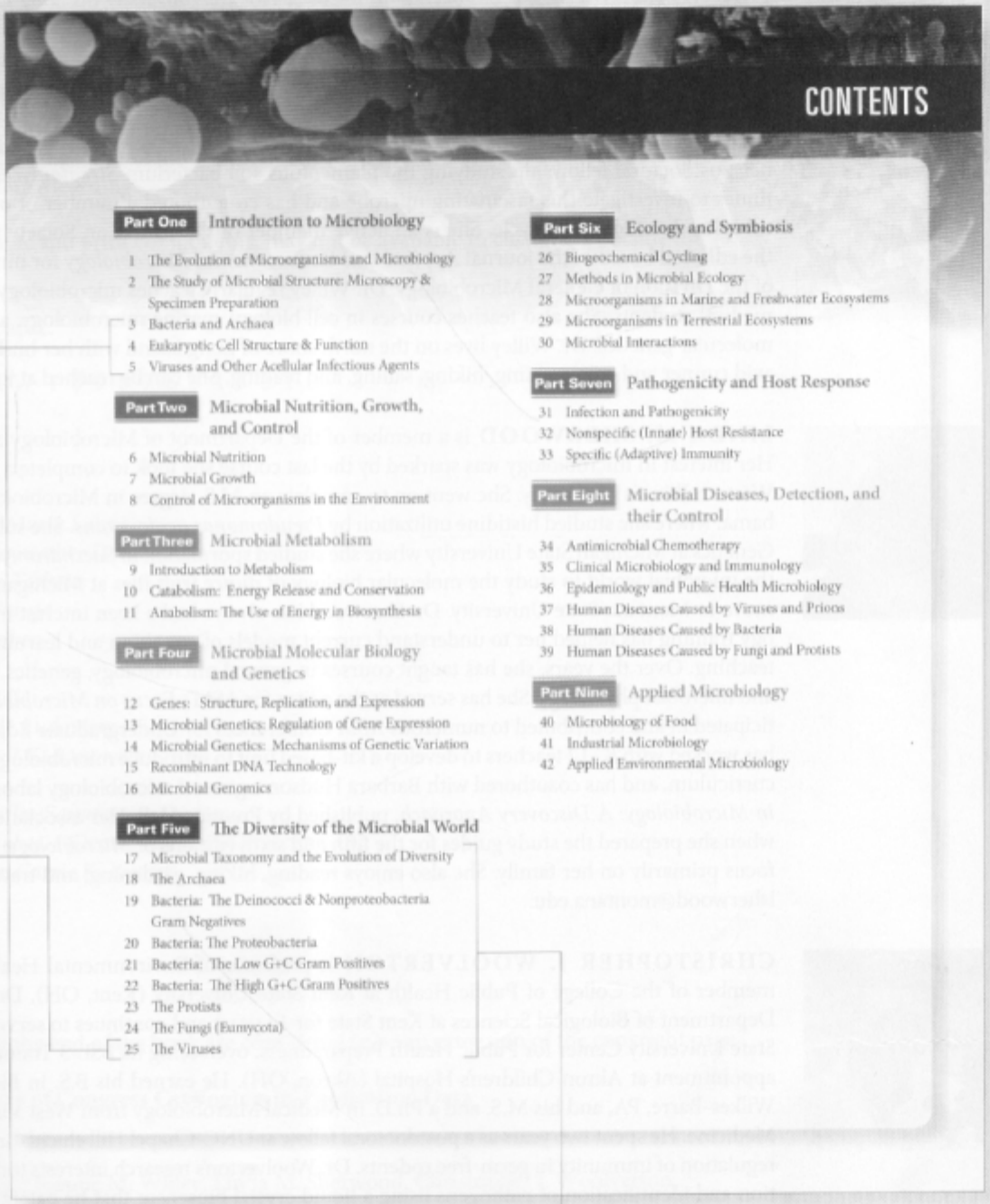
CONNECTING STUDENTS TO MICROBIOLOGY THROUGH...

INNOVATIVE TABLE OF CONTENTS:

- An **introduction to the entire microbial world** is now covered in Chapters 3, 4, and 5. Structure and function of Bacteria, Archaea, and Eukaryotes precede an introduction to the viruses that is extremely accessible to students.
- A more detailed look at specific viruses, replication, and classification is found later in the book (Chapter 25).



CONTENTS

- **Microbial diversity** is now integrated throughout the text. Chapters 17–25 have been thoroughly updated, with many new figures and physiological and genetic information added where appropriate.

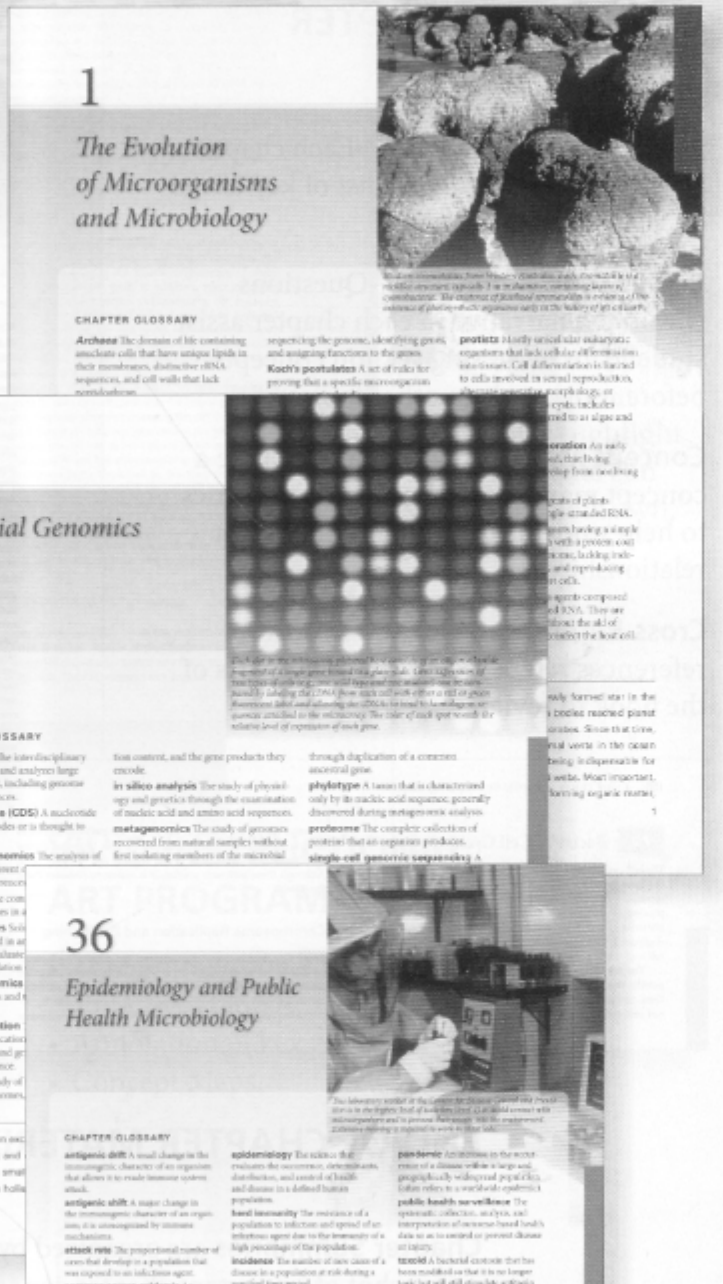
THEMATIC INTEGRATION

- **Evolution**—Introduced immediately in Chapter 1 and used as an overarching theme throughout, evolution helps tie the pieces together and provide a framework upon which students can build their knowledge of microbiology.

- **Microbial diversity**—Now integrated through the entire text, students are constantly reminded of the diversity of the microbial world.

HOT TOPICS

- **The GREEN text!** Global climate change, public health, alternative energy, and biofuels have all been added, making ***Prescott's Microbiology*** a very green text that will spark students' interest. **For more, see Chapters 26 and 41.**
- **H1N1**—This virus is ubiquitous in the news and sure to be a topic of interest to students. **For more, see Chapters 36 and 37.**
- **Updated Genomics**—21st-century genomic sequencing techniques are now covered in **Chapter 16.**



CONNECTING STUDENTS TO MICROBIOLOGY WITH...

INNOVATIVE CHAPTER FEATURES

NEW! Chapter Glossary—Each chapter begins with a glossary—a list of key terms discussed in the chapter.

Review and Reflection—Questions within the narrative in each chapter assist students in mastering section concepts before moving on to other topics.

Concept Maps—Key chapters include a concept map that outlines critical themes to help students understand important relationships.

Cross-Referenced Notes—In-text references refer students to other parts of the book to review.

7

Microbial Growth and Reproduction

CHAPTER GLOSSARY

acidophile A microorganism that has its growth optimum between pH 0 and about 5.5.

aerobe An organism that grows in the presence of atmospheric oxygen.

aerotolerant anaerobe A microbe that grows equally well whether or not oxygen is present.

alkaliphile (alkiphile) A microorganism that grows best at pH values from about 8.5 to 11.5.

anaerobe An organism that can grow in the absence of free oxygen.

batch culture A population of microorganisms growing in a closed culture vessel containing a single batch of medium.

biofilm Organized microbial communities consisting of layers of cells associated with surfaces and surrounded by an extracellular polymeric matrix.

chemostat A continuous-culture apparatus that feeds medium into the culture vessel at the same rate as medium containing microorganisms is removed; the medium contains a limiting quantity of one essential nutrient.

colony forming units (CFU) The number of microorganisms that form ... when cultured using spread ... pour plates; used as a measure ... number of viable microorganisms ...

...nesis Processes that apportion ...acellular contents, synthesize a septum, and divide a cell into two daughter cells during cell division.

exponential (log) phase The phase of a growth curve during which the microbial population is growing at a constant and maximum rate, dividing and doubling at regular intervals.

extremophiles Microorganisms that grow under harsh or extreme environmental conditions.

facultative anaerobe A microorganism that does not require oxygen for growth but grows better in its presence.

generation (doubling) time The time required for a microbial population to double in number.

halophile A microorganism that requires high levels of sodium chloride for growth.

hyperthermophile A bacterium or archaeon with a growth optimum above 85°C.

lag phase A period following the introduction of microorganisms into fresh batch culture medium when there is no increase in cell numbers or mass.

mesophile A microorganism with a growth optimum around 20 to 45°C, a minimum of 15 to 20°C, and a maximum of less than 45°C.

microaerophile A microorganism that requires low levels of oxygen for growth (2 to 10%) but is damaged by normal atmospheric oxygen levels.

most probable number (MPN) A method for determining number of viable cells in a liquid sample. Samples are incubated in a suitable liquid medium in a dilution series; the most dilute sample to show growth is assumed to have been inoculated with between 1 and 10 cells.

neutrophile A microorganism that grows best at a neutral pH range between pH 5.5 and 8.0.

obligate aerobe An organism that grows only when oxygen is present.

obligate anaerobe An organism that grows only when oxygen is absent.

osmotolerant Organisms that grow over a wide range of water activity or solute concentration.

psychrophile A microorganism that grows well at 0°C, has an optimum growth temperature of 15°C or lower, and a temperature maximum of around 20°C.

quorum sensing The exchange of extracellular molecules that allows microbial cells to sense cell density.

stationary phase The phase of microbial growth in a batch culture when population growth ceases and the growth curve levels off.

thermophile A microorganism that can grow at temperatures of 55°C or higher, with a minimum of around 45°C.

water activity (a_w) A quantitative measure of water availability in a habitat.

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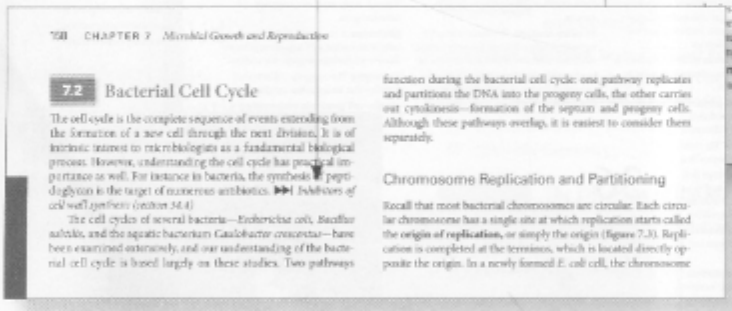


228 CHAPTER 7 *Microbial Growth and Reproduction*

7.2 Bacterial Cell Cycle

The cell cycle is the complete sequence of events extending from the formation of a new cell through the next division. It is of intrinsic interest to microbiologists as a fundamental biological process. However, understanding the cell cycle has practical importance as well. For instance in bacteria, the synthesis of peptidoglycan is the target of numerous antibiotics. ⏭ *Inhibitors of cell wall synthesis (section 14.4)*

The cell cycles of several bacteria—*Escherichia coli*, *Bacillus subtilis*, and the aquatic bacterium *Caulobacter crescentus*—have been examined extensively, and our understanding of the bacterial cell cycle is based largely on these studies. Two pathways function during the bacterial cell cycle: one pathway replicates and partitions the DNA into the progeny cells, the other carries out cytokinesis—formation of the septum and progeny cells. Although these pathways overlap, it is easiest to consider them separately.

Chromosome Replication and Partitioning

Recall that most bacterial chromosomes are circular. Each circular chromosome has a single site at which replication starts called the **origin of replication**, or simply the origin (figure 7.3). Replication is completed at the terminus, which is located directly opposite the origin. In a newly formed *E. coli* cell, the chromosome

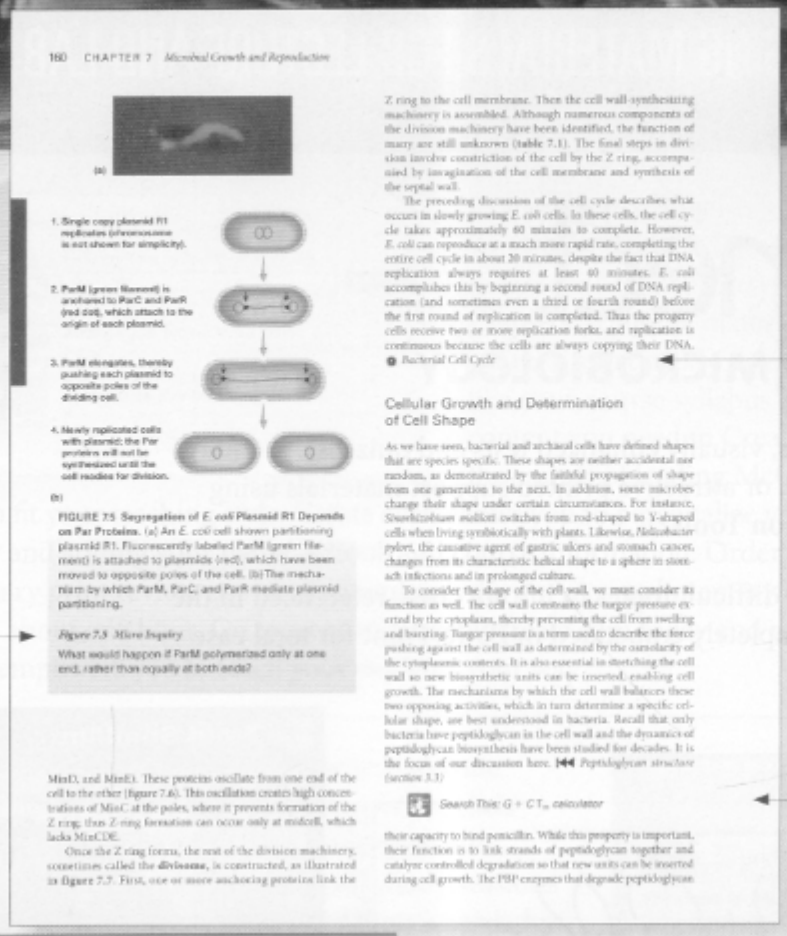
END OF CHAPTER MATERIAL

Chapter Summaries are organized by numbered headings and provide a snapshot of important chapter concepts.

Critical Thinking Questions taken from current literature supplement the questions for review and reflection found throughout each chapter; they are designed to stimulate analytical problem-solving skills.

NEW! Concept Mapping Challenge encourages students to build their own concept maps based on what they have learned in that chapter.

NEW!
Micro Inquiry
Select figures throughout every chapter contain thought questions adding another assessment opportunity for the student.


160 CHAPTER 7 *Microbial Growth and Reproduction*

(a)

1. Single copy plasmid R1 replicates (chromosome is not shown for simplicity).
2. ParM (green filament) is anchored to ParC and ParR (red dot), which attach to the origin of each plasmid.
3. ParM elongates, thereby pushing each plasmid to opposite poles of the dividing cell.
4. Newly replicated cells with plasmid; the Par proteins will not be synthesized until the cell readies for division.

(b)

FIGURE 7.5 Segregation of *E. coli* Plasmid R1 Depends on Par Proteins. (a) An *E. coli* cell shown partitioning plasmid R1. Fluorescently labeled ParM (green filament) is attached to plasmids (red), which have been moved to opposite poles of the cell. (b) The mechanism by which ParM, ParC, and ParR mediate plasmid partitioning.

Figure 7.5 Micro Inquiry
What would happen if ParM polymerized only at one end, rather than equally at both ends?

MinD, and MinE). These proteins oscillate from one end of the cell to the other (figure 7.6). This oscillation creates high concentrations of MinC at the poles, where it prevents formation of the Z ring; thus Z ring formation can occur only at midcell, which lacks MinCDE.

Once the Z ring forms, the rest of the division machinery, sometimes called the **divisome**, is constructed, as illustrated in figure 7.7. First, one or more anchoring proteins link the Z ring to the cell membrane. Then the cell wall-synthesizing machinery is assembled. Although numerous components of the division machinery have been identified, the function of many are still unknown (table 7.1). The final steps in division involve constriction of the cell by the Z ring, accompanied by invagination of the cell membrane and synthesis of the septal wall.

The preceding discussion of the cell cycle describes what occurs in slowly growing *E. coli* cells. In these cells, the cell cycle takes approximately 60 minutes to complete. However, *E. coli* can reproduce at a much more rapid rate, completing the entire cell cycle in about 20 minutes, despite the fact that DNA replication always requires at least 40 minutes. *E. coli* accomplishes this by beginning a second round of DNA replication (and sometimes even a third or fourth round) before the first round of replication is completed. Thus the progeny cells receive two or more replication forks, and replication is continuous because the cells are always copying their DNA.
Bacterial Cell Cycle

Cellular Growth and Determination of Cell Shape

As we have seen, bacterial and archaeal cells have defined shapes that are species specific. These shapes are neither accidental nor random, as demonstrated by the faithful propagation of shape from one generation to the next. In addition, some microbes change their shape under certain circumstances. For instance, *Sinorhizobium meliloti* switches from rod-shaped to Y-shaped cells when living symbiotically with plants. Likewise, *Helicobacter pylori*, the causative agent of gastric ulcers and stomach cancer, changes from its characteristic helical shape to a sphere in stomach infections and in prolonged culture.

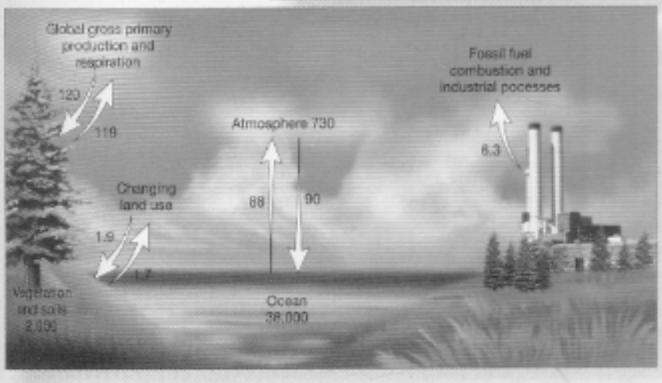
To consider the shape of the cell wall, we must consider its function as well. The cell wall constrains the turgor pressure exerted by the cytoplasm, thereby preventing the cell from swelling and bursting. Turgor pressure is a term used to describe the force pushing against the cell wall as determined by the osmolarity of the cytoplasmic contents. It is also essential in stretching the cell wall so new biosynthetic units can be inserted, enabling cell growth. The mechanisms by which the cell wall balances these two opposing activities, which in turn determine a specific cellular shape, are best understood in bacteria. Recall that only bacteria have peptidoglycan in the cell wall and the dynamics of peptidoglycan biosynthesis have been studied for decades. It is the focus of our discussion here. *Peptidoglycan structure* (section 3.3)

Search This: $G + C T_m$ calculator

their capacity to bind penicillin. While this property is important, their function is to link strands of peptidoglycan together and catalyze controlled degradation so that new units can be inserted during cell growth. The PBP enzymes that degrade peptidoglycan

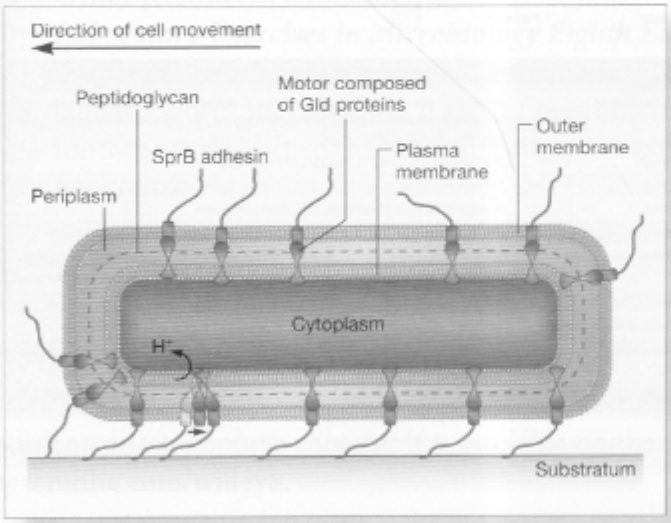
NEW! Animation Icon
This symbol indicates that material presented in the text is also accompanied by an animation on the text website at www.mhhe.com/willey8.

NEW! Search This
Icons throughout the chapter highlight topics students can search on their own.



VIVID INSTRUCTIONAL ART PROGRAM

- Three-dimensional renditions and bright, attractive colors.
- Annotation of key pathways.
- Concept Maps.



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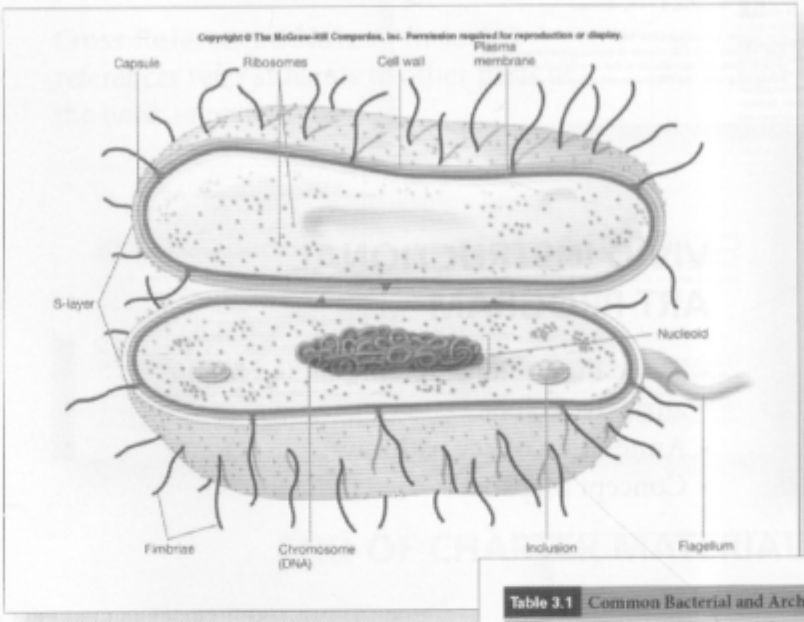

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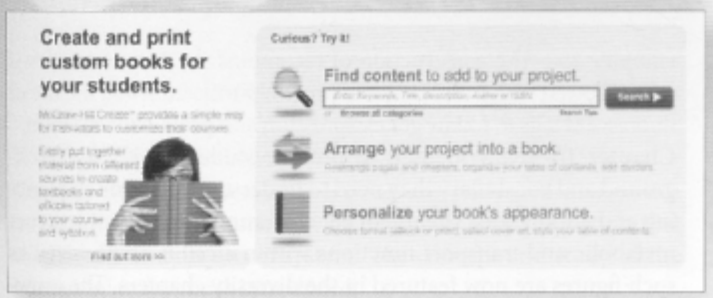
Table 3.1 Common Bacterial and Archaeal Structures and Their Functions

Plasma membrane	Selectively permeable barrier, mechanical boundary of cell, nutrient and waste transport, location of many metabolic processes (respiration, photosynthesis), detection of environmental cues for chemotaxis
Gas vacuole	Buoyancy for floating in aquatic environments
Ribosomes	Protein synthesis
Inclusions	Storage of carbon, phosphate, and other substances
Nucleoid	Localization of genetic material (DNA)
Periplasmic space	In gram-negative bacteria, contains hydrolytic enzymes and binding proteins for nutrient processing and uptake; in gram-positive bacteria and archaeal cells, may be smaller or absent
Cell wall	Provides shape and protection from osmotic stress
Capsules and slime layers	Resistance to phagocytosis, adherence to surfaces; rare in the *Archaea*
Fimbriae and pili	Attachment to surfaces, bacterial conjugation and transformation, twitching and gliding motility
Flagella	Swimming motility
Endospore	Survival under harsh environmental conditions; only observed in *Bacteria*



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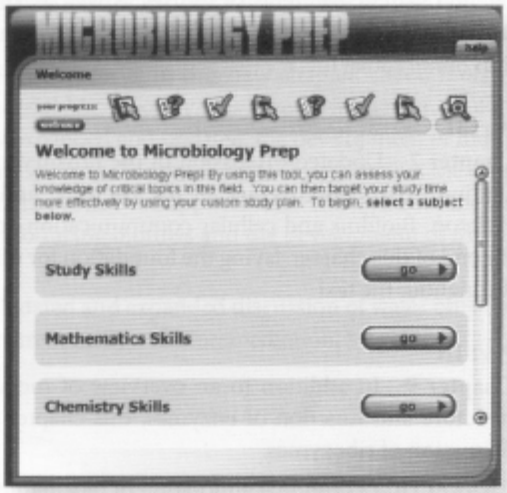
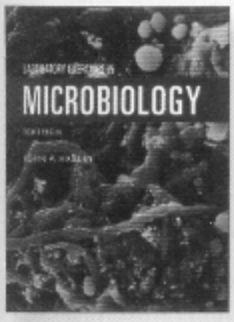
NEW! Microbiology Prep, also available on the text website at www.mhhe.com/willey8, helps students to prepare for their upcoming coursework in microbiology. This website enables students to perform self-assessments, conduct self-study sessions with tutorials, and perform a post-assessment of their knowledge in the following areas:

- Study Skills
- Mathematics Skills
- Chemistry Skills
- Biology Skills
- Metric System Skills
- Lab Reports and Referencing





Other Resources Available!

Laboratory Exercises in Microbiology Eighth Edition by John P. Harley has been prepared to accompany the text. Like the text, the laboratory manual provides a balanced introduction in each area of microbiology. The class-tested exercises are modular and short so that an instructor can easily choose those exercises that fit his or her course.

The **Student Study Guide** is a valuable resource that provides learning objectives, study outlines, learning activities, and self-testing material to help students master course content. It is available on the text website at www.mhhe.com/willey8.

Visit the text website at www.mhhe.com/willey8

LIST OF CHANGES

CONTENT CHANGES BY PART

Each chapter has been thoroughly reviewed and almost all have undergone significant revision. The highlights include:

Part I

Chapter 1—We open the text with the essential concepts of microbial evolution to underscore the role of evolution as the driving force of all biological systems.

Chapter 3—Discussion of archaeal and bacterial cellular structure is integrated throughout.

Chapter 4—The essentials of protist and fungal morphology are presented here, so that chapters 23 (The Protists) and 24 (The Fungi) now focus specifically on the diversity of these microbes.

Chapter 5—This new chapter, entitled *Viruses and Other Acellular Infectious Agents*, surveys the essential morphological, physiological, and genetic elements of viruses as well as viroids, virusoids, and prions. This chapter completes our three-chapter introduction of microbial life.

Part II

Chapter 7—Updated discussion of the prokaryotic cell cycle, including expanded coverage of the bacterial and archaeal cytoskeleton. Biofilms and cellular communication are introduced at the end of this chapter, laying the foundation for further discussion throughout the text.

Part III

Chapter 9—In addition to an overview of metabolism and the structure and function of enzymes, this chapter now includes a discussion of ribozymes.

Chapter 10—Additional annotation of biochemical pathways has been included. Rhodopsin-based phototrophy is introduced as well as oxygenic and anoxygenic photosynthesis.

Part IV

Chapter 12—Protein folding and secretion now completes this chapter on genome structure and replication, gene structure, and gene expression.

Chapter 13—Focus continues to be exclusively on the regulation of gene expression, presented according to the level at which regulation occurs; updated and expanded discussion of riboswitches and regulation by small RNA molecules. Quorum sensing and its role in microbial physiology and biofilm formation are given in-depth coverage.

Chapter 14—Covers mutation, repair, and recombination in the context of processes that introduce genetic variation into populations. The consequences of mutating protein coding genes, regulatory sequences, and RNA genes are given individual consideration.

Chapter 15—The construction of recombinant DNA molecules is now followed with a discussion of protein purification and the use of fluorescent tags to follow gene expression and protein localization.

Chapter 16—Now focused to provide students with the background and vocabulary they need to understand genome sequencing and annotation. The use of genome annotation to reconstruct metabolic and transport functions within a cell is emphasized as such figures are now featured in the diversity chapters. The growing importance of metagenomics is introduced here.

Part V

Chapter 17—Rewritten and re-titled *Microbial Taxonomy and the Evolution of Diversity*, this chapter features expanded coverage of the construction and utility of phylogenetic trees. Microbial evolution, introduced in chapter 1, is expanded with a complete discussion of the concept and definition of microbial species, the core genome and the importance of horizontal gene transfer and the development of the pan-genome.

Chapter 18—Expanded coverage of archaeal genetics and thermostabilty. Archaeal metabolism has been expanded with new figures presenting alternate, archaeal-specific modifications of the Embden-Meyerhoff and Entner-Douderoff pathways. Genome-based metabolic reconstructions based on genomic sequencing of a crenarchaeote (*Sulfolobus*) and a euryarchaeote (*Halobacterium*) are now included.

Chapter 19—Updated and expanded coverage of photosynthetic pigments, the anammox reaction, and exciting new discoveries within the phylum *Verrucomicrobia* are now included.

Chapter 20—Increased coverage of proteobacterial physiology includes discussion of topics such as photosynthetic pigment apparatus in purple bacteria, nitrification, methylotrophy, dissimilatory sulfate reduction, and gliding motility. Also featured are genome-based, metabolic reconstructions of several *Proteobacteria*.

Chapter 21—New discussions include the proposed mechanism of phototrophy in *Heliobacterium* and biofilm formation by *Bacillus subtilis*.

Part VI

Chapter 26—Re-titled *Biogeochemical Cycling*, this chapter now focuses only on biogeochemical cycling and the role of microbes in global climate change.

Chapter 27—This new chapter, entitled *Methods in Microbial Ecology*, surveys the most commonly used techniques in the field. The importance and difficulty of culturing microbes in the laboratory is stressed with coverage of novel approaches that have been developed for isolating and growing bacteria and archaea. Molecular and biogeochemical methods for the analysis of microbial diversity and community activity are also reviewed.

LIST OF CHANGES

Chapter 28—While the focus remains on microbial communities found in the major biomes within marine and freshwater environments, the importance of microbial primary production and its potential role in modulating global climate change is stressed.

Chapter 30—Microbial interactions are presented along with human-microbe relationships, helping to convey the notion that the human body is an ecosystem. The concept and study of the human microbiome is introduced.

Part VII

Chapter 31—This chapter has been re-titled *Infection and Pathogenicity*. It also now follows the chapter on microbial interactions to stress that pathogens represent one half of a parasite-host relationship. The essential elements required for a pathogen to establish infection are introduced followed by common virulence mechanisms.

Chapter 32—Reorganized and updated, this chapter on nonspecific (innate) host resistance provides in-depth coverage of physical and chemical components of the nonspecific host response followed by an overview of cells, tissues, and organs of the immune system. This includes a step-by-step discussion of phagocytosis and inflammation. The groundwork is laid for a full appreciation of the connections between the specific and nonspecific arms of the immune system.

Chapter 33—Reorganized and updated to enhance linkages between innate and acquired immune activities; integrated medical immunology concepts, including insights into regulatory mechanisms.

Part VIII

Chapter 34—Content focuses on the mechanism of action of each antimicrobial agent, with an additional emphasis on the development of antibiotic resistance.

Chapter 36—Expanded focus on the important role of epidemiology in preventative medicine and the role of the public health system.

Chapter 37—Updated and expanded coverage of viral pathogenesis; select (potential bioterrorism) agents highlighted.

Chapter 38—Expanded coverage of bacterial pathogenesis; select (potential bioterrorism) agents highlighted.

Chapter 39—Updated to reflect disease transmission routes (similar to chapters 37 and 38.

Part IX

Chapter 40—Expanded discussion of the control of food spoilage and probiotics.

Chapter 41—Some material in this new chapter, called *Biotechnology and Industrial Microbiology*, was covered in chapter 42 of the 7th edition. Now expanded and updated, the development of industrial strains of microbes is discussed, followed by some of the more important industrial microbial applications. This includes the use of microbes in producing biofuels and the development of microbial fuel cells.

Chapter 42—Updated and expanded discussion of water purification, wastewater treatment, and bioremediation.