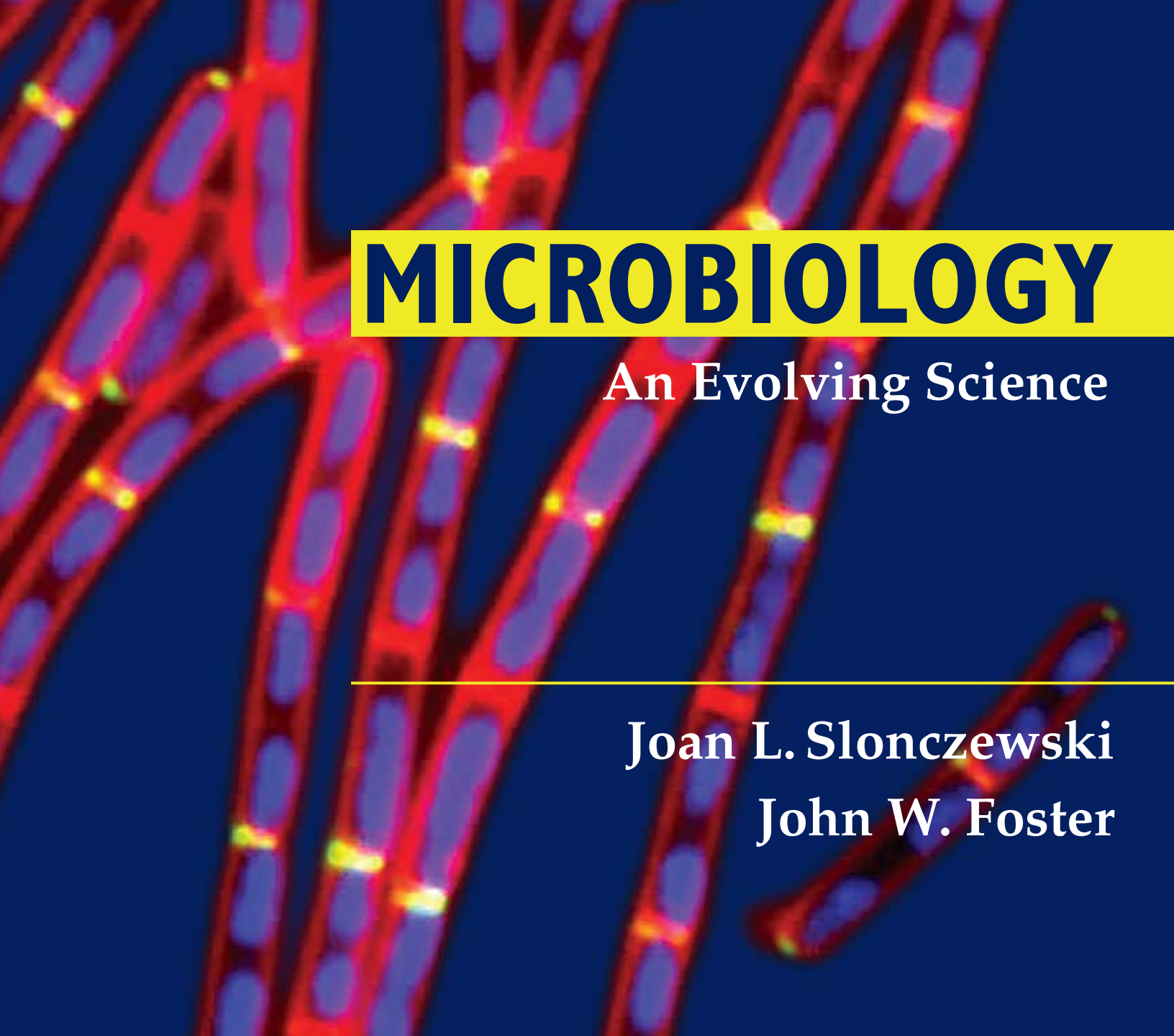


MICROBIOLOGY

An Evolving Science

Joan L. Slonczewski
John W. Foster

CONTENTS

Microbiology

An Evolving Science

Joan L. Slonczewski, *Kenyon College*
John W. Foster, *University of South Alabama*

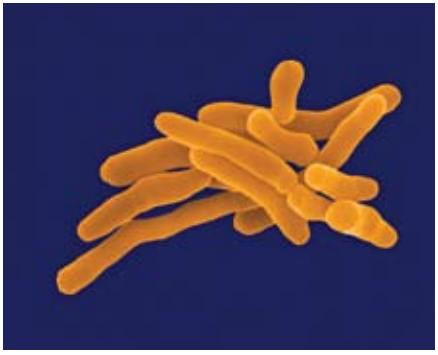
Microbiology: An Evolving Science promotes a clear understanding of this rapidly advancing field in two distinctive ways. First, an emphasis on current research, genomics, and molecular genetics enables students to learn how microbiologists think as they master the discipline's foundational topics. Second, a stunning and consistently executed art program helps students visualize key microbiological processes and structures.

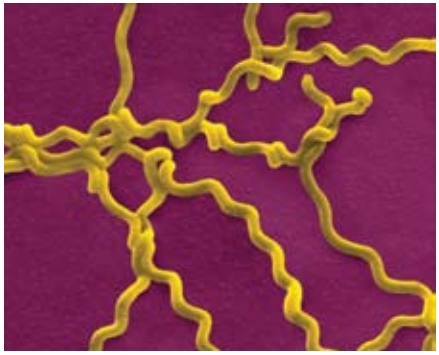
Hardcover, 1,100 pages ISBN 978-0-393-97857-5

Highlights

***Microbiology*'s emphasis on molecular genetics and genomics teaches students how contemporary microbiologists understand and approach the field.** Early coverage of genetics enables the authors to demonstrate the importance of genomics throughout the book. This approach gives students many advantages, including an understanding of how genomes reveal potential metabolic pathways of diverse organisms and how genomics and metagenomics reveal the character of microbial communities.

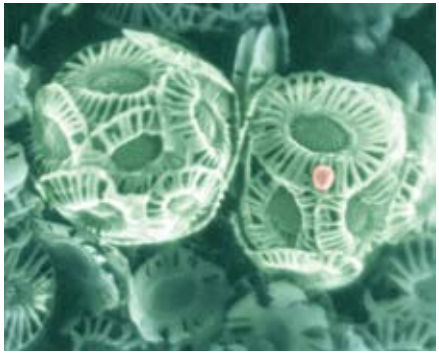
Current research examples throughout the text enrich students' understanding of foundational topics. Every chapter presents numerous current research examples within the up-to-date framework of molecular biology, facilitating the incorporation of the latest research into the foundational topics of genetics, physiology, ecology, evolution, and immunology.





COMMON SHAPES OF BACTERIA. The shape of most bacterial cells can be discerned with light microscopy, but their subcellular structures and surface details cannot be seen. *Left: Mediscan/Visuals Unlimited; center and right: Dennis Kunkel Microscopy.*

VIRUSES INFECT ALGAE. A virus attaches to the surface of a marine phytoplankton, Emiliana huxleyi (SEM). *Society for General Microbiology, Reading, UK*



Microbial ecology and medical microbiology receive equal emphasis, with much attention to the merging of these fields. *Microbiology* provides balanced coverage of microbial ecology and medical microbiology. In addition to devoting six chapters to each subject, the authors consider both ecological and medical examples each time a principle is introduced.

A stunning and consistently executed art program helps students visualize key processes and showcases the latest structural discoveries. Acknowledging that the successful microbiology student must learn to visualize key microbiological processes, *Microbiology* boasts a consistent, unified art program that speaks to today's visual student and showcases the latest structural discoveries.

In-text features throughout the book aid student understanding and stimulate inquiry. "Thought Questions" throughout the text prompt students to think about the core concepts. "To Summarize" features ensure that students understand the key concepts of each section before they continue with the reading. And optional "Special Topics" boxes show the process of science and give a human face to the research.

Conveying the excitement of an evolving scientific field, *Microbiology* portrays a science that is dynamic, exciting, and full of opportunities for students to do important research as undergraduates now or as graduate students. Each part begins with an interview of a prominent microbiologist working today, and the work of contemporary scientists is presented alongside that of the traditional icons.

Brief Contents

4 Chapter 4 introduces the fundamental classes of metabolism, to be developed further in Part III.

6 Viral genetics is introduced in preparation for the key roles viruses play in microbial genetics, which is covered in Part II.

Part II Genetics is covered before metabolism, enabling the authors to show the application of genetic analysis to metabolic questions and microbial diversity. Note, however, that metabolism is actually introduced in Chapter 4 and that the chapters of Part III can be covered earlier as desired.

11 Chapter 11 treats examples of viruses in depth, emphasizing the diversity of molecular mechanisms, such as primers consisting of host-derived proteins or transfer RNA.

Part III The text presents the fundamental chemistry of metabolism, including full structural formulas for most pathways. The diversity of bacterial and archaeal energetics is emphasized. The chapters of Part III can be covered before Part II, as desired.

Part IV The text presents up-to-date coverage of microbial evolution and a phylogeny-based view of microbial diversity in the three domains. The varied roles of microbes in Earth's biosphere are presented, with relevance to global concerns.

12 16 22 28 In addition to the numerous examples of applied microbiology throughout the text, Parts II through V each conclude with a chapter covering the practical applications of the preceding chapters.

Part V The microbial fundamentals and research perspectives of Parts I–IV are applied to show how modern research reveals causative agents and develops new therapies.

26 An organ systems approach is used to discuss disease in terms of the different microorganisms that can cause a given set of symptoms. Patient case histories illustrate key concepts of microbial diseases while showing students the clues used to rule out or rule in different possible causes.

Appendices For students in need of review, two appendices present essential material from introductory biology.

Part IV: Microbial Diversity and Ecology

17 Origins and Evolution

18 Bacterial Diversity

19 Archaeal Diversity

20 Eukaryotic Diversity

21 Microbial Ecology

22 Microbes and the Global Environment

Part V: Medicine and Immunology

23 Human Microflora and Nonspecific Host Defenses

24 The Adaptive Immune Response

25 Microbial Pathogenesis

26 Microbial Diseases

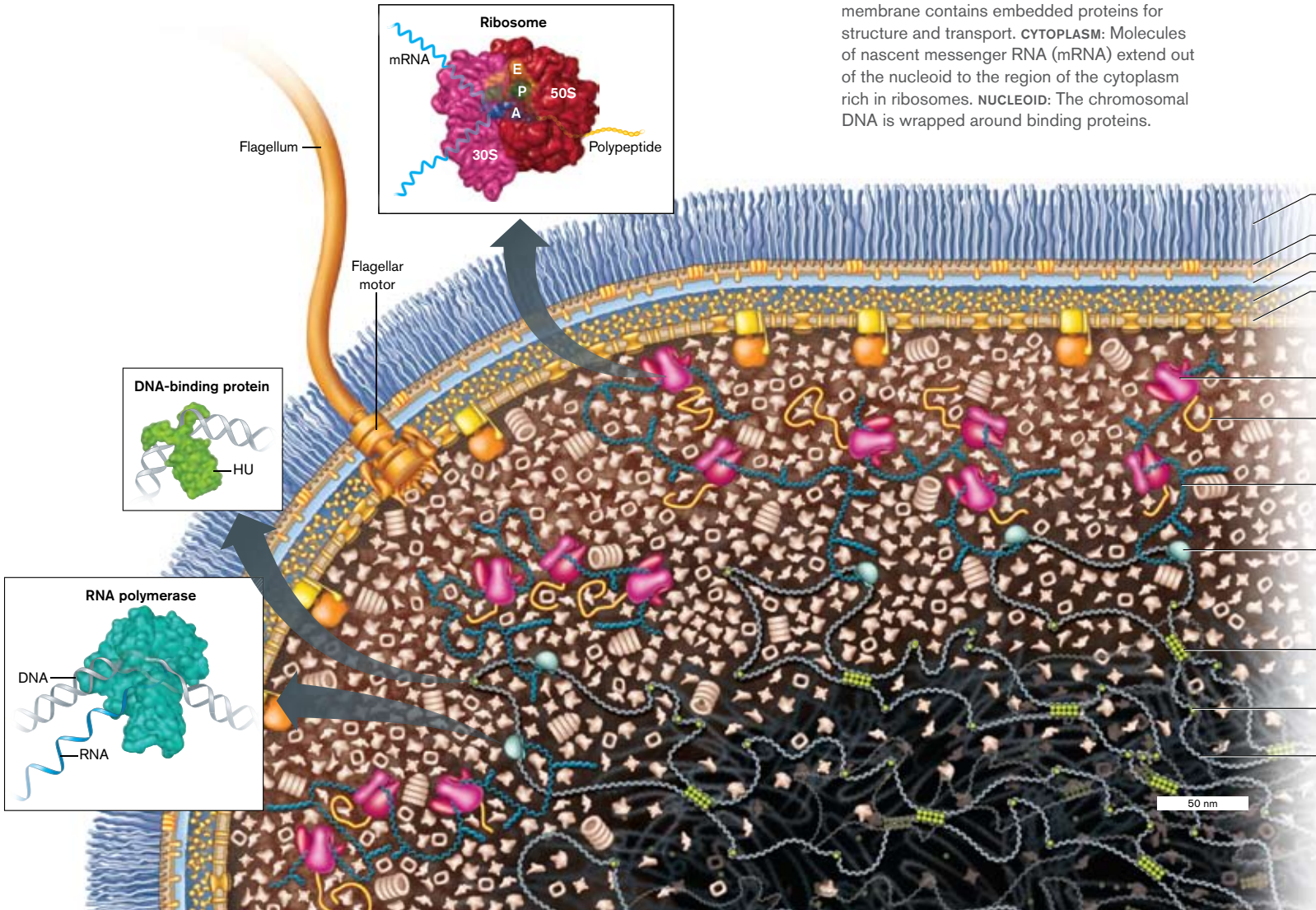
27 Antimicrobial Chemotherapy

28 Clinical Microbiology and Epidemiology

Appendices

A1 Biological Molecules

A2 Introductory Cell Biology



MODEL OF A BACTERIAL CELL. ENVELOPE: The cell membrane contains embedded proteins for structure and transport. **CYTOPLASM:** Molecules of nascent messenger RNA (mRNA) extend out of the nucleoid to the region of the cytoplasm rich in ribosomes. **NUCLEOID:** The chromosomal DNA is wrapped around binding proteins.

Extended Contents

Part I: The Microbial Cell

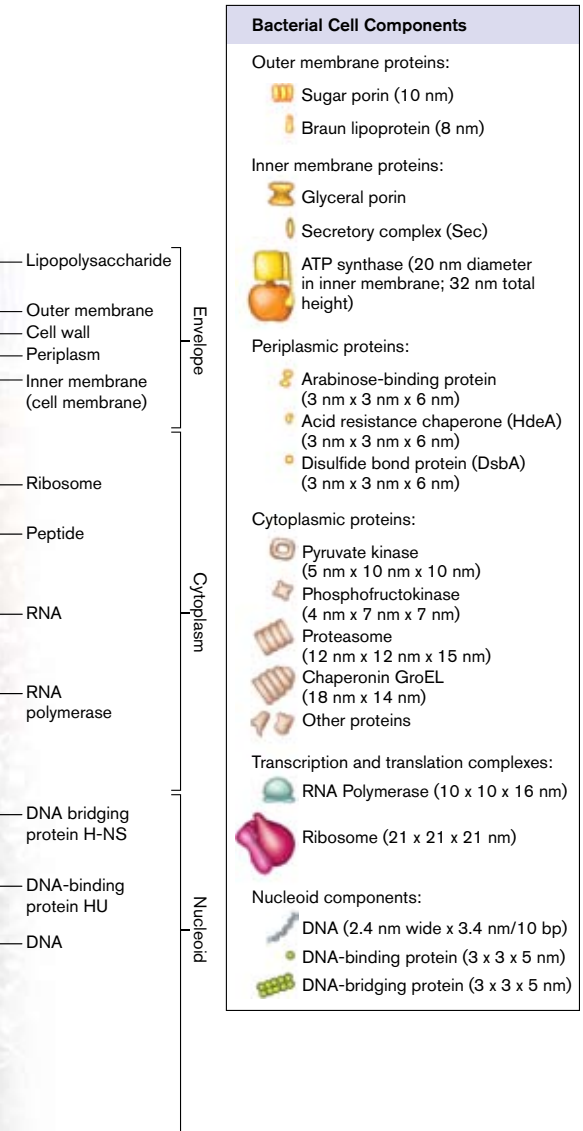
1 Microbial Life: Origin and Discovery presents the history of microbial discovery from ancient times up to the present day, including twentieth-century discoverers of gene cloning, the archaeal domain, and the ubiquity of horizontal gene transfer.

2 Observing the Microbial Cell presents microscopy as the key tool of microbial discovery, from an in-depth treatment of light microscopy and electron microscopy to examples of confocal fluorescence and scanning probe microscopy. In-depth coverage of microscopy helps the student evaluate models of the cell presented in Part II, Genes and Genomes, and Part III, Metabolism and Biochemistry.

3 Cell Structure and Function emphasizes the functional unity of the cell, from envelope to nucleoid. Coverage includes envelope diversity (Gram positive, Gram negative, mycobacteria, and archaea), up-to-date models of the prokaryotic cytoskeleton, and nucleoid organization. The organization of DNA and RNA synthesis points to detailed exploration in Part II.

4 Bacterial Culture, Growth, and Development introduces the fundamental classes of metabolism, to be developed further in Part III. Developmental diversity includes biofilm formation, sporulation, and "multicellular" fruiting body cycles.

5 Environmental Influence and Control of Microbial Growth presents "extreme" environments and microbial adaptations, as well as practical applications for control. Environmental topics are further explored in Part IV, Microbial Diversity and Ecology, while pathogens and their control are pursued in Part V, Medicine and Immunology.

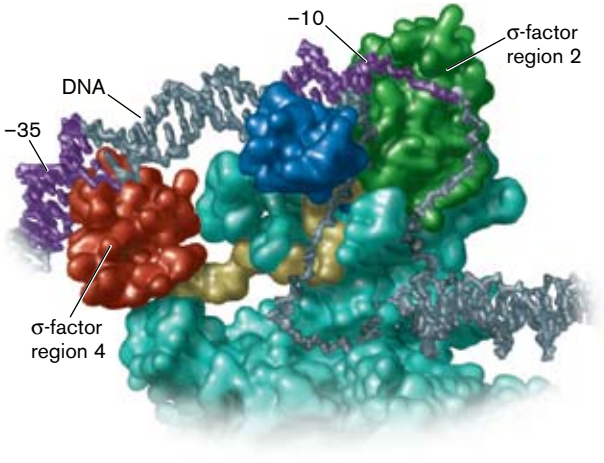


6 Virus Structure and Function includes up-to-date visualization methods such as cryo-EM as well as fluorescent-focus assays. Viral genetics is introduced in preparation for the key roles viruses play in microbial genetics, which is covered in Part II.

Part II: Genes and Genomes

7 Genomes and Chromosomes presents the structure and function of microbial DNA, emphasizing unity of mechanism as well as diversity of genome structure, such as the existence of multiple linear and circular chromosomes within some bacteria.

8 Transcription, Translation, and Bioinformatics presents gene expression, from transcription and translation through chaperone-assisted folding and transmembrane secretion. It also describes how knowledge of genes and proteins led to the science of bioinformatics.



E. COLI SIGMA FACTOR binds to two sequences in a DNA promoter. Colors on sigma show various domains. Green is region 2, which binds to the −10 region of promoters. Dark red represents region 4 of sigma that binds to the −35 promoter region. Blue and yellow mark regions 1 and 3, respectively, that have other functions. Gray is part of core RNA-P. Purple on DNA are the −10 and −35 promoter regions.

9 Gene Transfer, Mutations, and Genome Evolution emphasizes the multiple means of prokaryotic gene transfer, including its relevance to the evolution of pathogens and hosts. Intriguing variations include the role of the transformation apparatus in enabling bacteria to consume DNA for energy.

10 Molecular Regulation presents current models of molecular regulation, with relevance to survival in natural ecosystems and in host organisms.

11 Viral Molecular Biology treats examples of viruses in depth, emphasizing diversity of molecular mechanisms, such as primers consisting of host-derived proteins or transfer RNA.

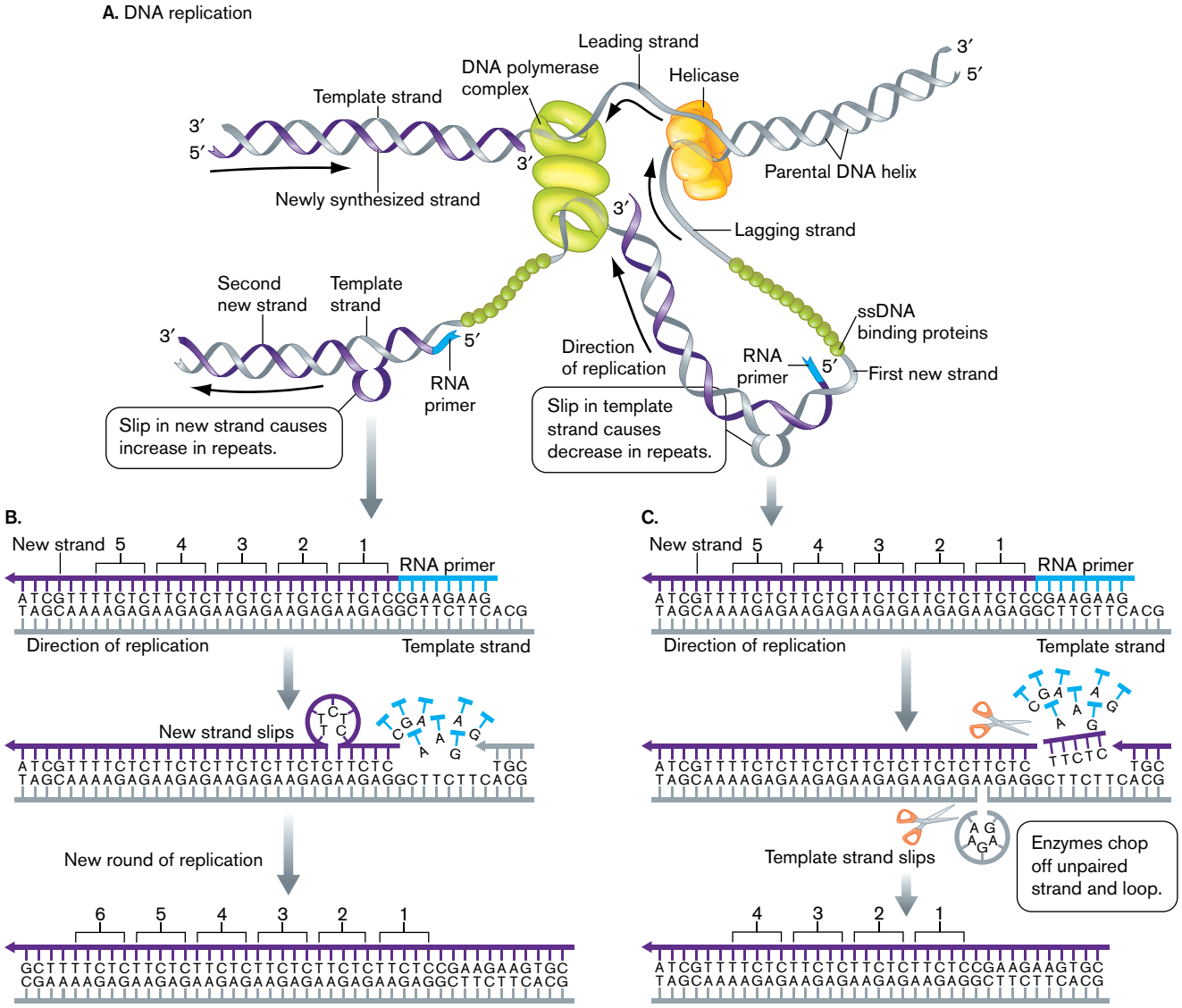
12 Molecular Techniques and Biotechnology presents research approaches and practical examples of applying molecular genetics to microbial discovery.

KARL STETTER COLLECTS THERMOPHILIC MICROBES from volcanic hot springs in Siberia. *Courtesy Karl Stetter.*

Part III: Metabolism and Biochemistry

13 Energetics and Catabolism presents the thermodynamic basis of microbial energetics, including emerging catabolic pathways with very small free-energy changes. We present experimental tools used to reveal previously unknown pathways.

14 Respiration, Lithotrophy, and Photolysis explores electron transport as a unifying principle of respiration, lithotrophy, and photosynthesis. Electrochemical potential is introduced with key supporting experiments. Lithotrophy is explored, including intriguing examples such as gold-reducing bacteria as well as emerging topics of anaerobic methane and ammonia oxidation.


A. DNA replication
Leading strand
DNA polymerase complex
Helicase
Template strand
3′
5′
3′
5′
3′
5′
Newly synthesized strand
Parental DNA helix
3′
Lagging strand
Second new strand
Template strand
3′
5′
RNA primer
ssDNA binding proteins
Direction of replication
RNA primer
5′
First new strand
Slip in new strand causes increase in repeats.
Slip in template strand causes decrease in repeats.
B.
New strand 5 4 3 2 1
RNA primer
ATCGTTTTCTCTTCTCTTCTCTTCTCTTCTCTTCTCCGAAGAAG
TAGCAAAAGAGAAGAGAAGAGAAGAGAAGAGAAGAGGCTTCTTCACG
Direction of replication
Template strand
New strand slips
TGC
New round of replication
6 5 4 3 2 1
GCTTTTCTCTTCTCTTCTCTTCTCTTCTCTTCTCCGAAGAAGTGC
CGAAAAGAGAAGAGAAGAGAAGAGAAGAGAAGAGGCTTCTTCACG
C.
New strand 5 4 3 2 1
RNA primer
ATCGTTTTCTCTTCTCTTCTCTTCTCTTCTCTTCTCCGAAGAAG
TAGCAAAAGAGAAGAGAAGAGAAGAGAAGAGAAGAGGCTTCTTCACG
Direction of replication
Template strand
TGC
Template strand slips
Enzymes chop off unpaired strand and loop.
4 3 2 1
ATCGTTTTCTCTTCTCTTCTCTTCTCTTCTCTTCTCCGAAGAAGTGC
TAGCAAAAGAGAAGAGAAGAGAAGAGAAGAGAAGAGGCTTCTTCACG

15 Biosynthesis presents key pathways of carbon and nitrogen fixation, as well as amino acid and fatty acid biosynthesis. Modular synthesis of polyketides and peptide antibiotics is presented.

16 Food and Industrial Microbiology shows how microbial metabolism contributes to food production, and how microbial pathways are applied in development of new industrial products ranging from drugs to clothing detergents.

Part IV: Microbial Diversity and Ecology

17 Origins and Evolution explores the evidence for origins of early life, including microfossils, chemical signatures, and molecular biology. Phylogeny and horizontal gene transfer are explored as the basis for microbial diversity.

18 Bacterial Diversity explores the diverse kinds of bacteria, organized in a framework that attracts student attention and aids memory. We include deep-branching thermophiles such as *Aquifex* and *Chloroflexus*, filamentous and colonial Cyanobacteria, spore-forming and non-spore-forming Firmicutes, Actinobacteria, the five classes of Proteobacteria, *Bacteroides* and related anaerobes, Spirochetes, and appendaged and cell wall-less bacteria. We discuss the challenges of defining new species and taxa. Chapters 18 through 20 are supplemented by the online student-authored Microbial Biorealm, which provides details on over 300 genera.

19 Archaeal Diversity explores the diversity of archaea. Originally thought to exist only in extreme environments, archaea are now found to be ubiquitous in soil and water, and even in the human digestive tract. We include the thermophilic Crenarchaeota, such as *Sulfolobus* and *Pyrodictium*, as well as mesophilic crenarchaeotes and even sponge endosymbionts. We cover the salt-loving Haloarchaea, the methanogens, and the elusive Nanoarchaea, whose tiny size pushes the limits of viability.

SLIPPED-STRAND MISPAIRING. **(A)** A DNA polymerase dimer moving along a replication fork. **(B)** The series of events that occur if the newly synthesized strand slips back relative to the template strand. **(C)** What happens if, prior to replication, the original template strand slips back relative to its complementary strand.

20 Eukaryotic Diversity presents major categories of eukaryotic organisms traditionally studied as microbes. Phylogeny is emphasized, including recent data revealing the unexpectedly close relatedness between fungi and metazoan animals. Key groups of algae and protists are presented, including lobed and shelled amebas, flagellates and ciliates, and colonial protists.

21 Microbial Ecology covers the role of microbes in soil, aquatic, and marine ecosystems, as well as animal- and plant-associated communities. In marine ecology we emphasize our growing awareness of the roles of previously unknown microbial phototrophs, archaea, and viruses.

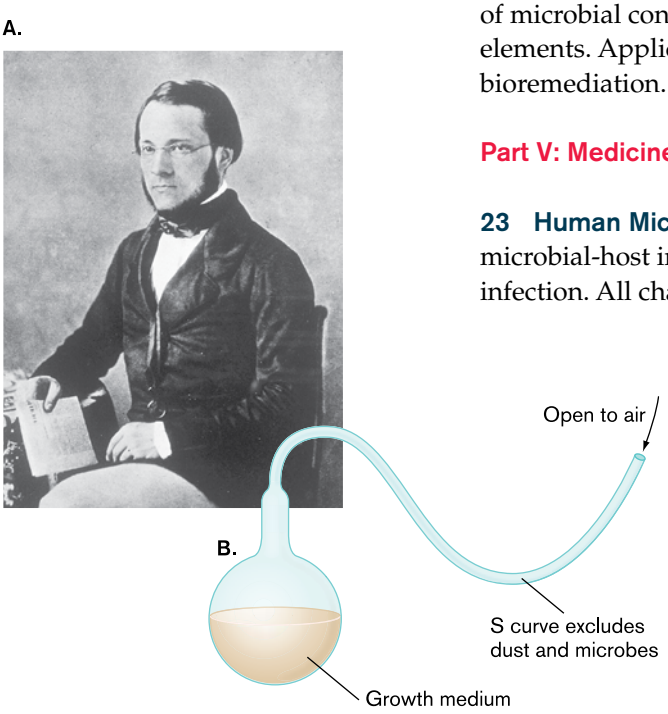
22 Microbes and the Global Environment presents a global picture of microbial contributions to cycling of carbon, nitrogen, and other elements. Applications are presented for environmental management and bioremediation.

Part V: Medicine and Immunology

23 Human Microflora and Nonspecific Host Defenses summarizes microbial-host interactions and describes the body's innate defenses against infection. All chapters of Part V present an integrated view of microbial disease in terms of identification, diagnosis, treatment and tracking through case histories, and descriptions of the thought processes and research practices that medical professionals and microbiologists use to understand host/microbe interactions.

24 The Adaptive Immune Response outlines the basics of the immune system from antibody synthesis to allergic reactions and illustrates how the many parts of the system collaborate to fight disease from without (microbial infections) and from within (cancer).

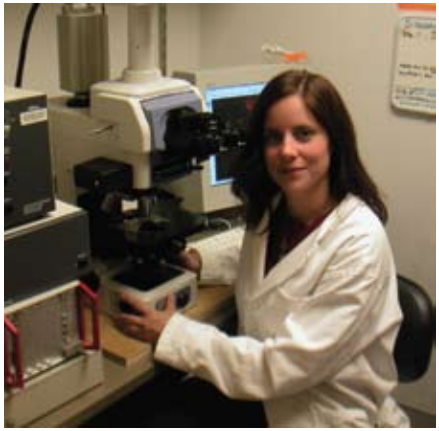
LOUIS PASTEUR, founder of medical microbiology and immunology. **(A)** Pasteur's contributions to the science of microbiology and immunology earned him lasting fame. **(B)** Swan-necked flask. Pasteur showed that in such a flask, the contents remain free of microbial growth, despite access to air. *Photo courtesy Institut Pasteur.*



25 Microbial Pathogenesis presents the different pathogenic mechanisms employed by various organisms to cause disease, such as the modes of action of various toxins and the mechanisms bacteria and viruses use to hijack host cell metabolism.

26 Microbial Diseases selects patient case histories to illustrate key concepts of microbial diseases while showing students the clues used to rule out or rule in different possible causes. Case histories draw the students into the material, and help them to more easily remember and integrate the concepts. An organ systems approach is taken to reflect how clinicians begin the process of diagnosing disease.

THE REPLISOME AND THE DNA ORIGIN. Melanie Berkmen, working in the laboratory of Alan Grossman, obtains the fluorescence micrographs shown. *Courtesy Melanie Berkmen.*



27 Antimicrobial Chemotherapy continues the case study approach to explore how antibiotics work, and how microbes continually evolve clever ways to circumvent or destroy antimicrobials, and reveals how diagnostic laboratories test microbes for antibiotic susceptibility.

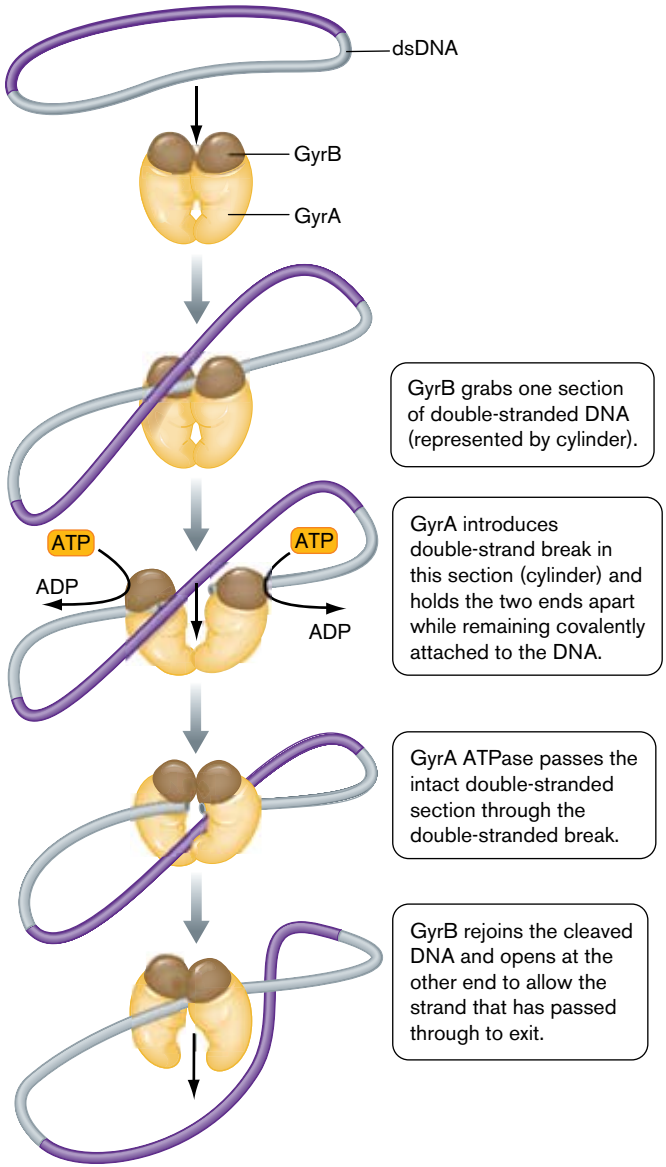
28 Clinical Microbiology and Epidemiology explains how clinical microbiology laboratories identify the agents of infectious disease and discusses the detective work used by local, national, and international agencies to study the epidemiology of known and newly emerging infectious diseases.

Appendices

1 Biological Molecules reviews the structures of fundamental molecules such as nucleotides, amino acids, and phospholipids.

2 Introductory Cell Biology reviews the structure of cells, including components such as membranes and organelles.

MECHANISM OF ACTION FOR TYPE II TOPOISOMERASES (DNA gyrase of E. coli). The gyrase enzyme grabs DNA and, in an ATP-dependent process, introduces a double-strand break, passes another part of the double helix through the break, and then reseals the break. The result is the introduction of a negative supercoil.



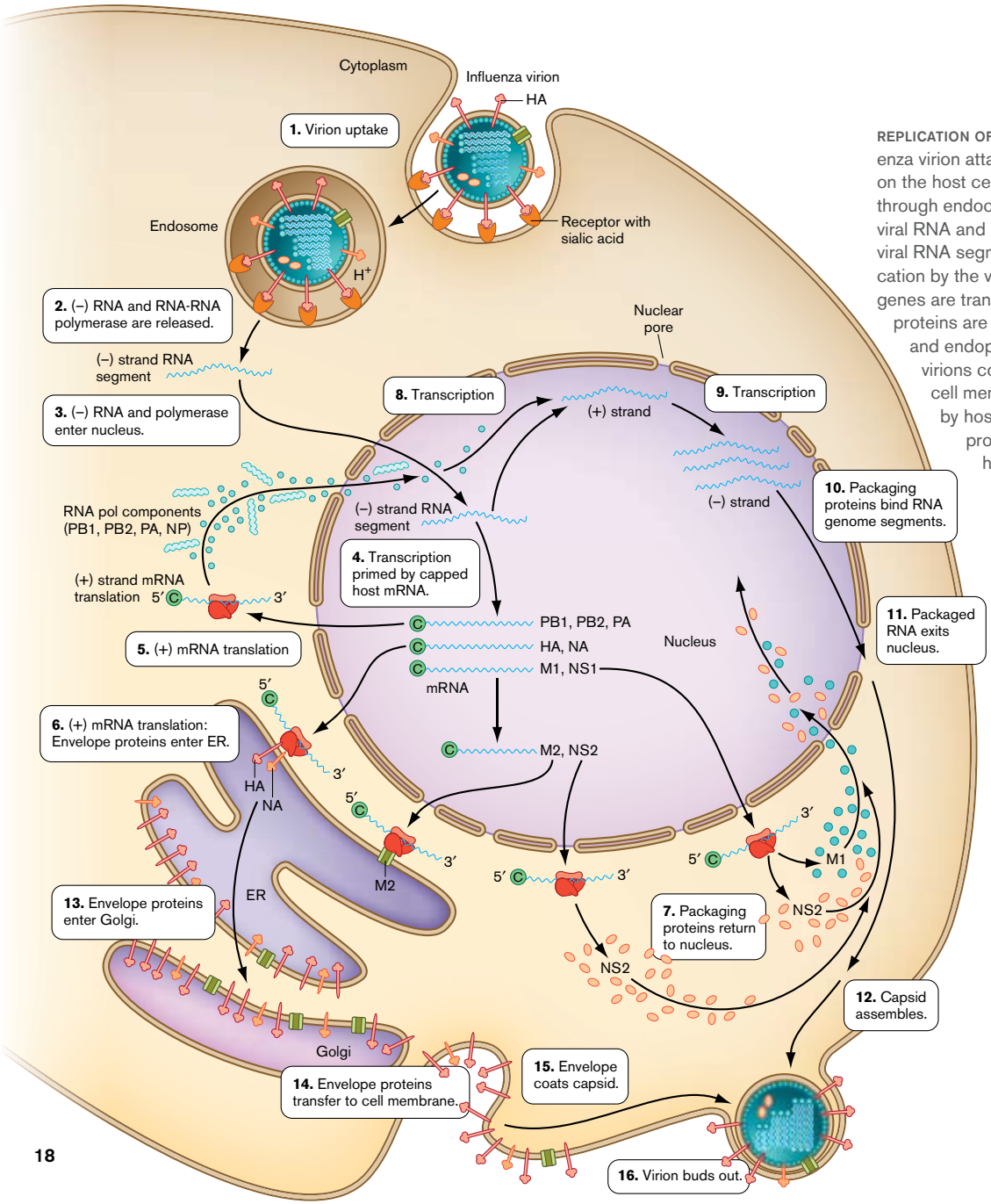
A complete, easy-to-use Media Package expands coverage of interesting topics and aids understanding of complex processes.

Process Animations Developed specifically for *Microbiology: An Evolving Science,* these animations bring key figures from the text to life, presenting central microbial processes in a dynamic format. The animations can be enlarged to full-screen view, and include VCR-like controls that make it easy for instructors to control the pace of the animation during lecture.

Weblink Icons throughout the text point students to the student website, which serves as a portal to websites where they can research a host of topics. Each link was reviewed and approved by the authors to ensure that only high-interest, high-quality sites were selected.

MicrobeWiki Joan Slonczewski hosts a free wiki—an online forum that allows users to add and edit content on microbes and microbiology. The site is refereed for accuracy and quality by Joan Slonczewski and includes several sub-areas:

- Microbial Biorealm: encylopedia of bacteria, archaea, and eukaryotic microbes.
- Viral Biorealm: encyclopedia of viruses of animals and plants and bacteriophages.
- Microbial World News: highlights of microbiology in the news.
- Microbial Mythology: common errors and controversies in microbiology.



REPLICATION OF THE INFLUENZA VIRUS The influenza virion attaches to glycoprotein receptors on the host cell membrane and is taken up through endocytosis. Acid triggers release of viral RNA and proteins into the cytoplasm. The viral RNA segments enter the nucleus for replication by the viral RNA-RNA polymerase. Viral genes are transcribed in the nucleus, and viral proteins are synthesized in the cytoplasm and endoplasmic reticulum (ER). Progeny virions complete their assembly at the cell membrane where they are coated by host membrane and viral envelope proteins, and are released from the host cell.

StudySpace This student website includes multiple-choice quizzes, process animations, vocabulary flashcards, indices of the Weblink reference sites from the text, and prominent links to Joan Slonczewski's MicrobeWiki.

Ebook Same great book at half the price. *Microbiology: An Evolving Science* is also available as an ebook from NORTONEBOOKS.COM. With a Norton ebook, you can electronically highlight text, use sticky notes, and work with fully zoomable images from the book.

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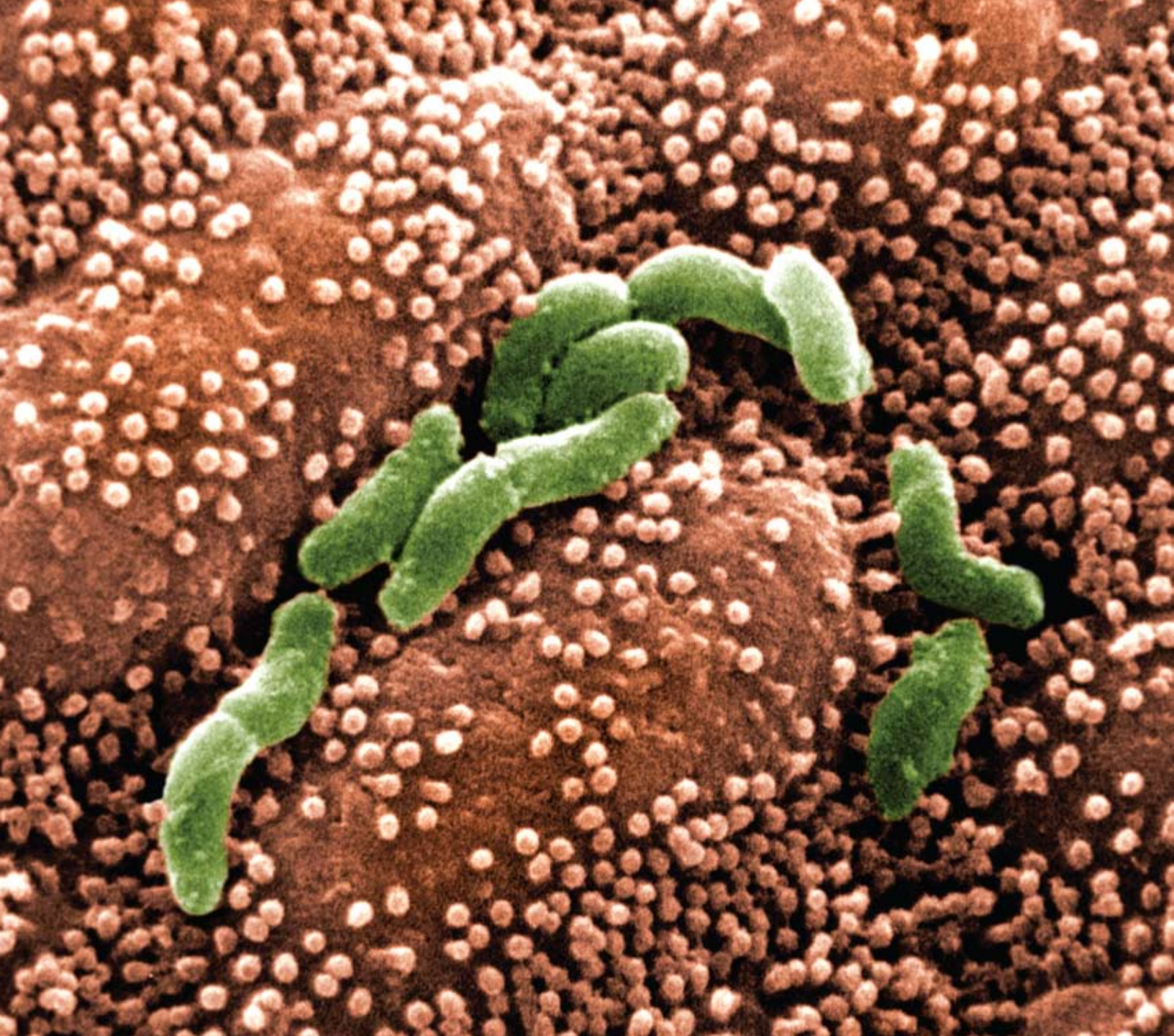

About the Authors

John W. Foster received his B.S. from the Philadelphia College of Pharmacy and Science (now the University of the Sciences in Philadelphia), and his Ph. D. from Hahnemann University (now Drexel University School of Medicine) also in Philadelphia, where he worked with Albert G. Moat. After postdoctoral work at Georgetown University, he joined the Marshall University School of Medicine in West Virginia and is currently teaching at the University of South Alabama College of Medicine in Mobile, Alabama. Dr. Foster has coauthored three editions of the textbook *Microbial Physiology* and has published over 100 journal articles describing the physiology and genetics of microbial stress responses. He has served as Chair of the Microbial Physiology and Metabolism division of the American Society for Microbiology, and is a member of the editorial advisory board of the journal *Molecular Microbiology*.

Joan L. Slonczewski received her B.A. from Bryn Mawr College, and her Ph.D. in Molecular Biophysics and Biochemistry from Yale University, where she studied bacterial motility with Robert M. Macnab. After postdoctoral work at the University of Pennsylvania, she taught undergraduate microbiology at Kenyon College, where she earned a Silver Medal in the National Professor of the Year program from the Council for the Advancement and Support of Education. She has published numerous research articles with undergraduate coauthors on bacterial pH regulation, and has published five science fiction novels including *A Door into Ocean* which earned the John W. Campbell Memorial Award. She serves as At-large Member representing Divisions on the Council Policy Committee of the American Society for Microbiology, and is a member of the Editorial Board of the journal *Applied and Environmental Microbiology.*

HELICOBACTER PYLORI WITHIN THE CRYPT CELLS OF THE STOMACH LINING. Microscopy demonstrated the presence of H. pylori, the causative agent of gastritis, growing on the lining of the human stomach, a location previously believed too acidic to permit microbial growth. *Mediscan/ Visuals Unlimited*

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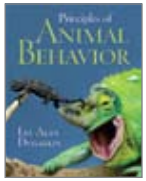

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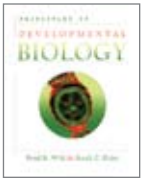

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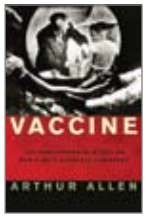

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You may also fill out and return the attached reply card. In order for us to consider your request, you must fill out the form completely. In the United States and Canada, mail your request to the address on the form; elsewhere, submit your request on college letterhead and mail it to the office that serves your area. Be sure to indicate the name and enrollment of your course, along with a phone number at which we might contact you for more information.

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