Preface

Welcome to *Microbiology*, an OpenStax resource. This textbook was written to increase student access to high-quality learning materials, maintaining highest standards of academic rigor at little to no cost.

About OpenStax

OpenStax is a nonprofit based at Rice University, and it's our mission to improve student access to education. Our first openly licensed college textbook was published in 2012, and our library has since scaled to over 20 books for college and AP® Courses used by hundreds of thousands of students. Our adaptive learning technology, designed to improve learning outcomes through personalized educational paths, is being piloted in college courses throughout the country. Through our partnerships with philanthropic foundations and our alliance with other educational resource organizations, OpenStax is breaking down the most common barriers to learning and empowering students and instructors to succeed.

About OpenStax Resources

Customization

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Errata

All OpenStax textbooks undergo a rigorous review process. However, like any professional-grade textbook, errors sometimes occur. Since our books are web-based, we can make updates periodically when deemed pedagogically necessary. If you have a correction to suggest, submit it through the link on your book page on openstax.org. Subject matter experts review all errata suggestions. OpenStax is committed to remaining transparent about all updates, so you will also find a list of past errata changes on your book page on openstax.org.

Format

You can access this textbook for free in web view or PDF through openstax.org, and for a low cost in print.

About *Microbiology*

Microbiology is designed to cover the scope and sequence requirements for the single-semester Microbiology course for non-majors. The book presents the core concepts of microbiology with a focus on applications for careers in allied health. The pedagogical features of *Microbiology* make the material interesting and accessible to students while maintaining the career-application focus and scientific rigor inherent in the subject matter.

Coverage and Scope

The scope and sequence of *Microbiology* has been developed and vetted with input from numerous instructors at institutions across the US. It is designed to meet the needs of most microbiology courses for non-majors and allied health students. In addition, we have also considered the needs of institutions that offer microbiology to a mixed audience of science majors and non-majors by frequently integrating topics that may not have obvious clinical

relevance, such as environmental and applied microbiology and the history of science.

With these objectives in mind, the content of this textbook has been arranged in a logical progression from fundamental to more advanced concepts. The opening chapters present an overview of the discipline, with individual chapters focusing on microscopy and cellular biology as well as each of the classifications of microorganisms. Students then explore the foundations of microbial biochemistry, metabolism, and genetics, topics that provide a basis for understanding the various means by which we can control and combat microbial growth. Beginning with Chapter 15, the focus turns to microbial pathogenicity, emphasizing how interactions between microbes and the human immune system contribute to human health and disease. The last several chapters of the text provide a survey of medical microbiology, presenting the characteristics of microbial diseases organized by body system.

A brief Table of Contents follows. While we have made every effort to align the Table of Contents with the needs of our audience, we recognize that some instructors may prefer to teach topics in a different order. A particular strength of *Microbiology* is that instructors can customize the book, adapting it to the approach that works best in their classroom.

Appendix B: Mathematical Basics

Appendix C: Metabolic Pathways

Appendix D: Taxonomy of Clinically Relevant Microorganisms

Appendix E: Glossary

American Society of Microbiology (ASM) Partnership

Microbiology is produced through a collaborative publishing agreement between OpenStax and the American Society for Microbiology Press. The book has been developed to align to the curriculum guidelines of the American Society for Microbiology.

About ASM

The American Society for Microbiology is the largest single life science society, composed of over 47,000 scientists and health professionals. ASM's mission is to promote and advance the microbial sciences.

ASM advances the microbial sciences through conferences, publications, certifications, and educational opportunities. It enhances laboratory capacity around the globe through training and resources and provides a network for scientists in academia, industry, and clinical settings. Additionally, ASM promotes a deeper understanding of the microbial sciences to diverse audiences and is committed to offering open-access materials through their new journals, American Academy of Microbiology reports, and textbooks.

ASM Recommended Curriculum Guidelines for Undergraduate Microbiology Education

PART 1: Concepts and Statements

Evolution

1. Cells, organelles (e.g., mitochondria and chloroplasts) and all major metabolic pathways evolved from early prokaryotic cells.
2. Mutations and horizontal gene transfer, with the immense variety of microenvironments, have selected for a huge diversity of microorganisms.
3. Human impact on the environment influences the evolution of microorganisms (e.g., emerging diseases and the selection of antibiotic resistance).
4. The traditional concept of species is not readily applicable to microbes due to asexual reproduction and the frequent occurrence of horizontal gene transfer.
5. The evolutionary relatedness of organisms is best reflected in phylogenetic trees.

Cell Structure and Function

6. The structure and function of microorganisms have been revealed by the use of microscopy (including bright field, phase contrast, fluorescent, and electron).
7. Bacteria have unique cell structures that can be targets for antibiotics, immunity and phage infection.
8. Bacteria and Archaea have specialized structures (e.g., flagella, endospores, and pili) that often confer critical capabilities.
9. While microscopic eukaryotes (for example, fungi, protozoa and algae) carry out some of the same processes as bacteria, many of the cellular properties are fundamentally different.
10. The replication cycles of viruses (lytic and lysogenic) differ among viruses and are determined by their unique structures and genomes.

Metabolic Pathways

11. Bacteria and Archaea exhibit extensive, and often unique, metabolic diversity (e.g., nitrogen fixation, methane

production, anoxygenic photosynthesis).

12. The interactions of microorganisms among themselves and with their environment are determined by their metabolic abilities (e.g., quorum sensing, oxygen consumption, nitrogen transformations).
13. The survival and growth of any microorganism in a given environment depends on its metabolic characteristics.
14. The growth of microorganisms can be controlled by physical, chemical, mechanical, or biological means.

Information Flow and Genetics

15. Genetic variations can impact microbial functions (e.g., in biofilm formation, pathogenicity and drug resistance).
16. Although the central dogma is universal in all cells, the processes of replication, transcription, and translation differ in Bacteria, Archaea, and Eukaryotes.
17. The regulation of gene expression is influenced by external and internal molecular cues and/or signals.
18. The synthesis of viral genetic material and proteins is dependent on host cells.
19. Cell genomes can be manipulated to alter cell function.

Microbial Systems

20. Microorganisms are ubiquitous and live in diverse and dynamic ecosystems.
21. Most bacteria in nature live in biofilm communities.
22. Microorganisms and their environment interact with and modify each other.
23. Microorganisms, cellular and viral, can interact with both human and nonhuman hosts in beneficial, neutral or detrimental ways.

Impact of Microorganisms

24. Microbes are essential for life as we know it and the processes that support life (e.g., in biogeochemical cycles and plant and/or animal microbiota).
25. Microorganisms provide essential models that give us fundamental knowledge about life processes.
26. Humans utilize and harness microorganisms and their products.
27. Because the true diversity of microbial life is largely unknown, its effects and potential benefits have not been fully explored.

PART 2: Competencies and Skills

Scientific Thinking

28. Ability to apply the process of science
    a. Demonstrate an ability to formulate hypotheses and design experiments based on the scientific method.
    b. Analyze and interpret results from a variety of microbiological methods and apply these methods to analogous situations.
29. Ability to use quantitative reasoning
    a. Use mathematical reasoning and graphing skills to solve problems in microbiology.
30. Ability to communicate and collaborate with other disciplines
    a. Effectively communicate fundamental concepts of microbiology in written and oral format.
    b. Identify credible scientific sources and interpret and evaluate the information therein.
31. Ability to understand the relationship between science and society
    a. Identify and discuss ethical issues in microbiology.

Microbiology Laboratory Skills

32. Properly prepare and view specimens for examination using microscopy (bright field and, if possible, phase contrast).
33. Use pure culture and selective techniques to enrich for and isolate microorganisms.
34. Use appropriate methods to identify microorganisms (media-based, molecular and serological).
35. Estimate the number of microorganisms in a sample (using, for example, direct count, viable plate count, and spectrophotometric methods).
36. Use appropriate microbiological and molecular lab equipment and methods.
37. Practice safe microbiology, using appropriate protective and emergency procedures.
38. Document and report on experimental protocols, results and conclusions.

OpenStax *Microbiology* Correlation to ASM Recommended Curriculum Guidelines for Undergraduate Microbiology Education

OpenStax *Microbiology* Correlation to ASM Curriculum Guidelines

Chapter	ASM Curriculum Guidelines
1—An Invisible World	2, 4, 5, 11, 16, 20, 23, 26, 27, 31
2—How We See the Invisible World	6, 31, 32, 33
3—The Cell	1, 2, 5, 9, 16, 21, 25, 31
4—Prokaryotic Diversity	2, 4, 8, 11, 12, 16, 20, 23, 24, 31
5—The Eukaryotes of Microbiology	2, 4, 5, 9, 12, 20, 23, 31
6—Acellular Pathogens	4, 10, 18, 23, 31
7—Microbial Biochemistry	1, 24, 33, 34
8—Microbial Metabolism	1, 11, 12, 13, 22, 24
9—Microbial Growth	12, 13, 29, 31, 33, 34, 35
10—Biochemistry of the Genome	1, 16, 25, 31
11—Mechanisms of Microbial Genetics	1, 2, 15, 16, 17, 31
12—Modern Applications of Microbial Genetics	19, 26, 31
13—Control of Microbial Growth	13, 14, 26, 31, 36, 37
14—Antimicrobial Drugs	3, 7, 14, 15, 23, 26, 31
15—Microbial Mechanisms of Pathogenicity	8, 9, 10, 15, 18, 23, 33
16—Disease and Epidemiology	7, 14, 23, 26, 31
17—Innate Nonspecific Host Defenses	7, 8, 23
18—Adaptive Specific Host Defenses	7, 23, 26, 31
19—Diseases of the Immune System	7, 8, 24
20—Laboratory Analysis of the Immune Response	31, 34
21—Skin and Eye Infections	8, 9, 10, 14, 18, 23, 24, 31
22—Respiratory System Infections	7, 8, 9, 14, 18, 23, 24, 31
23—Urogenital System Infections	7, 8, 9, 12, 14, 18, 22, 23, 24, 31

OpenStax *Microbiology* Correlation to ASM Curriculum Guidelines

Chapter	ASM Curriculum Guidelines
24—Digestive System Infections	7, 8, 9, 10, 14, 18, 23, 24, 31
25—Circulatory and Lymphatic System Infections	7, 8, 9, 14, 23, 31
26—Nervous System Infections	7, 8, 9, 14, 18, 23, 24, 31

Engaging Feature Boxes

Throughout *Microbiology*, you will find features that engage students by taking selected topics a step further. Our features include:

Clinical Focus. Each chapter has a multi-part clinical case study that follows the story of a fictional patient. The case unfolds in several realistic episodes placed strategically throughout the chapter, each episode revealing new symptoms and clues about possible causes and diagnoses. The details of the case are directly related to the topics presented in the chapter, encouraging students to apply what they are learning to real-life scenarios. The final episode presents a Resolution that reveals the outcome of the case and unpacks the broader lessons to be learned.

Case in Point. In addition to the Clinical Focus, many chapters also have one or more single-part case studies that serve to highlight the clinical relevance of a particular topic. These narratives are strategically placed directly after the topic of emphasis and generally conclude with a set of questions that challenge the reader to think critically about the case.

Micro Connections. All chapters contain several Micro Connections feature boxes that highlight real-world applications of microbiology, drawing often-overlooked connections between microbiology and a wide range of other disciplines. While many of these connections involve medicine and healthcare, they also venture into domains such as environmental science, genetic engineering, and emerging technologies. Moreover, many Micro Connections boxes are related to current or recent events, further emphasizing the intersections between microbiology and everyday life.

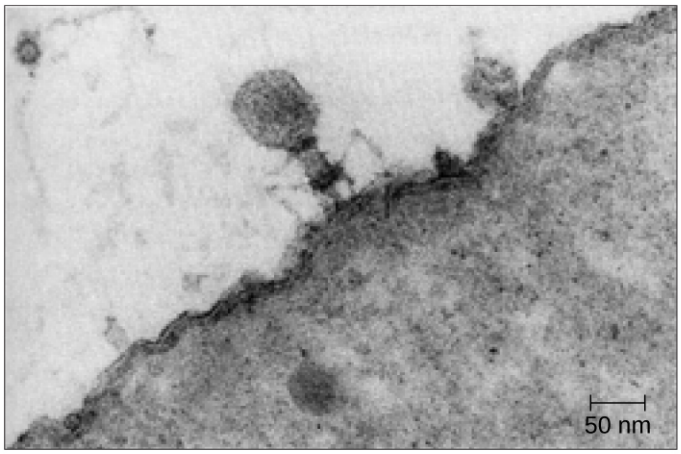
Sigma Xi Eye on Ethics. This unique feature, which appears in most chapters, explores an ethical issue related to chapter content. Developed in cooperation with the scientific research society Sigma Xi, each Eye on Ethics box presents students with a challenging ethical dilemma that arises at the intersection of science and healthcare. Often grounded in historical or current events, these short essays discuss multiple sides of an issue, posing questions that challenge the reader to contemplate the ethical principles that govern professionals in healthcare and the sciences.

Disease Profile. This feature, which is exclusive to Chapters 21–26, highlights important connections between related diseases. Each box also includes a table cataloguing unique aspects of each disease, such as the causative agent, symptoms, portal of entry, mode of transmission, and treatment. These concise tables serve as a useful reference that students can use as a study aid.

Link to Learning. This feature provides a brief introduction and a link to an online resource that students may use to further explore a topic presented in the chapter. Links typically lead to a website, interactive activity, or animation that students can investigate on their own.

Comprehensive Art Program

Our art program is designed to enhance students' understanding of concepts through clear and effective illustrations, diagrams, and photographs. Detailed drawings, comprehensive lifecycles, and clear micrographs provide visual reinforcement for concepts.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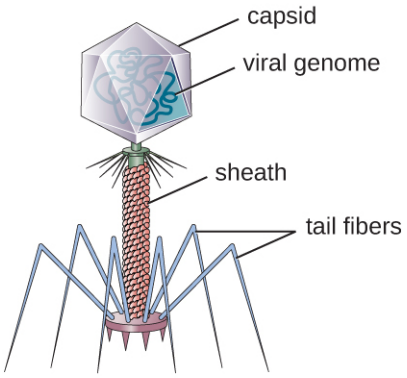
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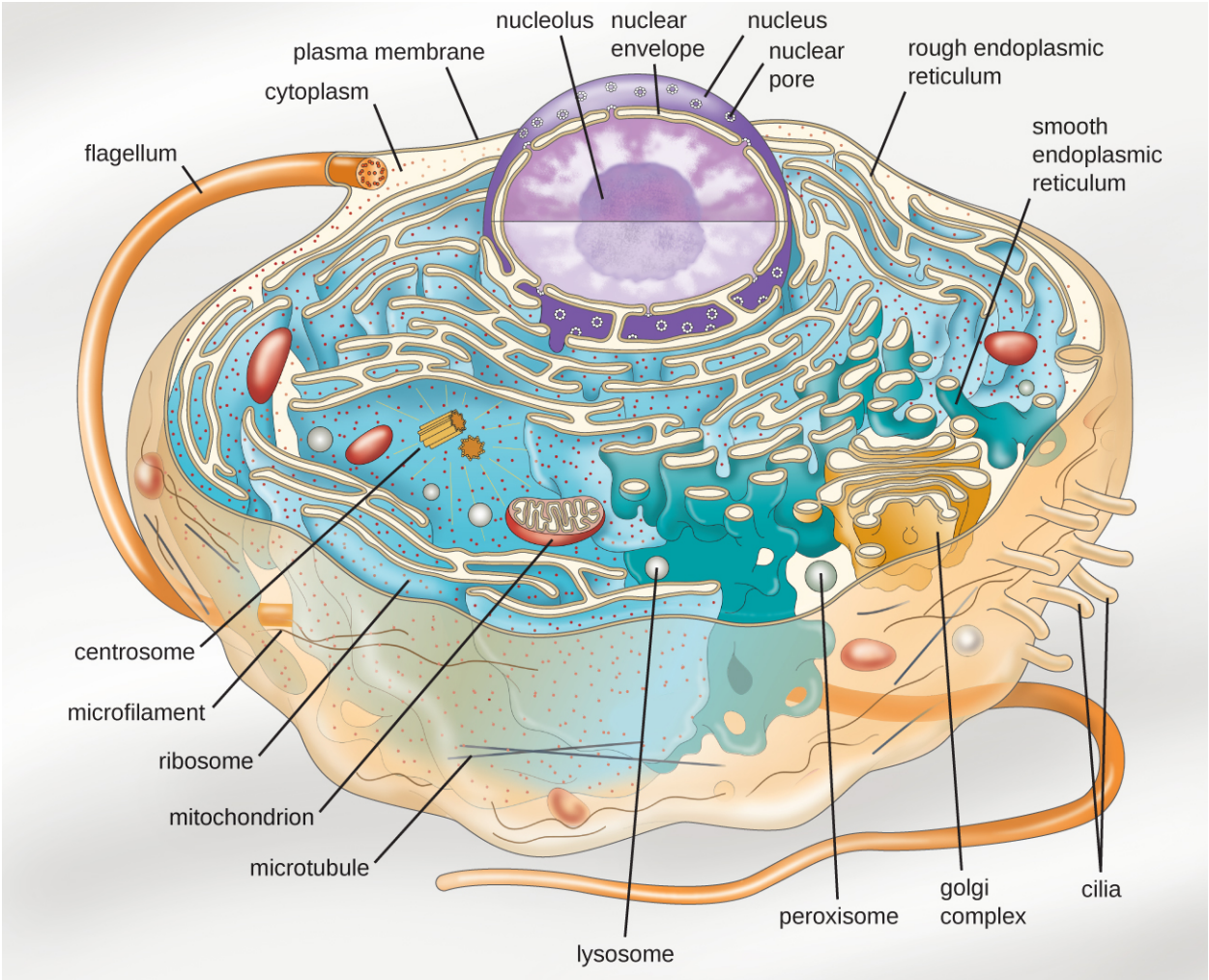
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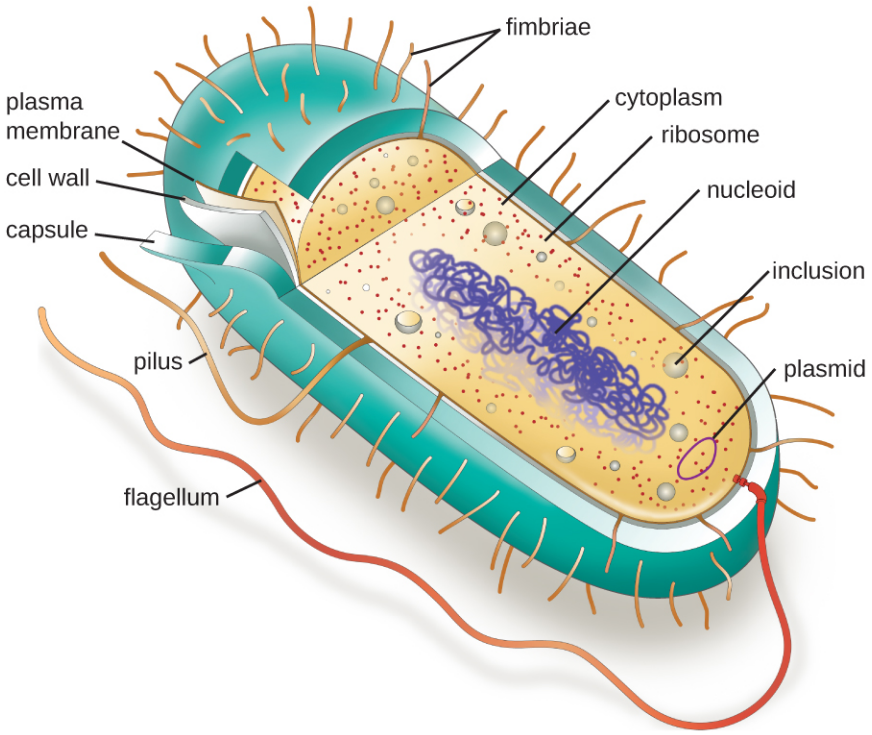
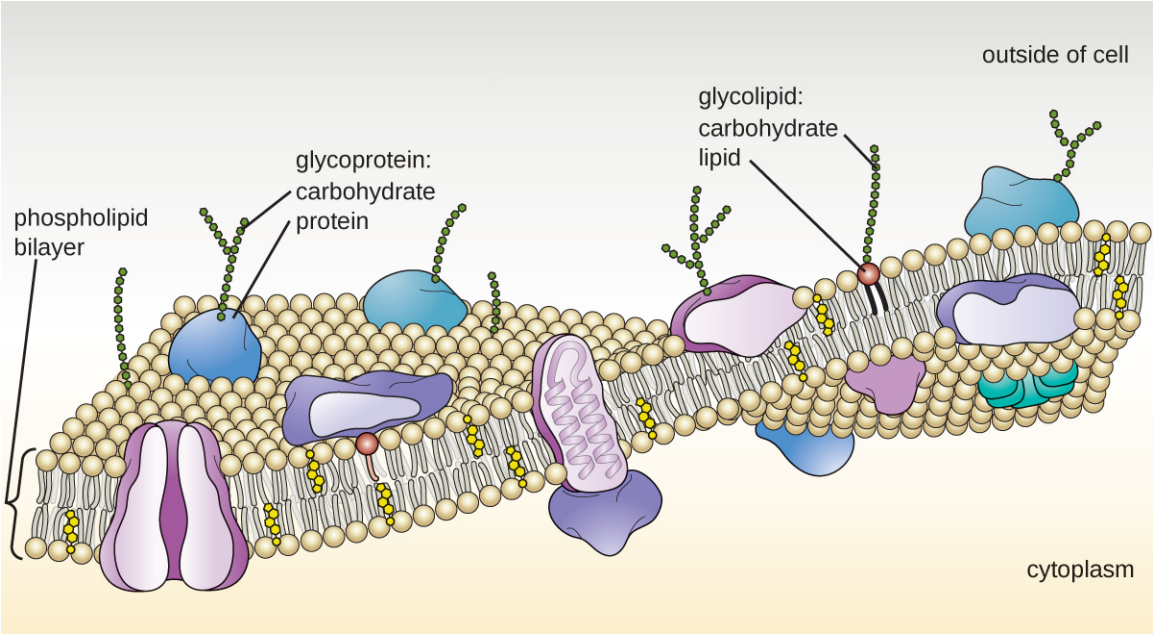
lysosome
peroxisome
golgi complex
cilia

ELECTRON MICROSCOPES Magnification: 20–100,000× or more Use electron beams focused with magnets to produce an image.		
Microscope Type	**Key Uses**	**Sample Images**
Transmission (TEM)	Uses electron beams that pass through a specimen to visualize small images; useful to observe small, thin specimens such as tissue sections and subcellular structures. **Example:** *Ebola* virus	
Scanning (SEM)	Uses electron beams to visualize surfaces; useful to observe the three-dimensional surface details of specimens. **Example:** *Campylobactor jejuni*	

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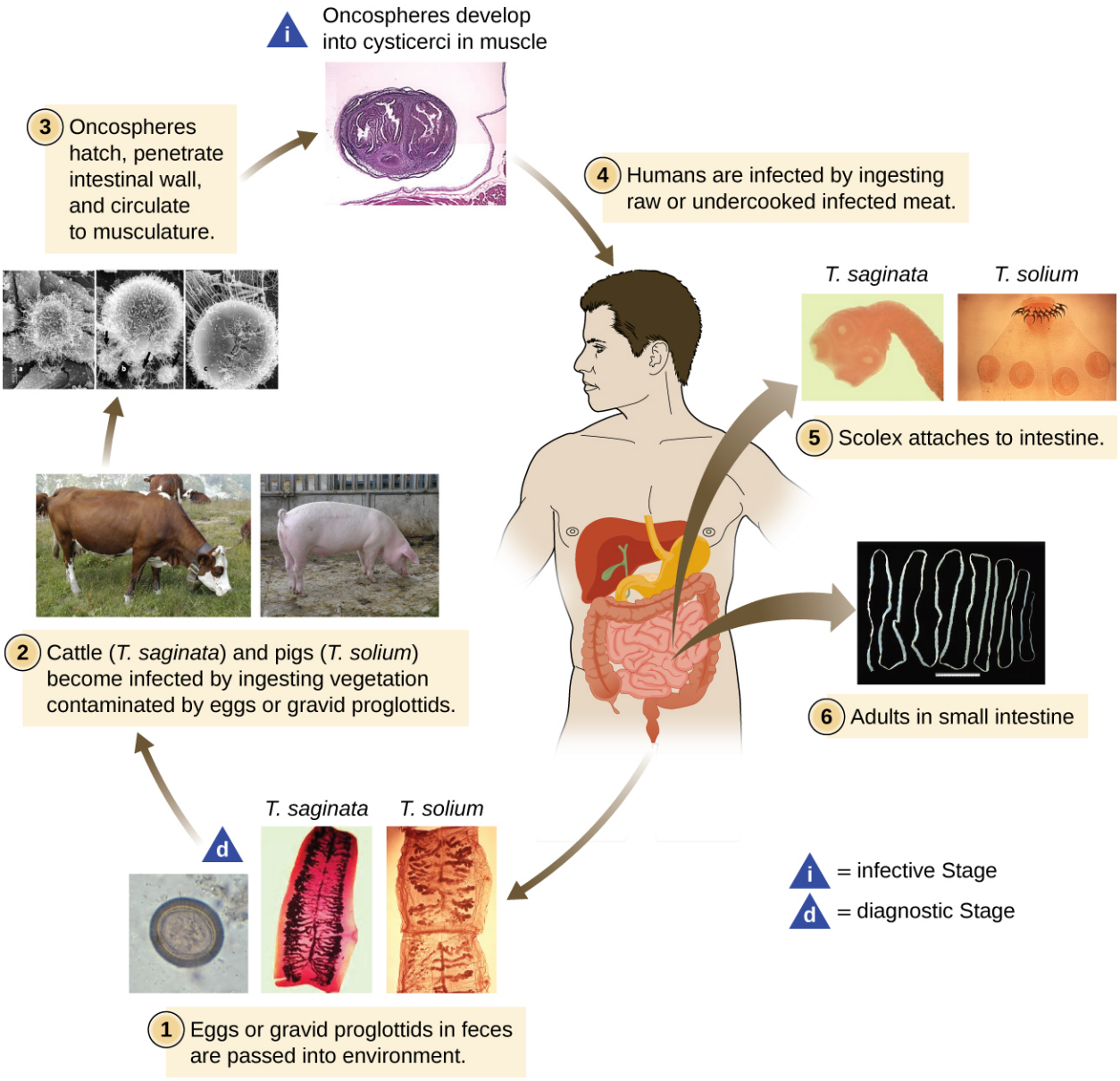

Materials That Reinforce Key Concepts

Learning Objectives. Every section begins with a set of clear and concise learning objectives that are closely aligned to the content and Review Questions.

Summary. The Summary distills the information in each section into a series of concise bullet points. Key Terms in the Summary are bold-faced for emphasis.

Key Terms. New vocabulary is bold-faced when first introduced in the text and followed by a definition in context. Definitions of key terms are also listed in the Glossary in (**Appendix E**).

Check Your Understanding questions. Each subsection of the text is punctuated by one or more comprehension-level questions. These questions encourage readers to make sure they understand what they have read before moving on to the next topic.

Review Questions. Each chapter has a robust set of review questions that assesses students' mastery of the

Learning Objectives. Questions are organized by format: multiple choice, matching, true/false, fill-in-the-blank, short answer, and critical thinking.

Additional Resources

Student and Instructor Resources

We've compiled additional resources for both students and instructors, including Getting Started Guides, a test bank, and an instructor answer guide. Instructor resources require a verified instructor account, which can be requested on your openstax.org log-in. Take advantage of these resources to supplement your OpenStax book.

Partner Resources

OpenStax Partners are our allies in the mission to make high-quality learning materials affordable and accessible to students and instructors everywhere. Their tools integrate seamlessly with our OpenStax titles at a low cost. To access the partner resources for your text, visit your book page on openstax.org.

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