparing exams and a grade-recording program.
2. A set of 250 full-color acetate ***Transparencies*** is available to supplement classroom lectures. These have been enhanced for projection and are available to adopters of the fifth edition.
3. The ***Visual Resource Library*** CD-ROM contains virtually all of the art and many of the photos from *Microbiology,* Fifth Edition, as well as the tables that appear in the text. 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. Features include an Interactive Slide Show and a Slide Editor.
4. A set of 50 ***Projection Slides*** provides clinical examples of diseases and pathogens to supplement the illustrations in the text.
5. Your McGraw-Hill representative may arrange a ***Customized Laboratory Manual*** combining your own material with exercises from *Laboratory Exercises in Microbiology,* Fifth Edition, by John P. Harley and Lansing M. Prescott. Contact your McGraw-Hill representative for details about this custom publishing service.
6. Designed specifically to help you with your individual course needs, ***PageOut, PageOut Lite,*** and ***McGraw-Hill Course Solutions*** will assist you in integrating your syllabus with the fifth edition's 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!

Online Resources

Through the Prescott 2002 ***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 WebCT or Blackboard. Through the Online Learning Center, you will also link to McGraw-Hill's new ***Biocourse.com*** site with a huge dynamic array of resources to supplement your learning experience in microbiology.



Some of the online features you will find to support your use of *Microbiology* by Prescott, Harley, and Klein include the following.

For the Student:

- Additional multiple-choice questions in a self-quizzing interactive format
- Electronic flashcards to review key vocabulary
- Study Outlines
- Web Links and Exercises
- Clinical Case Studies
- An Interactive Time Line detailing events and highlighting personalities critical to the development of microbiology
- Study Tips
- Student ***Tutorial Service***

For the Instructor:

- A complete ***Instructor's Manual and Test Item File*** written by David Mullin of Tulane University. The Instructor's Manual contains chapter overviews and objectives, correlation guides, and more. The Test Item File containing over 2,500 questions, and password protected, provides a powerful instructional tool.
- The ***Laboratory Resource Guide*** provides answers to all exercises in *Laboratory Exercises in Microbiology,* Fifth Edition, by John P. Harley and Lansing M. Prescott.
- Images and tables from the text in a downloadable format for classroom presentation.
- ***Correlation guides*** for use of all resources available with the text and correlations of text material with the ASM Guidelines.
- ***Answers to Critical Thinking Questions*** in the text.
- ***Web Links*** to active microbiology sites and to other sites with teaching resources.
- A ***Course Consultant*** to answer your specific questions about using McGraw-Hill resources with your syllabus.

Acknowledgments

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Reviewers for the First and Second Editions

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Lansing M. Prescott
John P. Harley
Donald A. Klein

VISUAL PREVIEW

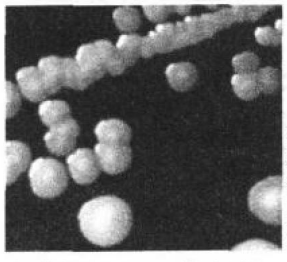
The next few pages show you the tools found throughout the text to help you in your study of microbiology.

PART II

Microbial Nutrition, Growth, and Control

CHAPTER 5

Microbial Nutrition



Staphylococcus aureus forms large, golden colonies when growing on blood agar. This human pathogen causes diseases such as boils, abscesses, bacteremia, endocarditis, food poisoning, pharyngitis, and pneumonia.

Outline

Concepts

1. Microorganisms require about 10 elements in large quantities, in part because they are used to construct carbohydrates, lipids, proteins, and nucleic acids. Several other elements are needed in very small amounts and are parts of enzymes and cofactors.
2. All microorganisms can be placed in one of a few nutritional categories on the basis of their requirements for carbon, energy, and hydrogen atoms or electrons.
3. Nutrient molecules frequently cannot cross selectively permeable plasma membranes through passive diffusion. They must be transported by one of three major mechanisms involving the use of membrane carrier proteins. Eucaryotic microorganisms also employ endocytosis for nutrient uptake.
4. Culture media are needed to grow microorganisms in the laboratory and to carry out specialized procedures like microbial identification, water and food analysis, and the isolation of particular microorganisms. Many different media are available for these and other purposes.
5. Pure cultures can be obtained through the use of spread plates, streak plates, or pour plates and are required for the careful study of an individual microbial species.

Chapter Outlines include all major headings in the chapter with section and page numbers. This helps the reader quickly locate topics of interest.

Chapter Concepts briefly summarize some of the most important concepts the student should master.

Opening Quotes are designed to perk student interest and provide perspective on chapter contents.

Chapter Preface is composed of one or two short paragraphs that preview the chapter contents and relate it to the rest of the text. The preface is not a summary, but allows the student to put the chapter into perspective at the start.

We all labour against our own cure, for death is the cure of all diseases.

—Sir Thomas Browne

The chapters in Part II are concerned with the nutrition, growth, and control of microorganisms. This chapter addresses the subject of the nonspecific control and destruction of microorganisms, a topic of immense practical importance. Although many microorganisms are beneficial and necessary for human well-being, microbial activities may have undesirable consequences, such as food spoilage and disease. Therefore it is essential to be able to kill a wide variety of microorganisms or inhibit their growth to minimize their destructive effects. The goal is twofold: (1) to destroy pathogens and prevent their transmission, and (2) to reduce or eliminate microorganisms responsible for the contamination of water, food, and other substances.

This chapter focuses on the control of microorganisms by nonspecific physical and chemical agents. Chapter 35 introduces the use of antimicrobial chemotherapy to control microbial disease.

From the beginning of recorded history, people have practiced disinfection and sterilization, even though the existence of microorganisms was long unsuspected. The Egyptians used fire to sterilize infectious material and disinfectants to embalm bodies, and the Greeks burned sulfur to fumigate buildings. Mosaic law commanded the Hebrews to burn any clothing suspected of being contaminated with the leprosy bacterium. Today the ability to destroy microorganisms is no less important; it makes possible the aseptic techniques used in microbiological research, the preservation of food, and the prevention of disease. The techniques described in this chapter are also essential to personal safety in both the laboratory and hospital (**Box 7.1**).

There are several ways to control microbial growth that have not been included in this chapter, but they should be considered for a more complete picture of how microorganisms are controlled. Chapter 6 describes the effects of osmotic activity, pH, temperature, O_2, and radiation on microbial growth and survival (*see pp. 121–31*). Chapter 41 discusses the use of physical and chemical agents in food preservation (*see pp. 000–00*).

7.1 *Definition of Frequently Used Terms*

Terminology is especially important when the control of microorganisms is discussed because words like disinfectant and antiseptic often are used loosely. The situation is even more confusing because a particular treatment can either inhibit growth or kill depending on the conditions.

The ability to control microbial populations on inanimate objects, like eating utensils and surgical instruments, is of considerable practical importance. Sometimes it is necessary to eliminate all microorganisms from an object, whereas only partial destruction of the microbial population may be required in other situations. **Sterilization** [Latin *sterilis*, unable to produce offspring or barren] is the process by which all living cells, viable spores, viruses, and viroids (*see chapter 18*) are either destroyed or removed from an object or habitat. A sterile object is totally free of viable microorganisms, spores, and other infectious agents. When sterilization is achieved by a chemical agent, the chemical is called a sterilant. In

Box 7.1

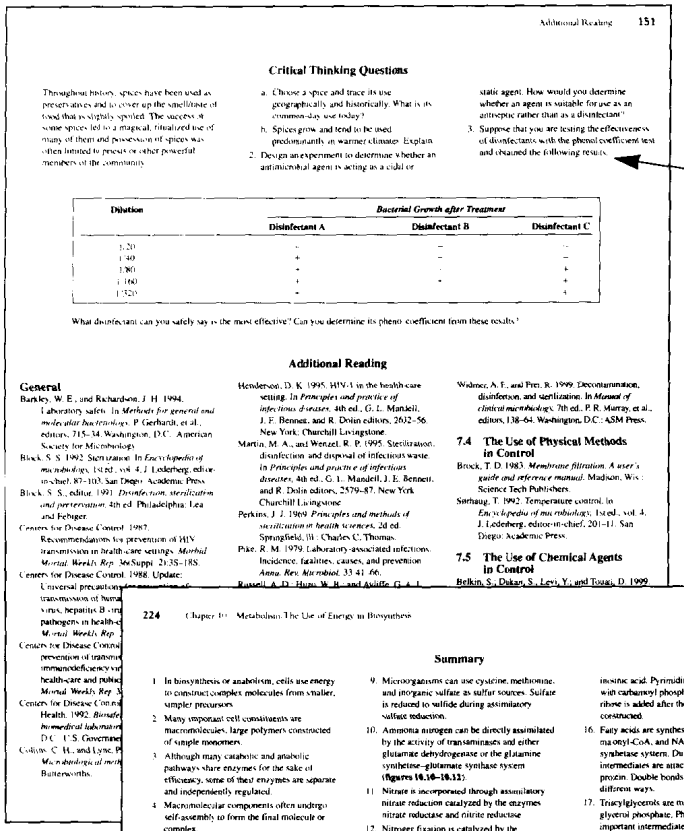
Safety in the Microbiology Laboratory

Personnel safety should be of major concern in all microbiology laboratories. It has been estimated that thousands of infections have been acquired in the laboratory, and many persons have died because of such infections. The two most common laboratory-acquired bacterial diseases are typhoid fever and brucellosis. Most deaths have come from typhoid fever (20 deaths) and Rocky Mountain spotted fever (13 deaths). Infections by fungi (histoplasmosis) and viruses (Venezuelan equine encephalitis and hepatitis B virus from monkeys) are also not uncommon. Hepatitis is the most frequently reported laboratory-acquired viral infection, especially in people working in clinical laboratories and with blood. In a survey of 426 U.S. hospital workers, 40% of those in clinical chemistry and 21% in microbiology had antibodies to hepatitis B virus, indicating their previous exposure (though only about 19% of these had disease symptoms).

Efforts have been made to determine the causes of these infections in order to enhance the development of better preventive measures. Although often it is not possible to determine the direct cause of infection, some major potential hazards are clear. One of the most frequent causes of disease is the inhalation of an infectious aerosol. An aerosol is a gaseous suspension of liquid or solid particles that may be generated by accidents and laboratory operations such as spills, centrifuge accidents, removal of closures from shaken culture tubes, and plunging of contaminated loops into a flame. Accidents with hypodermic syringes and needles, such as self-inoculation and spraying solutions from the needle, also are common. Hypodermics should be employed only when necessary and then with care. Pipette accidents involving the mouth are another major source of infection; pipettes should be filled with the use of pipette aids and operated in such a way as to avoid creating aerosols.

People must exercise care and common sense when working with microorganisms. Operations that might generate infectious aerosols should be carried out in a biological safety cabinet. Bench tops and incubators should be disinfected regularly. Autoclaves must be maintained and operated properly to ensure adequate sterilization. Laboratory personnel should wash their hands thoroughly before and after finishing work.

Boxed Readings are found in most chapters and describe items of interest that are not essential to the primary thrust of the chapter. Topics include currently exciting research areas, the practical impact of microbial activities, items of medical significance, historical anecdotes, and descriptions of extraordinary organisms.



Additional Reading 151

Critical Thinking Questions

Throughout history, spices have been used as preservatives and to cover up the smell/taste of food that is slightly spoiled. The success of some spices led to a magical, fetishized use of many of them and possession of spices was often limited to priests or other powerful members of the community.

a. Choose a spice and trace its use geographically and historically. What is its common-day use today?
b. Spices grow, and tend to be used predominantly in warmer climates. Explain.

2. Design an experiment to determine whether an antimicrobial agent is acting as a cidal or static agent. How would you determine whether an agent is suitable for use as an antiseptic rather than as a disinfectant?
3. Suppose that you are testing the effectiveness of disinfectants with the phenol coefficient test and obtained the following results:

Dilution	*Bacterial Growth after Treatment*		
	Disinfectant A	Disinfectant B	Disinfectant C
1:20	-	-	-
1:40	+	-	-
1:80	-		+
1:160	+	-	+
1:320	-		+

What disinfectant can you safely say is the most effective? Can you determine its phenol coefficient from these results?

Additional Reading

General

Barkley, W. E., and Richardson, J. H. 1994. Laboratory safety. In *Methods for general and molecular bacteriology*. P. Gerhardt, et al., editors. 715–34. Washington, D.C.: American Society for Microbiology.

Block, S. S. 1992. Sterilization. In *Encyclopedia of microbiology*. 1st ed., vol. 4. J. Lederberg, editor-in-chief. 87–103. San Diego: Academic Press.

Block, S. S., editor. 1991. *Disinfection, sterilization and preservation*. 4th ed. Philadelphia: Lea and Febiger.

Centers for Disease Control. 1987. Recommendations for prevention of HIV transmission in health-care settings. *Morbid Mortal. Weekly Rep.* 36(Suppl. 2):3S–18S.

Centers for Disease Control. 1988. Update: Universal precautions for prevention of transmission of human immunodeficiency virus, hepatitis B virus, and other bloodborne pathogens in health-care settings. *Morbid. Mortal. Weekly Rep.*

Centers for Disease Control and Prevention. 1992. *Biosafety in microbiological and biomedical laboratories*. 3rd ed. Washington, D.C.: U.S. Government Printing Office.

Collins, C. H., and Lyne, P. M. 1989. *Microbiological methods*. 6th ed. Boston: Butterworths.

Henderson, D. K. 1995. HIV-1 in the health-care setting. In *Principles and practice of infectious diseases*. 4th ed., G. L. Mandell, J. E. Bennett, and R. Dolin editors. 2632–56. New York: Churchill Livingstone.

Martin, M. A., and Wenzel, R. P. 1995. Sterilization, disinfection and disposal of infectious waste. In *Principles and practice of infectious diseases*. 4th ed., G. L. Mandell, J. E. Bennett, and R. Dolin editors. 2579–87. New York: Churchill Livingstone.

Perkins, J. J. 1969. *Principles and methods of sterilization in health sciences*. 2d ed. Springfield, Ill.: Charles C. Thomas.

Pike, R. M. 1979. Laboratory-associated infections: Incidence, fatalities, causes, and prevention. *Annu. Rev. Microbiol.* 33:41–66.

Russell, A. D., Hugo, W. B., and Ayliffe, G. A. J. 1992. *Principles and practice of disinfection, preservation and sterilization*. 2d ed. Oxford: Blackwell Scientific Publications.

Widmer, A. F., and Frei, R. 1999. Decontamination, disinfection, and sterilization. In *Manual of clinical microbiology*. 7th ed. P. R. Murray, et al., editors. 138–64. Washington, D.C.: ASM Press.

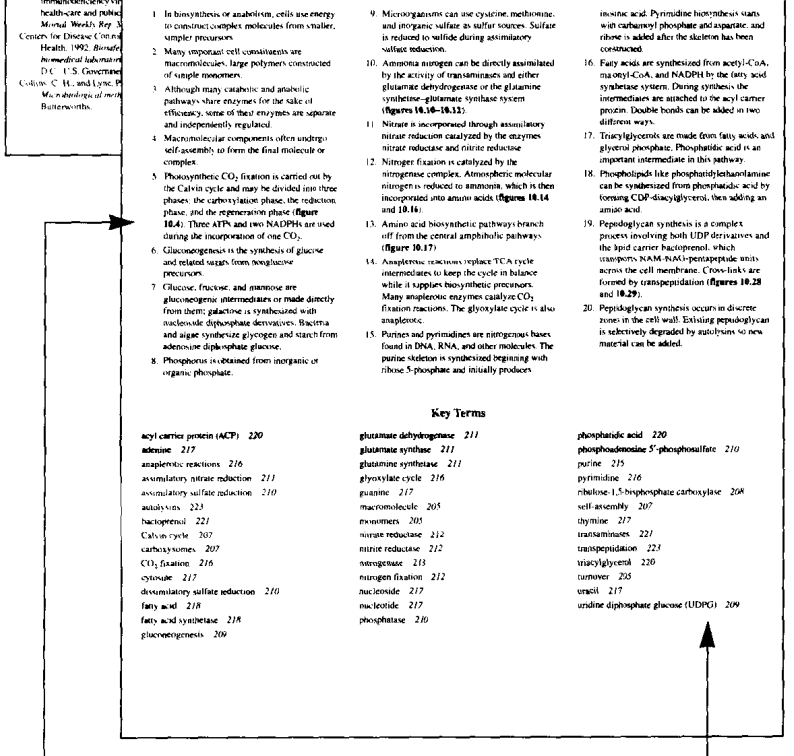
7.4 The Use of Physical Methods in Control

Brock, T. D. 1983. *Membrane filtration: A user's guide and reference manual*. Madison, Wis.: Science Tech Publishers.

Sarhaug, T. 1992. Temperature control. In *Encyclopedia of microbiology*. 1st ed., vol. 4. J. Lederberg, editor-in-chief. 201–11. San Diego: Academic Press.

7.5 The Use of Chemical Agents in Control

Belkin, S., Dakar, S., Levi, Y., and Tovar, D. 1999.



224 Chapter 10 Metabolism: The Use of Energy in Biosynthesis

Summary

1. In biosynthesis or anabolism, cells use energy to construct complex molecules from smaller, simpler precursors.
2. Many important cell constituents are macromolecules, large polymers constructed of simple monomers.
3. Although many catabolic and anabolic pathways share enzymes for the sake of efficiency, some of these enzymes are separate and independently regulated.
4. Macromolecular components often undergo self-assembly to form the final molecule or complex.
5. Photosynthetic CO_2 fixation is carried out by the Calvin cycle and may be divided into three phases: the carboxylation phase, the reduction phase, and the regeneration phase (**figure 10.4**). Three ATPs and two NADPHs are used during the incorporation of one CO_2.
6. Gluconeogenesis is the synthesis of glucose and related sugars from nonglucose precursors.
7. Glucose, fructose, and mannose are gluconeogenic intermediates or made directly from them; galactose is synthesized with nucleoside diphosphate derivatives. Bacteria and algae synthesize glycogen and starch from adenosine diphosphate glucose.
8. Phosphorus is obtained from inorganic or organic phosphate.
9. Microorganisms can use cysteine, methionine, and inorganic sulfate as sulfur sources. Sulfate is reduced to sulfide during assimilatory sulfate reduction.
10. Ammonia nitrogen can be directly assimilated by the activity of transaminases and either glutamate dehydrogenase or the glutamine synthetase–glutamate synthase system (**figures 10.10–10.12**).
11. Nitrate is incorporated through assimilatory nitrate reduction catalyzed by the enzymes nitrate reductase and nitrite reductase.
12. Nitrogen fixation is catalyzed by the nitrogenase complex. Atmospheric molecular nitrogen is reduced to ammonia, which is then incorporated into amino acids (**figures 10.14** and **10.16**).
13. Amino acid biosynthetic pathways branch off from the central amphibolic pathways (**figure 10.17**).
14. Anaplerotic reactions replace TCA cycle intermediates to keep the cycle in balance while it supplies biosynthetic precursors. Many anaplerotic enzymes catalyze CO_2 fixation reactions. The glyoxylate cycle is also anaplerotic.
15. Purines and pyrimidines are nitrogenous bases found in DNA, RNA, and other molecules. The purine skeleton is synthesized beginning with ribose 5-phosphate and initially produces inosinic acid. Pyrimidine biosynthesis starts with carbamoyl phosphate and aspartate, and ribose is added after the skeleton has been constructed.
16. Fatty acids are synthesized from acetyl-CoA, malonyl-CoA, and NADPH by the fatty acid synthetase system. During synthesis the intermediates are attached to the acyl carrier protein. Double bonds can be added in two different ways.
17. Triacylglycerols are made from fatty acids and glycerol phosphate. Phosphatidic acid is an important intermediate in this pathway.
18. Phospholipids like phosphatidylethanolamine can be synthesized from phosphatidic acid by forming CDP-diacylglycerol, then adding an amino acid.
19. Pepodoglycan synthesis is a complex process involving both UDP derivatives and the lipid carrier bactoprenol, which transports NAM-NAG-pentapeptide units across the cell membrane. Cross-links are formed by transpeptidation (**figures 10.28** and **10.29**).
20. Pepidoglycan synthesis occurs in discrete zones in the cell wall. Existing pepudoglycan is selectively degraded by autolysins so new material can be added.

Key Terms

acyl carrier protein (ACP) *220*
adenine *217*
anaplerotic reactions *216*
assimilatory nitrate reduction *211*
assimilatory sulfate reduction *210*
autolysins *223*
bactoprenol *221*
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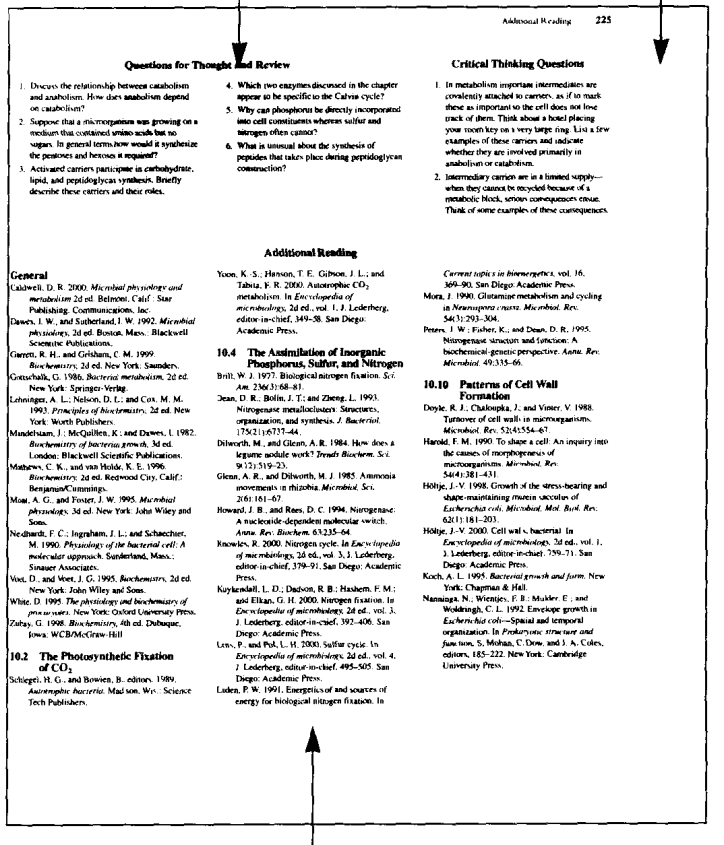
turnover *205*
uracil *217*
uridine diphosphate glucose (UDPG) *209*



Additional Reading 225

Questions for Thought and Review

1. Discuss the relationship between catabolism and anabolism. How does anabolism depend on catabolism?
2. Suppose that a microorganism was growing on a medium that contained amino acids but no sugars. In general terms, how would it synthesize the pentoses and hexoses it required?
3. Activated carriers participate in carbohydrate, lipid, and peptidoglycan synthesis. Briefly describe these carriers and their roles.
4. Which two enzymes discussed in the chapter appear to be specific to the Calvin cycle?
5. Why can phosphorus be directly incorporated into cell constituents whereas sulfur and nitrogen often cannot?
6. What is unusual about the synthesis of peptides that takes place during peptidoglycan construction?

Critical Thinking Questions

1. In metabolism important intermediates are covalently attached to carriers, as if to mark these as important so the cell does not lose track of them. Think about a hotel placing your room key on a very large ring. List a few examples of these carriers and indicate whether they are involved primarily in anabolism or catabolism.
2. Intermediary carriers are in a limited supply—when they cannot be recycled because of a metabolic block, serious consequences ensue. Think of some examples of these consequences.

Additional Reading

General

Caldwell, D. R. 2000. *Microbial physiology and metabolism*. 2d ed. Belmont, Calif.: Star Publishing Communications, Inc.

Dawes, I. W., and Sutherland, I. W. 1992. *Microbial physiology*. 2d ed. Boston, Mass.: Blackwell Scientific Publications.

Garrett, R. H., and Grisham, C. M. 1999. *Biochemistry*. 2d ed. New York: Saunders.

Gottschalk, G. 1986. *Bacterial metabolism*. 2d ed. New York: Springer-Verlag.

Lehninger, A. L.; Nelson, D. L.; and Cox, M. M. 1993. *Principles of biochemistry*. 2d ed. New York: Worth Publishers.

Mandelstam, J.; McQuillen, K.; and Dawes, I. 1982. *Biochemistry of bacterial growth*. 3d ed. London: Blackwell Scientific Publications.

Mathews, C. K., and van Holde, K. E. 1996. *Biochemistry*. 2d ed. Redwood City, Calif.: Benjamin/Cummings.

Moat, A. G., and Foster, J. W. 1995. *Microbial physiology*. 3d ed. New York: John Wiley and Sons.

Neidhardt, F. C.; Ingraham, J. L.; and Schaechter, M. 1990. *Physiology of the bacterial cell: A molecular approach*. Sunderland, Mass.: Sinauer Associates.

Voet, D., and Voet, J. G. 1995. *Biochemistry*. 2d ed. New York: John Wiley and Sons.

White, D. 1995. *The physiology and biochemistry of prokaryotes*. New York: Oxford University Press.

Zubay, G. 1998. *Biochemistry*. 4th ed. Dubuque, Iowa: WCB/McGraw-Hill.

10.2 The Photosynthetic Fixation of CO_2

Schlegel, H. G., and Bowien, B., editors. 1989. *Autotrophic bacteria*. Madison, Wis.: Science Tech Publishers.

Yoon, K.-S.; Hanson, T. E.; Gibson, J. L.; and Tabita, F. R. 2000. Autotrophic CO_2 metabolism. In *Encyclopedia of microbiology*. 2d ed., vol. 1. J. Lederberg, editor-in-chief. 349–58. San Diego: Academic Press.

10.4 The Assimilation of Inorganic Phosphorus, Sulfur, and Nitrogen

Britt, W. J. 1977. Biological nitrogen fixation. *Sci. Am.* 236(3):68–81.

Dean, D. R.; Bolin, J. T.; and Zheng, L. 1993. Nitrogenase metalloclusters: Structures, organization, and synthesis. *J. Bacteriol.* 175(21):6737–44.

Dilworth, M., and Glenn, A. R. 1984. How does a legume nodule work? *Trends Biochem. Sci.* 9(12):519–23.

Glenn, A. R., and Dilworth, M. J. 1985. Ammonia movements in rhizobia. *Microbiol. Sci.* 2(6):181–87.

Howard, J. B., and Rees, D. C. 1994. Nitrogenase: A nucleotide-dependent molecular switch. *Annu. Rev. Biochem.* 63:235–64.

Knowles, R. 2000. Nitrogen cycle. In *Encyclopedia of microbiology*. 2d ed., vol. 3. J. Lederberg, editor-in-chief. 379–91. San Diego: Academic Press.

Kuylenstall, L. D.; Dadson, R. B.; Hashem, F. M.; and Elkan, G. H. 2000. Nitrogen fixation. In *Encyclopedia of microbiology*. 2d ed., vol. 3. J. Lederberg, editor-in-chief. 392–406. San Diego: Academic Press.

Lees, P., and Pol, L. H. 2000. Sulfur cycle. In *Encyclopedia of microbiology*. 2d ed., vol. 4. J. Lederberg, editor-in-chief. 495–505. San Diego: Academic Press.

Liden, P. W. 1991. Energetics of and sources of energy for biological nitrogen fixation. In *Current topics in bioenergetics*, vol. 16. 369–90. San Diego: Academic Press.

Mora, J. 1990. Glutamine metabolism and cycling in *Neurospora crassa*. *Microbiol. Rev.* 54(3):203–304.

Peters, J. W.; Fisher, K.; and Dean, D. R. 1995. Nitrogenase structure and function: A biochemical-genetic perspective. *Annu. Rev. Microbiol.* 49:335–66.

10.10 Patterns of Cell Wall Formation

Doyle, R. J.; Chaloupka, J.; and Vinter, V. 1988. Turnover of cell walls in microorganisms. *Microbiol. Rev.* 52(4):554–67.

Harold, F. M. 1990. To shape a cell: An inquiry into the causes of morphogenesis of microorganisms. *Microbiol. Rev.* 54(4):381–431.

Höltje, J.-V. 1998. Growth of the stress-bearing and shape-maintaining murein sacculus of *Escherichia coli*. *Microbiol. Mol. Biol. Rev.* 62(1):181–203.

Höltje, J.-V. 2000. Cell wall, bacterial. In *Encyclopedia of microbiology*. 2d ed., vol. 1. J. Lederberg, editor-in-chief. 759–71. San Diego: Academic Press.

Koch, A. L. 1995. *Bacterial growth and form*. New York: Chapman & Hall.

Nanninga, N., Wientjes, F. B.; Mulder, E.; and Woldringh, C. L. 1992. Envelope growth in *Escherichia coli*—Spatial and temporal organization. In *Prokaryotic structure and function*, S. Mohan, C. Dow, and J. A. Coles, editors. 185–222. New York: Cambridge University Press.

Critical Thinking Questions contains questions designed to stimulate more analytical and synthetic reasoning.

Questions for Thought and Review at the end of the chapter contains factual questions and some thought-provoking questions to aid the student in reviewing, integrating, and applying the material in the chapter.

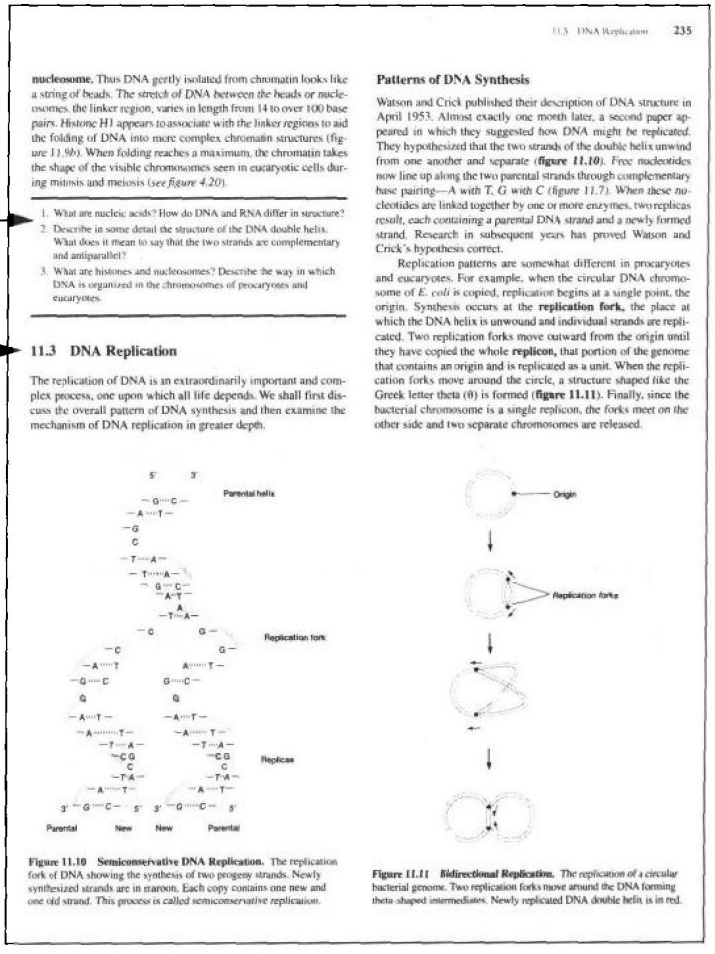
Chapter Summaries are a series of brief numbered statements designed to serve more as a study guide than as a complete, detailed summary of the chapter. Useful tables and figures are cited in the summary.

Key Terms is a list of all boldfaced terms and is provided at the end of the chapter to emphasize the most significant facts and concepts. Each term is page-referenced to the page on which the term is first introduced in the chapter.

Additional Readings are provided for further study. Most are reviews, monographs, and *Scientific American* articles rather than original research papers. Publications cited in these reviews introduce sufficiently interested students to the research literature. References through early 2001 have been included. The reference sections are organized into topical groups that correspond to the major sections in each chapter. This arrangement provides ease of access for students interested in particular topics.

Review Questions appear in small boxes at the end of most major sections. These questions help the student master the section's factual material and major concepts before continuing with the chapter.

Numbered Headings identify each major topic and are used for easy reference throughout the text and the accompanying laboratory manual.



11.3 DNA Replication 235

nucleosome. Thus DNA gently isolated from chromatin looks like a string of beads. The stretch of DNA between the heads or nucleosomes, the linker region, varies in length from 14 to over 100 base pairs. Histone H1 appears to associate with the linker regions to aid the folding of DNA into more complex chromatin structures (figure 11.9b). When folding reaches a maximum, the chromatin takes the shape of the visible chromosomes seen in eucaryotic cells during mitosis and meiosis (see figure 4.20).

1. What are nucleic acids? How do DNA and RNA differ in structure?
2. Describe in some detail the structure of the DNA double helix. What does it mean to say that the two strands are complementary and antiparallel?
3. What are histones and nucleosomes? Describe the way in which DNA is organized in the chromosomes of procaryotes and eucaryotes.

11.3 DNA Replication

The replication of DNA is an extraordinarily important and complex process, one upon which all life depends. We shall first discuss the overall pattern of DNA synthesis and then examine the mechanism of DNA replication in greater depth.

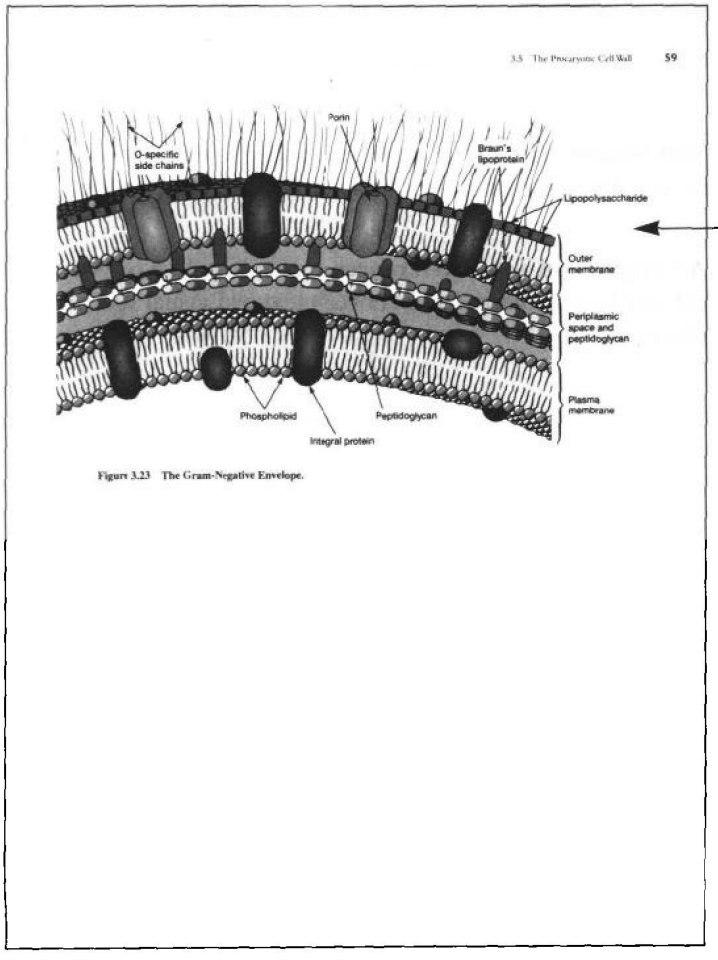
Patterns of DNA Synthesis

Watson and Crick published their description of DNA structure in April 1953. Almost exactly one month later, a second paper appeared in which they suggested how DNA might be replicated. They hypothesized that the two strands of the double helix unwind from one another and separate (**figure 11.10**). Free nucleotides now line up along the two parental strands through complementary base pairing—A with T, G with C (figure 11.7). When these nucleotides are linked together by one or more enzymes, two replicas result, each containing a parental DNA strand and a newly formed strand. Research in subsequent years has proved Watson and Crick's hypothesis correct.

Replication patterns are somewhat different in procaryotes and eucaryotes. For example, when the circular DNA chromosome of *E. coli* is copied, replication begins at a single point, the origin. Synthesis occurs at the **replication fork,** the place at which the DNA helix is unwound and individual strands are replicated. Two replication forks move outward from the origin until they have copied the whole **replicon,** that portion of the genome that contains an origin and is replicated as a unit. When the replication forks move around the circle, a structure shaped like the Greek letter theta (θ) is formed (**figure 11.11**). Finally, since the bacterial chromosome is a single replicon, the forks meet on the other side and two separate chromosomes are released.

Figure 11.10 Semiconservative DNA Replication. The replication fork of DNA showing the synthesis of two progeny strands. Newly synthesized strands are in maroon. Each copy contains one new and one old strand. This process is called *semiconservative replication.*

Figure 11.11 Bidirectional Replication. *The replication of a circular* bacterial genome. Two replication forks move around the DNA forming theta-shaped intermediates. Newly replicated DNA double helix is in red.



3.5 The Procaryotic Cell Wall 59

Figure 3.23 The Gram-Negative Envelope.

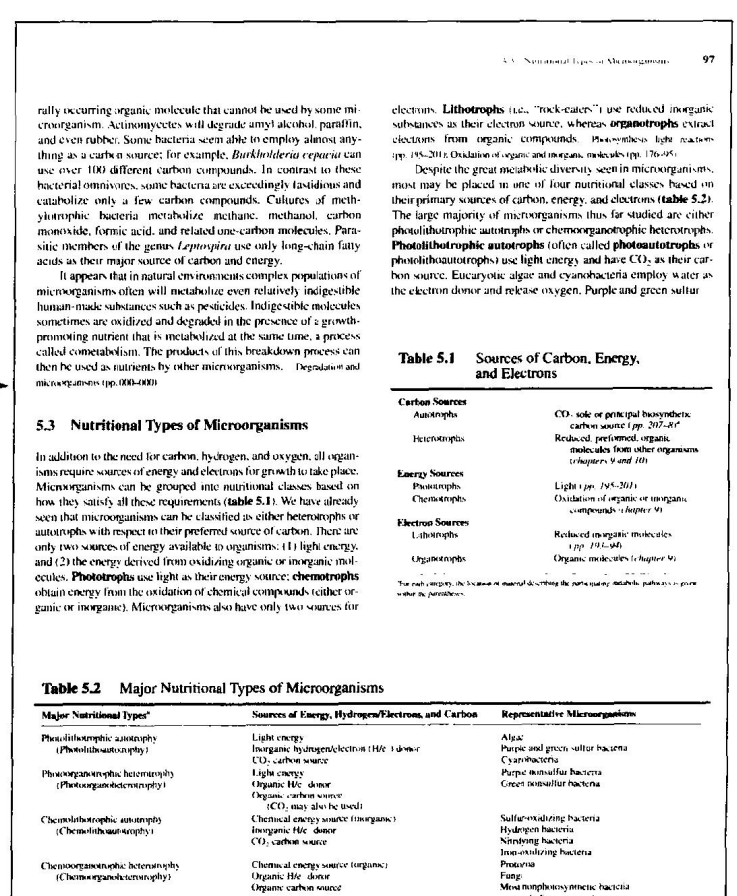
Multimedia-Supported Illustrations appear throughout the text. To facilitate finding corresponding full-color video, animations, or interactive screens from the third edition of ***Microbes in Motion,*** a correlation guide is provided on the CD-ROM, on the Student ***Online Learning Center,*** and in the ***Student Study Guide.***

Microbes in Motion, Third Edition, CD-ROM is organized into 18 topical "books," the books are divided into "chapters," and the chapters have numbered "pages." For each multimedia-supported illustration, the correlation guide directs the reader to the book, chapter, and page on the CD-ROM where corresponding material can be found.

Figure 3.23 Bacterial Structure and Function Book Cell Wall Chapter Peptidoglycan Topic pp. 2–3

Cross-Reference Notes refer the student to major topics that are difficult and may need review in order to understand the current material. They also point the student either forward or backward to a related item of unusual interest or importance. Normally a reference is to either a specific section number or a page so that students can easily locate the item.

Boldfaced Terms are the important terms and are emphasized and clearly defined when they are first used. Bold terms are listed at the end of the chapter and most appear in the glossary.



rally occurring organic molecule that cannot be used by some microorganism. Actinomycetes will degrade amyl alcohol, paraffin, and even rubber. Some bacteria seem able to employ almost anything as a carbon source; for example, *Burkholderia cepacia* can use over 100 different carbon compounds. In contrast to these bacterial omnivores, some bacteria are exceedingly fastidious and catabolize only a few carbon compounds. Cultures of methylotrophic bacteria metabolize methane, methanol, carbon monoxide, formic acid, and related one-carbon molecules. Parasitic members of the genus *Leptospira* use only long-chain fatty acids as their major source of carbon and energy.

It appears that in natural environments complex populations of microorganisms often will metabolize even relatively indigestible human-made substances such as pesticides. Indigestible molecules sometimes are oxidized and degraded in the presence of a growth-promoting nutrient that is metabolized at the same time, a process called cometabolism. The products of this breakdown process can then be used as nutrients by other microorganisms. Degradation and microorganisms (pp. 000–000)

5.3 Nutritional Types of Microorganisms

In addition to the need for carbon, hydrogen, and oxygen, all organisms require sources of energy and electrons for growth to take place. Microorganisms can be grouped into nutritional classes based on how they satisfy all these requirements (**table 5.1**). We have already seen that microorganisms can be classified as either heterotrophs or autotrophs with respect to their preferred source of carbon. There are only two sources of energy available to organisms: (1) light energy, and (2) the energy derived from oxidizing organic or inorganic molecules. **Phototrophs** use light as their energy source; **chemotrophs** obtain energy from the oxidation of chemical compounds (either organic or inorganic). Microorganisms also have only two sources for electrons. **Lithotrophs** (i.e., "rock-eaters") use reduced inorganic substances as their electron source, whereas **organotrophs** extract electrons from organic compounds. Photosynthesis, light reactions (pp. 195–201); Oxidation of organic and inorganic molecules (pp. 176–95)

Despite the great metabolic diversity seen in microorganisms, most may be placed in one of four nutritional classes based on their primary sources of carbon, energy, and electrons (**table 5.2**). The large majority of microorganisms thus far studied are either photolithotrophic autotrophs or chemoorganotrophic heterotrophs. **Photolithotrophic autotrophs** (often called **photoautotrophs** or photolithoautotrophs) use light energy and have CO_2 as their carbon source. Eucaryotic algae and cyanobacteria employ water as the electron donor and release oxygen. Purple and green sulfur

Table 5.1 Sources of Carbon, Energy, and Electrons

Carbon Sources	
Autotrophs	CO_2 sole or principal biosynthetic carbon source (*pp. 207–8*)
Heterotrophs	Reduced, preformed, organic molecules from other organisms (*chapters 9 and 10*)
Energy Sources	
Phototrophs	Light (*pp. 195–201*)
Chemotrophs	Oxidation of organic or inorganic compounds (*chapter 9*)
Electron Sources	
Lithotrophs	Reduced inorganic molecules (*pp. 193–96*)
Organotrophs	Organic molecules (*chapter 9*)

The only category, the location of material describing the particular metabolic pathways is given after its parentheses.

Table 5.2 Major Nutritional Types of Microorganisms

Major Nutritional Types*	Sources of Energy, Hydrogen/Electrons, and Carbon	Representative Microorganisms
Photolithotrophic autotrophy (Photolithoautotrophy)	Light energy Inorganic hydrogen/electron (H/e⁻) donor CO_2 carbon source	Algae Purple and green sulfur bacteria Cyanobacteria
Photoorganotrophic heterotrophy (Photoorganoheterotrophy)	Light energy Organic H/e⁻ donor Organic carbon source (CO_2 may also be used)	Purple nonsulfur bacteria Green nonsulfur bacteria
Chemolithotrophic autotrophy (Chemolithoautotrophy)	Chemical energy source (inorganic) Inorganic H/e⁻ donor CO_2 carbon source	Sulfur-oxidizing bacteria Hydrogen bacteria Nitrifying bacteria Iron-oxidizing bacteria
Chemoorganotrophic heterotrophy (Chemoorganoheterotrophy)	Chemical energy source (organic) Organic H/e⁻ donor Organic carbon source	Protozoa Fungi Most nonphotosynthetic bacteria (including most pathogens)

*Bacteria in other nutritional categories have been found. The categories are defined in terms of energy, electrons, and carbon sources. Underlined synonyms of these names are given in parentheses.

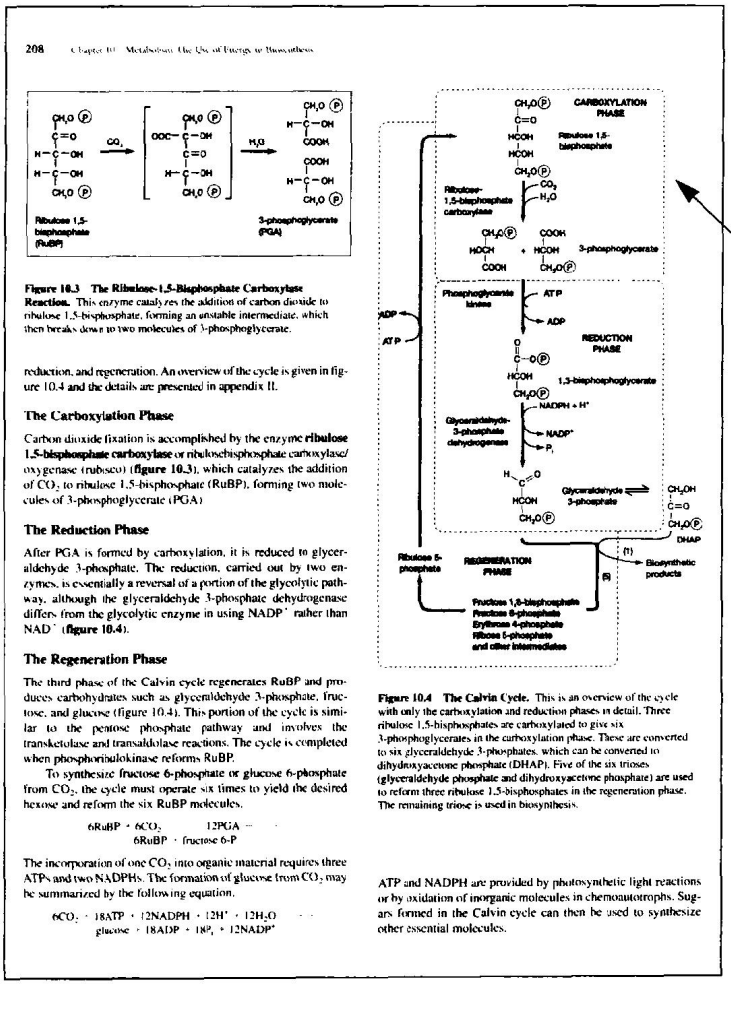


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Figure 10.3 The Ribulose-1,5-Bisphosphate Carboxylase Reaction. This enzyme catalyzes the addition of carbon dioxide to ribulose 1,5-bisphosphate, forming an unstable intermediate, which then breaks down to two molecules of 3-phosphoglycerate.

reduction, and regeneration. An overview of the cycle is given in figure 10.4 and the details are presented in appendix II.

The Carboxylation Phase

Carbon dioxide fixation is accomplished by the enzyme **ribulose 1,5-bisphosphate carboxylase** or ribulosebisphosphate carboxylase/oxygenase (rubisco) (**figure 10.3**), which catalyzes the addition of CO_2 to ribulose 1,5-bisphosphate (RuBP), forming two molecules of 3-phosphoglycerate (PGA)

The Reduction Phase

After PGA is formed by carboxylation, it is reduced to glyceraldehyde 3-phosphate. The reduction, carried out by two enzymes, is essentially a reversal of a portion of the glycolytic pathway, although the glyceraldehyde 3-phosphate dehydrogenase differs from the glycolytic enzyme in using $NADP^+$ rather than NAD^+ (**figure 10.4**).

The Regeneration Phase

The third phase of the Calvin cycle regenerates RuBP and produces carbohydrates such as glyceraldehyde 3-phosphate, fructose, and glucose (figure 10.4). This portion of the cycle is similar to the pentose phosphate pathway and involves the transketolase and transaldolase reactions. The cycle is completed when phosphoribulokinase reforms RuBP.

To synthesize fructose 6-phosphate or glucose 6-phosphate from CO_2, the cycle must operate six times to yield the desired hexose and reform the six RuBP molecules.

$$6RuBP + 6CO_2 \rightarrow 12PGA \rightarrow 6RuBP + \text{fructose 6-P}$$

The incorporation of one CO_2 into organic material requires three ATPs and two NADPHs. The formation of glucose from CO_2 may be summarized by the following equation.

$$6CO_2 + 18ATP + 12NADPH + 12H^+ + 12H_2O \rightarrow \text{glucose} + 18ADP + 18P_i + 12NADP^+$$

Figure 10.4 The Calvin Cycle. This is an overview of the cycle with only the carboxylation and reduction phases in detail. Three ribulose 1,5-bisphosphates are carboxylated to give six 3-phosphoglycerates in the carboxylation phase. These are converted to six glyceraldehyde 3-phosphates, which can be converted to dihydroxyacetone phosphate (DHAP). Five of the six trioses (glyceraldehyde phosphate and dihydroxyacetone phosphate) are used to reform three ribulose 1,5-bisphosphates in the regeneration phase. The remaining triose is used in biosynthesis.

ATP and NADPH are provided by photosynthetic light reactions or by oxidation of inorganic molecules in chemoautotrophs. Sugars formed in the Calvin cycle can then be used to synthesize other essential molecules.

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.

To the Student

One of the most important factors contributing to success in college, and in microbiology courses, is the use of good study techniques. This textbook is organized to help you to study more efficiently. But even a text with many learning aids is not effective unless used properly. Thus this section briefly outlines some practical study skills that will help ensure success in microbiology and make your use of this textbook more productive. Many of you already have the study skills mentioned here and will not need to spend time reviewing familiar material. These suggestions are made in the hope that they may be useful to those who are unaware of approaches like the SQ4R technique for studying textbooks.

Time Management and Study Environment

Many students find it difficult to study effectively because of a lack of time management and a proper place to study. Often a student will do poorly in courses because not enough time has been spent studying outside class. For best results you should plan to spend at least an average of four to eight hours a week outside class working on each course. There is sufficient time in the week for this, but it does require time management. If you spend a few minutes early in the morning planning how the day is to be used and allow adequate time for studying, much more will be accomplished. Students who make efficient use of every moment find that they have plenty of time for recreation.

A second important factor is a proper place to study so that you can concentrate and efficiently use your study time. Try to find a quiet location with a desk and adequate lighting. If possible, always study in the same place and use it only for studying. In this way you will be mentally prepared to study when you are at your desk. This location may be in the dorm, the library, a special study room, or somewhere else. Wherever it is, your study area should be free from distractions—including friends who drop by to socialize. Much more will be accomplished if you really study during your designated study times.

Making the Most of Lectures

Attendance at lectures is essential for success. Students who chronically miss classes usually do not do well. To gain the most from lectures, it is best to read any relevant text material beforehand. Be prepared to concentrate during lectures; do not simply sit back passively and listen to the instructor. During the lecture record your notes in a legible way so that you can understand them later. It is most efficient to employ an outline or simple paragraph format. The use of abbreviations or some type of shorthand notation often is effective. During lecture concentrate on what is being said and be sure to capture all of the main ideas, concepts, and definitions of important terms. Do not take sketchy notes assuming that you will remember things because they are easy or obvious; you won't. Diagrams, lists, and terms written on the board are almost always important, as is anything the instructor clearly emphasizes by tone of voice. Feel free to ask questions during class when you don't understand something or wish the instructor to pursue a point further. Remember that if you don't understand, it is very likely that others in the class don't either but simply aren't willing to show their confusion. As soon as possible after a lecture, carefully review your notes to be certain that they are complete and understandable. Refer to the textbook when uncertain about something in your notes; it will be invaluable in clearing up questions and amplifying major points. When studying your notes for tests, it is a good idea to emphasize the most important points with a highlighter just as you would when reading the textbook.

Studying the Textbook

Your textbook is one of the most important learning tools in any course and should be very carefully and conscientiously used. Many years ago Francis P. Robinson developed a very effective study technique called SQ3R (survey, question, read, recite, and review). More recently L. L. Thistlethwaite and N. K. Snouffer have slightly modified it to yield the SQ4R approach (survey, question, read, revise, record, and review). This latter approach is summarized here:

1. *Survey.* Briefly scan the chapter to become familiar with its general content. Quickly read the title, introduction, summary, and main headings. Record the major ideas and points that you think the chapter will make. If there are a list of chapter concepts and a chapter outline, pay close attention to these. This survey should give you a feel for the topic and how the chapter is approaching it.
2. *Question.* As you reach each main heading or subheading, try to compose an important question or two that you believe the section will answer. This preview question will help focus your reading of the section. It is also a good idea to keep asking yourself questions as you read. This habit facilitates active reading and learning.
3. *Read.* Carefully read the section. Read to understand concepts and major points, and try to find the answer to your preview question(s). You may want to highlight very important terms or explanations of concepts, but do not indiscriminantly highlight everything. Be sure to pay close attention to any terms printed in color or boldface since the author(s) considered these to be important.
4. *Revise.* After reading the section, revise your question(s) to more accurately reflect the section's contents. These questions should be concept type questions that force you to bring together a number of details. They can be written in the margins of your text.

5. *Record.* Underline the information in the text that answers your questions, if you have not already done so. You may wish to write down the answers in note form as well. This process will give you good material to use in preparing for exams.
6. *Review.* Review the information by trying to answer your questions without looking at the text. If the text has a list of key words and a set of study questions, be sure to use these in your review. You will retain much more if you review the material several times.

Preparing for Examinations

It is extremely important to prepare for examinations properly so that you will not be rushed and tired on examination day. All textbook reading and lecture note revision should be completed well ahead of time so that the last few days can be spent in mastering the material, not in trying to understand the basic concepts. Cramming at the last moment for an exam is no substitute for daily preparation and review. By managing time carefully and keeping up with your studies, you will have plenty of time to review thoroughly and clear up any questions. This will allow you to get sufficient rest before the test and to feel confident in your preparation. Because both physical condition and general attitude are important factors in test performance, you will automatically do better. Proper reviewing techniques also aid retention of the material.

Our website **(www.mhhe.com/prescott5)** contains many useful study aids. For example, the Student Center has more study tips, chapter overviews and outlines with links, flash cards, quizzes, a tutorial service, microbiology web links, clinical case studies, a Microbiology in the News page, and a correlation guide to the Microbes in Motion program.

For more useful study aids visit www.mhhe.com/prescott5.