

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 concern 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 core topics are essential to microbiology and have been given more extensive treatment. The chapters that cover these topics (chapters 2–18 and 29–32) are somewhat longer than others and may be combined with a selection of noncore chapters to achieve the desired orientation, whether basic, applied, or medical. The first nine parts of the text also are available as two separate paperback volumes. Volume one covers the general aspects of microbiology (chapters 1–27); and volume two, immunology and medical microbiology (chapters 28–39). This allows use of separate volumes in courses with a specific focus.

The book is divided into 11 parts. The first 5 introduce the foundations of microbiology: the development of microbiology, the structure of microorganisms, microbial growth and its

control, metabolism, microbial genetics, and the nature of viruses. In this third edition the microbial genetics unit directly follows microbial growth and metabolism (Parts Two and Three) and discusses genetics before the introduction to viruses (Part Five). Part Six is a survey of the microbial world. The bacterial survey closely follows the organization of *Bergey's Manual of Systematic Bacteriology*. Because of the importance and uniqueness of archaeobacteria, the third edition contains a separate chapter on them. 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 Seven discusses symbiotic associations and parasitism in depth, providing a good foundation for the later survey of specific diseases. The chapters in Part Eight describe in detail all major aspects of the immune response. Part Nine begins with an introduction to antimicrobial chemotherapy, epidemiology, and clinical microbiology. This is followed by a survey of the major human microbial diseases. The disease survey is primarily organized taxonomically on the chapter level; within each chapter, diseases are covered according to mode of transmission. This approach provides flexibility and allows the student easy access to information about any disease of interest. The survey is not a simple cataloguing of diseases; diseases are included because of their medical importance and their ability to illuminate basic principles of disease and resistance. Part Ten focuses on the relationship of microorganisms to aquatic and terrestrial environments. Chapter 40 presents the general principles underlying microbial ecology and environmental microbiology, and the chapters on aquatic and terrestrial habitats can be used without excessive redundancy. Part Eleven concludes the text with an introduction to food and industrial microbiology. The 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.

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

1. The organization of the book has been modified slightly to make it more logical. The chapter on the control of microorganisms by physical and chemical agents has been moved to the section on growth and nutrition (Part Two). The antimicrobial therapy chapter now is in the section on microbial diseases (Part Nine). Parts Two and Nine have been renamed to reflect this change in organization.
2. Reference sections have been reorganized to group references under topical heads (these usually correspond to the major sections in each chapter). This arrangement provides ease of access for students interested in particular topics. New references have been added through the middle of 1995 and some older references deleted.
3. The appendices have been revised. A new appendix that visually compares the relative sizes of biomolecules, viruses, bacteria, and eucaryotic cells has been added.
4. Many new topics and sections have been added and others have been substantially revised. Some examples are the following:
 - a. Chapter 3—The molecular mechanism of chemotaxis is described, and molecular chaperones and heat-shock proteins are discussed. A box on *Epulopiscium fishelsoni* has been added.
 - b. Chapter 12—There is a new section on regulation by sigma factors and updated material on regulation of the bacterial cell cycle.
 - c. Chapter 19—The chapter on microbial taxonomy has been reorganized to make it more logical. Phylogenetic diagrams are updated. Six- and eight-kingdom systems are described.
 - d. Chapters 20–24—The taxonomy of bacteria has been updated to correspond more closely to that in the ninth edition of *Bergey's Manual of Determinative Bacteriology* and reflect recent developments in bacterial classification.
 - e. Chapter 26—There is new material on toxic algal blooms.
 - f. Chapter 28—A section covering the symbiosis between hydrothermal vent tube worms and bacteria has been added. There is a new box on probiotics for humans and animals.
 - g. Chapter 29—There is new material on the causes of inflammation.
 - h. Chapter 31—The section on cytokines has been expanded to incorporate recent research findings. There is new material on T cells and their activation. Sections on superantigens and cell-associated differentiation antigens have been added.
 - i. Chapter 35—The relationship between virulence and the mode of transmission is discussed.
 - j. Chapter 36—New material or substantial updates have been added for hantaviruses, AIDS, herpesvirus 6, parvovirus, rabies virus, and the hepatitis viruses.
 - k. Chapter 37—There is new or expanded coverage of invasive streptococci and necrotizing fasciitis, multi-drug-resistant tuberculosis, *Helicobacter pylori*, shigellosis, diarrheagenic *Escherichia coli* infections, septic shock, and the medical aspects of biofilms.
 - l. Chapter 38—A section on ehrlichiosis has been included.
 - m. Chapter 41—There is new material on biofilms in microbial ecology, confocal scanning microscopy, the sea as a source of biomedicines, and *Cryptosporidium* as a waterborne disease agent.
 - n. Chapter 42—The sections on the *Rhizobium* infection of legumes and microbial effects on atmospheric gases have been significantly updated.
 - o. Chapter 44—The material on bioremediation and the use of *Bacillus thuringiensis* as an insecticide has been revised and updated.

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 third 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) an 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 as many color photographs as possible 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. About a third of the art in this edition is either new or revised, and all line art has been produced under the direct supervision of 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 permeate 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 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 this affects society.

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. Each chapter contains the following:

1. **Opening quote(s):** These are designed to perk student interest and provide perspective on the chapter's contents.
2. **Chapter outline:** The chapter outline, with page numbers, includes all major headings in the chapter. This helps the reader locate particular topics of interest.
3. **Chapter concepts:** Several statements briefly summarize the most important concepts the student should master.
4. **Chapter preface:** One or two short paragraphs preview the chapter's contents and relate it to the rest of the text. The preface is not a summary but allows the student to put the chapter in perspective at the start.
5. **Boldfaced terms:** Important terms are emphasized and clearly defined when they are first used.
6. **Chapter summaries:** A series of brief, numbered statements is designed to serve more as a study guide than as a complete, detailed summary of the chapter.
7. **Key terms:** A list of all boldfaced terms 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.
8. **Review questions and activities:** Two kinds of review questions appear in each chapter. A small box with one to five brief review questions is located 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. An example of these in-chapter review questions from page 49 has been reproduced here.

1. Briefly describe the nature and function of the cytoplasmic matrix and the ribosome. What is a protoplast?
2. What kinds of inclusion bodies do procaryotes have? What are their functions?
3. What is a gas vacuole? Relate its structure to its function.
4. What are molecular chaperones and heat-shock proteins? Describe their functions.

The "Questions for Thought and Review" section at the end of the chapter contains factual questions and some synthetic questions to aid the student in reviewing, integrating, and applying the material in the chapter.

9. **Multimedia-supported illustrations:** Throughout the text the reader will find illustrations of microbiological concepts and processes that can be supplemented with full-color video, animations, or interactive screens from *Microbes in Motion* (0-697-24596-9), the interactive CD-ROM available from Wm. C. Brown Publishers. The reader will be able to easily recognize these figures, as the figure legends are preceded by a CD icon. Figure 3.37, page 62, is one example of such an illustration.

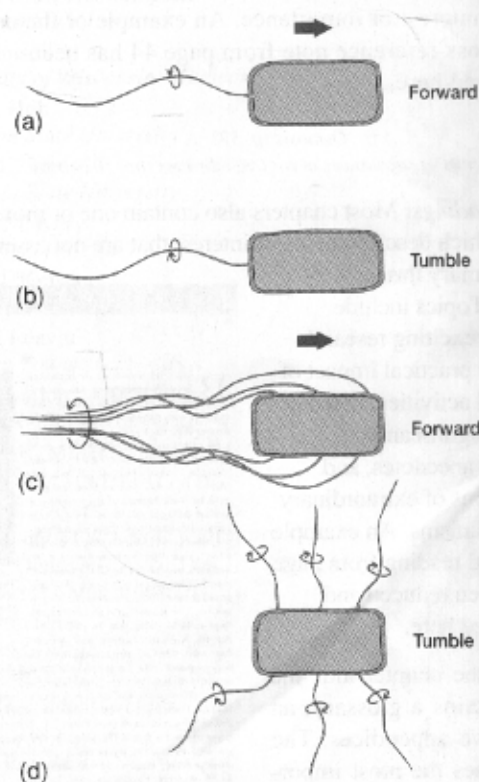


Figure 3.37 Flagellar Motility. The relationship of flagellar rotation to bacterial movement. Parts (a) and (b) describe the motion of monotrichous, polar bacteria. Parts (c) and (d) illustrate the movement of peritrichous organisms.

10. *Correlation guide to microbes in motion*: To facilitate finding the corresponding information on the *Microbes in Motion* CD-ROM for the multimedia-supported illustrations described above, a correlation guide is provided following the preface. The *Microbes in Motion* CD-ROM is organized into 15 topical "books," the books are divided up 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. The correlation guide entry is shown here for the multimedia-supported illustration referred to above.

Fig. 3.7 Bacterial Structure & Function Book
Cell Membrane Chapter
pp. 8 & 10 (animation)

11. *Additional readings*: References 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 the middle of 1995 have been included. The reference sections also 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.
12. *Cross-reference notes*: These 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. An example of the usage of the cross-reference note from page 44 has been reproduced here.

Osmosis (p. 57).

Transport of substances across membranes (pp. 102–106).

13. *Boxed readings*: Most chapters also contain one or more boxes, which 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 microorganisms. An example of a boxed reading from page 41 has been reduced and reproduced here.

Besides the chapter aids the text also contains a glossary, an index, and five appendices. The 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 third edition has an extensive, 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, provide further details about the taxonomy of bacteria and viruses, and compare the sizes of various molecules and cells.

Supplementary Materials

Many supplementary materials are available to help instructors with their presentations and general course management.

1. *An Instructor's Manual*, written by Ralph Rascati, Kennesaw College, includes a list of transparencies, a set of two slide sets, and a correlation guide that ties *Microbiology*, third edition, to the *Microbes in Motion* CD-ROM. In addition, the number of test questions has been increased to about 60 for each chapter. This extensive battery of more than 2,600 test items is a powerful instructional tool.
2. The *WCB Microtest* is a computerized testing and classroom management service that is offered free on request to adopters of this text. The service provides a database of objective questions for preparing exams and a grade-recording program. The software requires no programming experience and is available in DOS (3.5 disk only), WINDOWS, and MAC.
3. A set of 150 full-color acetate transparencies is available and may be used to supplement classroom lectures.
4. A *Student Study Art Notebook* is available as a free ancillary with all new textbook orders. The *Student Study Art Notebook* will come packaged with *Microbiology*, third edition by Prescott, Harley, and

Klein and contains the 150 illustrations found in the transparency set. With this notebook, students no longer have to worry about trying to sketch out the images that appear on the overhead projector while trying to take notes and listen to the professor's lecture. The art is reproduced in a hardcover notebook that the student can use to take notes on the figures.

5. The *WCB Electronic Image Bank* contains virtually all line art illustrations from *Microbiology*, third edition. The CD-ROM with easy to use presentation software. The

Box 3.1

A Monstrous Microbe

Bacteriologists often have distinguished between prokaryotes and eukaryotes based in part on cell size. Generally, prokaryotic cells are supposed to be smaller than eukaryotic cells. Prokaryotes grow extremely rapidly compared to most eukaryotes and lack the complex vascular transport systems of eukaryotic cells (see chapter 4). It has been assumed that they must be small because of the slowness of nutrient diffusion and the need for a large surface-to-volume ratio. Thus when Fialson, Montgomery, and Morley discovered a large, cup-shaped microorganism in the intestinal tract of the Red Sea brown sepioidfish, *Acetularia stegifera*, they suggested in their 1985 publication that it was a protist. The microorganism seemed too large to be anything else. In 1993 Esther Arger, Randall Clements, and Norman Pace used rRNA sequence comparisons (pp. 60–61) to identify the microorganism, now called *Epilophococcus fialsonii*, as a prokaryote related to the green-pigmented genus *Chlorobium*.

E. fialsonii (Latin, spade, a flat or trumpet, and prokion, field) can reach a size of 300 µm by 600 µm, and normally ranges from 200 to 500 µm in length (Box Figure 3.1). It is about a million times larger in volume than *Escherichia coli*. Despite its huge size the organism does have prokaryotic cell structure. It is motile and carries out about two body lengths a second (approximately 2.4 cm/min) using the bacterial-type flagella that cover its surface. The cytoplasm contains large nucleoids and many ribosomes, as would be required for such a large cell. *Epilophococcus* appears to overcome the size limits set by diffusion by having an outer layer consisting of a highly convoluted plasma membrane. This increases the cell's surface area and is able to resist osmotic pressure. The bacterium reproduces when bacteria



Box Figure 3.1 *Epilophococcus fialsonii*. This photograph, taken with phase-contrast light illumination, shows *E. fialsonii* at the tip of the figure devouring paramecia at the bottom (x250).

one and about seven daughter cells develop axonically within the parent and then escape through a centrally located slit in the parental cell envelope.

Epilophococcus also has been found in sepioids from the Great Barrier Reef in Australia. Presumably it is a symbiont of the sepioidfish, and its reproductive and behavior are closely correlated with its host's feeding habits. During the day when the sepioidfish feeds, the bacteria are in the middle intestine with the partially digested food and grow larger. At night when the fish is resting, the bacteria move to the back of the intestine where they reside in a belt of food and divide repeatedly. Because there is little growth between divisions, the bacteria become smaller. In the morning, *Epilophococcus* leaves the belt of food and moves forward again.

It appears that *Epilophococcus* is transmitted between hosts through fecal contamination of the fish's food. The bacterium can be eliminated by starving the sepioidfish for a few days. If juvenile fish that lack the bacterium are placed with infected hosts, they are colonized. Interestingly this does not work with unrelated adult sepioidfish.

The discovery of this prokaryote greatly weakens the distinction between prokaryotes and eukaryotes based on cell size. *Epilophococcus* is a completely larger than a typical eukaryotic cell. In addition, some eukaryotic cells have been discovered that are smaller than previously thought possible. The best example is *Nauplotherium antarcticum*. *Nauplotherium* is only about 1 to 2 µm in diameter, just as tiny as a prokaryotic cell and has a nucleus, a chloroplast, and a mitochondrion. Our understanding of the factors limiting prokaryotic cell size must be reevaluated. It is no longer safe to assume that large cells are eukaryotic and small cells are prokaryotic.

Interactive Slide Show program allows you to present the ready to play slide show offered on CD-ROM, and the *Slide Editor* program enables you to maneuver among the images to create your own multimedia presentation.

6. A set of *projection slides* provides clinical examples of diseases to supplement the illustrations in the text. A second set of *projection slides* provides examples of microbial specimens.
7. A *Student Study Guide* by Ralph Rascati contains chapter objectives, focus questions, mastery tests, and other activities to aid student comprehension.
8. *QuickStudy*, written by David Mardon of Eastern Kentucky University, is a computerized study guide available in IBM and Macintosh formats for student purchase. This program contains approximately 1,700 page-referenced questions that review the material covered in *Microbiology*. If incorrect answers are chosen, this study guide provides the student with a page-referenced study plan for further review. See page iv preceding the preface for further information about this study aid.
9. *Microbes in Motion* is an interactive CD-ROM for Windows that brings microbiology to life. This easy to use tutorial can go from the classroom to the resource center to your 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. See page iii preceding the preface for further information regarding this valuable study/teaching aid.
10. A third edition of the *laboratory manual*, *Laboratory Exercises in Microbiology* by John P. Harley and Lansing M. Prescott, has been prepared to accompany the text. This manual is directly correlated with the text and designed to be used with it (although it may be used easily with other microbiology textbooks). 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 third edition of the manual contains recipes for all reagents and media. Each exercise in this manual can also be customized by combining the exercises with one's own materials. The local Wm. C. Brown Publishers representative should be contacted for more details on this custom publishing service. A *lab resource guide* has been prepared by David Mardon of Eastern Kentucky University. It has complete answers to all laboratory report questions.
11. A set of 305, 3" × 5" *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.

Acknowledgments

The authors wish to thank the reviewers, who provided detailed criticism and analysis. Their suggestions greatly improved the final product.

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The publication of a textbook requires the effort of many people besides the authors. We would like to express special appreciation to the editorial and production staffs of Wm. C. Brown Publishers for their excellent work. In particular, we would like to thank our project editor, Elizabeth Sievers, for her guidance and support, and our production editor, Julie Wilde, for her effort and attention to detail. Our copy editor, Beatrice Sussman, contributed greatly to the third edition's clarity, consistency, and readability. We would like to offer our special thanks to Raymond B. Otero, Eastern Kentucky University, for the many excellent clinical photographs he contributed to this textbook.

Finally, but most important, we wish to extend appreciation to our families for their patience and encouragement, especially to our wives, Linda Prescott, Jane Harley, and Sandra Klein. To them, we dedicate this book.

Lansing M. Prescott

John P. Harley

Donald A. Klein

Correlation Guide for *Microbes in Motion to Microbiology*

This correlation guide was compiled in order to assist you in integrating the information from *Microbes in Motion*, the tutorial CD-ROM developed and published by Wm. C. Brown Publishers, into the textual material presented in this third edition of *Microbiology* by Prescott, Harley, and Klein.

Microbes in Motion is an interactive tutorial that can be used by professors and students alike. This highly visual tutorial brings the study of microbiology to life through use of animations, video, audio, music, interactive screens, and quizzes. Your understanding of microbiological concepts will be enhanced using this CD-ROM

tutorial. In some cases the discussion on *Microbes in Motion* will be different in level, emphasis, or presentation than those found in this textbook, but this can actually enhance understanding.

You will encounter a CD-ROM icon  in figure legends throughout the text. When you see a CD-ROM icon be sure to refer to this correlation guide for corresponding information on *Microbes in Motion*. In some cases, there will be a reference to supporting information on *Microbes in Motion* in this correlation guide but no icon in the text. This CD material usually contains supporting textual material in the third edition of *Microbiology*, and an icon could not be inserted into the text narrative. Be sure to check this correlation table prior to reading a chapter in case there is supporting information on *Microbes in Motion*.

Chapter 2

- Fig. 2.13 Bacterial Structure & Function Book
Bacteria Groups/Overview
- Fig. 2.14 Bacterial Structure & Function Book
Bacteria Groups/Categories and Classification

Chapter 3

- Fig. 3.5 Bacterial Structure & Function Book
Cell Membrane Chapter
pp. 5 & 6 (animation)
- Fig. 3.7 Bacterial Structure & Function Book
Cell Membrane Chapter
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- Fig. 3.18 Bacterial Structure & Function Book
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pp. 2 & 3
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p. 7 (Peptidoglycan Synthesis Animation)
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- Fig. 3.28 Antimicrobial Action Book
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- Fig. 3.29 Bacterial Structure & Function Book
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Tables 5.1 &
Table 5.2

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- Fig. 5.3 Bacterial Structure & Function Book
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Chapter 6

- Fig. 6.1 Microbial Growth & Metabolism Book
Microbial Growth Chapter/Growth Curves
pp. 26, 33, & 34 (animation)

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*Note—this animation is showing translation of viral RNA but it helps illustrate the general concept of protein synthesis.

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