PREFACE

In the first two editions of *Microbiology: An Evolving Science*, we worked to write the defining core text of our generation—the book that would inspire undergraduate science majors to embrace the microbial world. Our emphasis on genetics and ecology, the use of case histories in the medical section, and the balanced depiction of women and minority scientists, including young researchers, drew—and continues to draw—enthusiastic responses from our more than one hundred adopters. Our focus on evolution, and our modern organization reflecting changes in the field, proved so successful that other textbooks have adjusted their chapter sequence to parallel *An Evolving Science*. In the Third Edition, we maintain this chapter organization to facilitate year-to-year course transitions for instructors. In addition, we incorporate exciting new research advances to ensure that *An Evolving Science* is the most current and engaging microbiology textbook available.

Also in this Third Edition, we maintain our signature balance between cutting-edge ecology and medicine, while adding new research topics and emerging microbial-human partnerships. The book opens with a new Part 1 Interview with Richard Lenski, in which he presents his personal perspective on the groundbreaking bacterial evolution experiment. Experimental evolution now fills a new section in Chapter 17, Origins and Evolution. Other chapters that underwent major revision include Chapter 3, Cell Structure and Function, with a tightened opener and a new section on cell aging; and Chapter 21, Microbial Ecology, which opens with a new section on metagenomics and the culturing of "unculturables."

In many chapters, we relate topics to current events, to keep students interested in and informed on the role of microbiology in the world today. One example is synthetic biology, the construction of microbes with genetic circuits engineered for commercial use (Chapter 12, Biotechnology and Synthetic Biology). Another example is the use of of viral replication cycles to develop lentiviral treatments for cancer and inherited disorders, including the first possible "cure" for pediatric leukemia (presented in Chapter 11, Viral Molecular Biology).

Our Third Edition continues as a community project, drawing on our experience as researchers and educators as well as the input of hundreds of colleagues to create a microbiology text for the twenty-first century. We present the story of molecular microbiology and microbial ecology from its classical history of Koch, Pasteur, and Winogradsky, to twenty-first-century researchers Rita Colwell and Bonnie Bassler. The Third Edition includes many contributions recommended by colleagues from around the world, at institutions such as Washington University, University of California–Davis, University of Wisconsin–Madison, Cornell University, Florida State University, University of Toronto, University of Edinburgh, University of Antwerp, Seoul National University, Chinese University of Hong Kong, and many more. We are grateful to you all.

While we have expanded and developed new topics, we also recognized the need to keep the length and "core" of the book to a size reasonable enough for the undergraduate student. In order to contain length while adding new material, we continue transferring certain topics online as "eTopics." The eTopics are called out in the text, hyperlinked to the ebook, and their key terms are fully indexed in the printed book. Therefore, returning adopters can be confident of keeping access to all of the material they taught from the Second Edition, but now they also have new topics on *Mycobacterium tuberculosis* cell aging and drug resistance (Chapter 3) and on bacteria that convert phage genes into toxin secretion systems (Chapter 25), and many more.

Major Features

Our book targets the science major in biology, microbiology, or biochemistry. Several important features make our book the best text available for undergraduates today:

- **New research on contemporary themes** such as evolution, genomics, metagenomics, molecular genetics, and biotechnology enrich students' understanding of foundational topics and highlight the current state of the field. Every chapter presents numerous current research examples within the up-to-date framework of molecular biology. Examples of current research include measuring the movement of a single translating ribosome; transplanting a whole genome; determining the "pangenome," the overall set of genes available to a species; and the spectroscopic measurement of carbon flux from microbial communities.
- **A comprehensively updated art program with engaging figures that are also dynamic learning tools.** A fresh, contemporary new design and an updated art program presents content in an engaging, visually dynamic manner. New in-figure Thought Questions encourage students to interpret and analyze visuals of important concepts. Figures that pair with a process animation online include a QR code in the text that students can scan using their smartphones to immediately view online.
- **Core concepts are presented in a student friendly way that motivates learning.** Ample Thought Questions throughout every chapter challenge students to think critically about core concepts, the way a scientist would. In addition, scientists pursuing research today are presented alongside the traditional icons. For example, Chapter 1 introduces historical figures such as Koch and Pasteur alongside genome sequencer Claire Fraser-Liggett and young microbial ecologist Kazem Kashefi growing a hyperthermophile in an autoclave, and undergraduate students conducting transcriptomics in *E. coli*. Medical microbiology is presented using the physician-scientist's approach to microbial diseases. Case histories present how a physician-scientist approaches the interplay between the human immune response and microbial diseases.
- **An innovative media package provides powerful tools for instructors and students.** A new Micrograph Database for instructors includes hundreds of micrographs from the book and beyond tagged by easy-to-browse categories as well as by chapter. For students, a new ebook integrates powerful new self-study questions, process animations, quiz questions, weblinks, eTopics, and more to encourage the use of multimedia to enhance their learning of core concepts.

Additional features of the Third Edition include:

- **Genetics and genomics are presented as the foundation of microbiology.** Molecular genetics and genomics are thoroughly integrated with core topics throughout the book. This approach gives students an understanding of how genomes reveal potential metabolic pathways in diverse organisms, and how genomics and metagenomics reveal the character of microbial communities.
- **Microbial ecology and medical microbiology receive equal emphasis,** with particular attention paid to the merging of these fields. Throughout the book, phenomena are presented with examples from both ecology and medicine; for example, when discussing horizontal transfer of "genomic islands" we present symbiosis islands associated with nitrogen fixation, as well as pathogenicity islands associated with disease (Chapter 9).
- **Unlike most microbiology textbooks,** our text provides size scale information for nearly every micrograph.
- **Viruses are presented in molecular detail and in ecological perspective.** For example, in marine ecosystems, viruses play key roles in limiting algal populations while selecting for species diversity (Chapter 6). Similarly, a constellation of bacteriophages influences enteric flora.
- **Microbial diversity that students can grasp.** We present microbial diversity in a manageable framework that enables students to grasp the essentials of the most commonly presented taxa, the continual discovery of organisms ranging from anammox bacteria to emerging pathogenic *Escherichia* strains.
- **Appendices for review and further study.** Our book assumes a sophomore-level understanding of introductory biology and chemistry. For those in need of review, Appendices 1 and 2 summarize the fundamental structure and function of biological molecules and cells. A new Appendix 3 explains many commonly used molecular techniques used to probe microbes, such as fluorescence in situ hybridization (FISH). A new Appendix 4 compiles the taxonomy of commonly studied bacteria, archaea, microbial eukaryotes, and viruses.

Organization

The topics in this book are arranged so that students can progressively develop an understanding of microbiology from key concepts and research tools. The chapters of Part 1 present key foundational topics: history, visualization, the bacterial cell, microbial growth and control, and virology.

The six chapters in Part 1 present many topics that are then developed in further detail throughout Parts 2 through 5. Part 2 presents modern genetics and genomics. Part 3 presents cell metabolism and biochemistry, although the chapters in Part 2 are written in such a way that they can be presented before the genetics material if so desired. Part 4 explores microbial ecology and diversity and discusses the roles of microbial communities in local ecosystems and global cycling. And the chapters of Part 5 (Chapters 23–28) present medical and disease microbiology from an investigative perspective, founded on the principles of genetics, metabolism, and microbial ecology.

What's New in the Third Edition?

The Third Edition of *Microbiology: An Evolving Science* has been thoroughly revised and updated. We have added more up-to-the-minute research and current events as well as incorporating much of the generous feedback that we have received from our many reviewers and adopters. The following list highlights some of the more important content changes for the Third Edition.

Two new part-opening interviews highlight contemporary scientists and their research.

PART 1: Richard Lenski, Professor at Michigan State University, conducts a decades-long evolution experiment in which *Escherichia coli* evolves a new trait of citrate metabolism.

PART 3: Nicole Dubilier, Symbiosis Group Leader at the Max Planck Institute for Marine Microbiology, discovers extraordinary mutualisms between lithotrophic bacteria and deep-ocean invertebrates such as conches and tube worms.

Content changes throughout the text include:

CHAPTER 1: Microbial Life: Origin and Discovery. The chapter opener features biofilm growth of *Vibrio cholerae*, and the Mars landing of Curiosity rover to seek evidence for life.

CHAPTER 2: Observing the Microbial Cell. A new topic presents chemical imaging microscopy—a tool to reveal chemical distributions within a cell, addressing questions about nitrogen fixation.

CHAPTER 3: Cell Structure and Function. A new section presents bacterial cell polarity and aging, contrasting the different models of *Caulobacter crescentis*, *E. coli*, and *Mycobacterium tuberculosis.*

CHAPTER 4: Bacterial Culture, Growth, and Development. The chapter opener highlights an example of bacterial cannibalism in biofilms and a new special topic describes how the unique pattern of shark skin can retard microbial biofilm formation.

CHAPTER 5: Environmental Influences and Control of Microbial Growth. The chapter opener highlights a form of sibling rivalry practiced by *Paenibacillus* in which bacterial colonies spreading toward each other secrete chemical signl molecules that convert the motile rival cells into sessile forms. In addition, new information is included about disinfectants and the growing business of antimicrobial touch surfaces.

CHAPTER 6: Viruses. A new topic explores symbiotic viruses that contribute positive benefits to their hosts, such as the fungal virus that contributes thermal resistance to the host fungus—and to a fungus-associated plant. An expanded section presents CRISPR, a bacterial molecular defense against bacteriophages, with relevance for human gene therapy.

CHAPTER 7: Genomes and Chromosomes. The chapter opener describes the choreography of nucleoid movement during replication. New details about DNA replication have been added, and there is an expanded discussion of deep sequencing technologies and their use in revealing secrets of the many environmental and human microbiomes that exist.

CHAPTER 8: Transcription, Translation, and Bioinformatics. The molecular movements of chaperones as they prepare to refold unfolded proteins are explored in the chapter opener. In addition, the revised chapter includes new details about protein synthesis and the science of bioinformatics, such as how bioinformatic strategies re-

vealed that a eukaryotic pathogen *Trypanosoma brucei* (the cause of African sleeping sickness) employs a bacterial-like enzyme to synthesize a critical membrane lipid.

CHAPTER 9: Gene Transfer, Mutations, and Genome Evolution. This chapter describes the recent discovery of human DNA sequences within the genome of *Neisseria gonorrhoeae* and new topics such as the RNA-based CRISPR defense against phage and its role in preserving biofilms, and the DNA repair mechanism called non-homologous end joining that can fix otherwise catastrophic DNA damage.

CHAPTER 10: Molecular Regulation. The opening research highlight describes a bacterial "lobster trap" engineered to explore quorum sensing parameters of bacterial cell-cell communication. There is also expanded coverage of transcriptomics, proteomics; regulatory RNAs (including cis-antisense RNAs), and of signal molecules such as cyclic di GMP that govern biofilm development. A new special topic describes how cell-to-cell bridge structures called nanotubes allow bacteria to communicate one-on-one.

CHAPTER 11: Viral Molecular Biology. A new section on hepatitis C presents the molecular biology of this emerging virus, and the new CDC recommendations for widespread testing. An expanded section on viral gene therapy presents the growing therapeutic use of lentiviral vectors.

CHAPTER 12: Biotechniques and Synthetic Biology. A new section on synthetic biology presents how bacterial gene circuits are mixed and reassembled like electronic circuits. Next generation synthetic biologists are now building bacterial computer switches that can produce a living computer, and biosensor organisms that "flash" a warning light when toxic materials approach.

CHAPTER 13: Energetics and Catabolism. A new topic on syntrophy explains how pairs of microbial species cooperate to catabolize organic substrates such as sewage and petroleum contaminants.

CHAPTER 14: Electron Flow in Organotrophy, Lithotrophy, and Phototrophy. A new chapter opener highlights nanowires conducting electric current between bacteria of a fuel cell. Electron transport systems are presented for anaerobic ammonia oxidation (anammox) and for iron-oxidizing acidophiles. Coverage of phototrophs is updated.

CHAPTER 15: Biosynthesis. A new topic describes mining a bacterial genome for modules encoding biosynthesis of peptide antibiotics.

CHAPTER 16: Food and Industrial Microbiology. New topics show how bacterial alginate is used to make medical sutures, and how an industrial enzyme company designs a microbial enzyme to brighten laundry.

CHAPTER 17: Origins and Evolution. A new section on experimental evolution shows how evolution in the laboratory reveals bacteria in the act of evolving new traits under natural selection. A new special topic shows how industry applies laboratory evolution to develop a thermophilic enzyme for paper production.

CHAPTER 18: Bacterial Diversity. Additional diverse bacterial species are introduced, such as *Lyngbya*, the giant filamentous cyanobacteria; the biomat-forming sulfur oxidizer *Thioploca*; and the emerging pathogenic mycoplasma *Ureaplasma urealyticum*.

CHAPTER 19: Archaeal Diversity. A new section features the ammonia-oxidizing Thaumarchaeota, including the ecological role of thaumarchaeotes in tidal pools. Coverage of methanogens is updated.

CHAPTER 20: Eukaryotic Diversity. A new topic presents the use of eukaryotic microbes such as yeast to model human biology. The phylogeny of eukaryotic microbes is updated.

CHAPTER 21: Microbial Ecology. A new opening section, "Metagenomics—And Beyond" explains the step by step process of analyzing a metagenome: sampling the target community, high-throughput DNA extraction and sequencing, genome scaffold assembly, and bioinformatic analysis. Featured examples include marine metagenomes, the rumen microbiome, and urban air metagenomes. A new topic presents oil-metabolizing bacteria from habitats contaminated by the Deepwater Horizon oil rig collapse.

CHAPTER 22: Microbes in Global Elemental Cycles. Exanded coverage of bioremediation includes the dechlorination of weapons materials in soil by a bacterial consortium, and the removal of arsenic from groundwater by a bioreactor. Coverage of the nitrogen cycle is updated.

CHAPTER 23: Human Microbiota and Innate Immunity. Expanded coverage of microbiomes includes a description of gut bacteria that are important for immune system development and the role of "fecal transplants" in curing previously untreatable gastrointestinal diseases such as irritable bowel disease. New aspects of innate immunity are discussed such as neutrophil extracellular traps (NETs) "thrown" by neutrophils around nearby pathogens.

CHAPTER 24: The Adaptive Immune Response. The chapter opener describes the finger-like membrane protrusions on immune T cell lymphocytes that probe antigen-presenting cell surfaces for antigens, an early step in the immune response. A new section expands on the relationship between vaccines and different immune system compartments.

CHAPTER 25: Microbial Pathogenesis. This chapter describes how the pathogen *Salmonella enterica* converts a gastrointestinal epithelial cell into a "gateway" M cell that the organism uses to invade the intestine. A new special topic on Type VI secretion shows how Gram negative pathogens capture phage genes and convert them into protein secretion systems that "fire" toxic proteins into host cells. A new section on host mimicry shows how pathogens produce host enzyme mimics that misdirect the host's response to infection, essentially making the pathogen nearly invisible to the immune system.

CHAPTER 26: Microbial Diseases. This chapter highlights recent outbreaks of fungal meningitis in the United States caused by contaminated, injectable steroid solutions, and the spate of hemolytic uremic syndrome cases in Europe caused by the newly emerged *E. coli* O104:H4. Updated sections include those on tuberculosis, *Clostridium difficile*, HIV, and the role of the appendix in reseeding the intestine.

CHAPTER 27: Antimicrobial Therapy. The exciting discovery of a new antibiotic, bedaquiline, is discussed in the opening research highlight, and an expanded section has been added about the success of HIV antiviral therapies. The chapter also describes the emergence of a novel antibiotic resistance enzyme, the New Delhi metallo-beta-lactamase, and the nearly indestructible pathogenic strains of *Klebsiella pneumoniae* that carry it. New information is also presented about the real reason certain classes of antibiotics kill while others only stop growth.

CHAPTER 28: Clinical Microbiology and Epidemiology. The chapter opening highlights heroic efforts of modern day microbe hunters at the CDC to track monkeypox in South America. Revisions reflect how today's diagnostic laboratories use rapid molecular-based technologies, such as PCR, immunochromatography, and even deep sequencing strategies to identify pathogens. A new section describes "point-of-care" diagnostic tests that can be performed not only in a hospital laboratory, but also in a doctor's office or, in some cases, by the patients themselves.

Resources

PRESENTATION TOOLS. Every figure and photograph in the textbook is available in JPEG and PowerPoint format for use in lecture. In order to provide stunning, high-quality visuals, every image has been hand-examined to make sure colors will not fade when projected and to optimize font size and composition for clear, legible viewing even in the back row. Labeled and unlabeled versions are available for download at wwnorton.com/instructors.

MICROGRAPH DATABASE. The NEW Micrograph Database includes searchable access to all of the micrographs in the textbook, tagged by characteristics such as taxonomy, shape, and habitat. The Micrograph Database can be accessed at wwnorton.com/instructors.

PROCESS ANIMATIONS. Sixty process animations depicting key processes of microbiology are offered in Flash, QT, and embedded in PowerPoint files. These animations are all based on the art found in the textbook and were developed under the careful supervision of the textbook authors. Student access to the animations is available in the ebook or via QR codes in the print book, which students can scan with their smartphones. Instructor access to the process animations is available at wwnorton.com/instructors.

Animation Topics Include:

Microscopy
Replisome Movement in a Dividing Cell
Chemotaxis
Phosphotransferase System (PTS) Transport
Dilution Streaking Technique
Biofilm Formation
Endospore Formation
Lysis and Lysogeny
Supercoiling and Topoisomerases
DNA Replication
Rolling Circle Mechanism of Plasmid Replication
PCR
Protein Synthesis
Protein Export
SecA-Dependent General Secretion Pathway
ABC Transporters
Bacterial Conjugation
Recombination
DNA Repair Mechanisms: Methyl Mismatch Repair
DNA Repair Mechanisms: Nucleotide Excision Repair
DNA Repair Mechanisms: Base Excision Repair
Transposition
The *lac* Operon
Transcriptional Attenuation
Chemotaxis: Molecular Events
Quorum Sensing
Influenza Virus Entry into a Cell
Influenza Virus Replication
HIV Replication
Herpes Virus Replication
Construction of a Gene Therapy Vector
Tagging Proteins for Easy Purification
Real-Time PCR
A Bacterial Electron Transport System
ATP Synthase Mechanism
Oxygenic Photosynthesis
Agrobacterium: A Plant Gene Transfer Vector
Phylogenetic Trees
DNA Shuffling
Listeria Infection
Light-Driven Pumps and Sensors
Malaria: A Cycle of Transmission between Mosquito and Human
The Basic Inflammatory Response
Phagocytosis
The Activation of the Humoral and Cell-Mediated Pathways
Cholera Toxin Mode of Action
Process of Type III Secretion
Retrograde Movement of Tetanus Toxin to an Inhibitory Neuron
DNA Sequencing

TEST BANK. Thoroughly revised for the Third Edition and using the Norton Assessment Guidelines, each chapter of the Test Bank consists of five question types classified according to the first five levels of Bloom's taxonomy of knowledge types: Remembering, Understanding, Applying, Analyzing, and Evaluating. Questions are further classified by section and difficulty, making it easy to construct tests and quizzes that are meaningful and diagnostic according to instructors' needs. Questions are multiple-choice and short-answer. The Test Bank is available in *ExamView Assessment Suite*, Word RTF, and PDF formats, downloadable from wwnorton.com/instructors. The Test Bank is also available on a disc. To receive a test bank disc, contact your Norton representative.

COURSEPACKS. At no cost to professors or students, Norton Coursepacks are available in a variety of formats, including all versions of Blackboard and WebCT. With just a simple download, an adopter can bring high-quality Norton digital media into a new or existing online course (no extra student passwords required), and it's theirs to keep forever. Content includes chapter-based assignments, quizzes, and interactive learning tools. Coursepacks can be downloaded at wwnorton.com/instructors.

ENHANCED EBOOK. An affordable and convenient alternative to the print book, Norton Ebooks retain the content and design of the print book and allow students to highlight and take notes, print chapters as needed, and search the text with ease. The enhanced ebook includes:

- **Process animations** based on the text art and developed under the watchful eyes of the textbook authors.
- **Self-study questions** with feedback designed to help students learn as they read. They are included in every section of every chapter as well as for the process animations.
- **Weblinks**, which send students to sites such as the CDC to learn more about concepts and examples discussed in the text.
- **Links to eTopics** written by Joan Slonczewski and John Foster, which supplement and enrich concepts covered in the text.
- **Flashcards** of all the key terms in the book and their definitions.

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To the Reader: Thanks!

We greatly appreciate your selection of this book as your introduction to the science of microbiology. As our textbook continues to evolve, it benefits greatly from the input of its many readers, students as well as professors. We truly welcome your comments, especially if you find text or figures that are in error or unclear. Feel free to contact us at the addresses listed below.

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