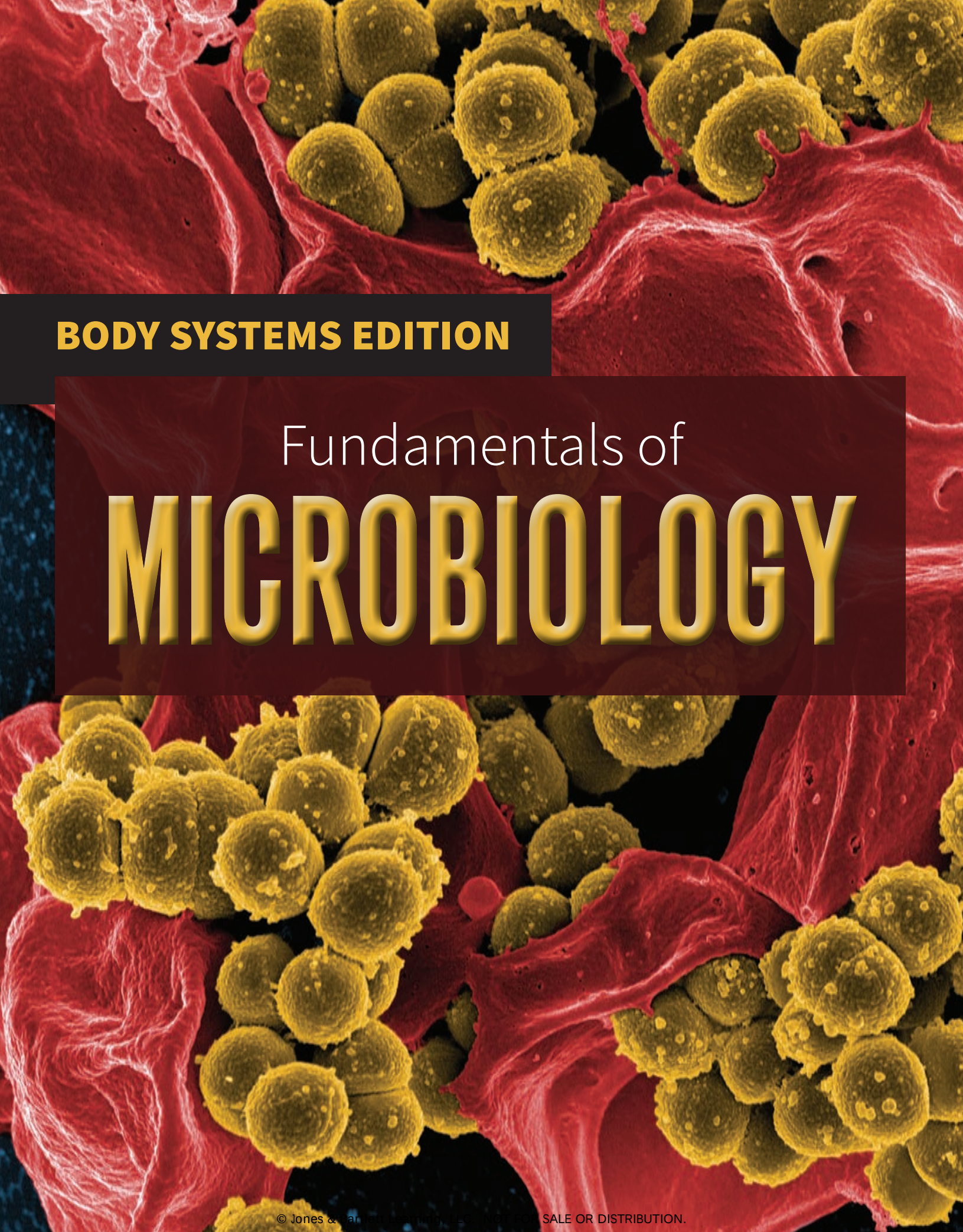

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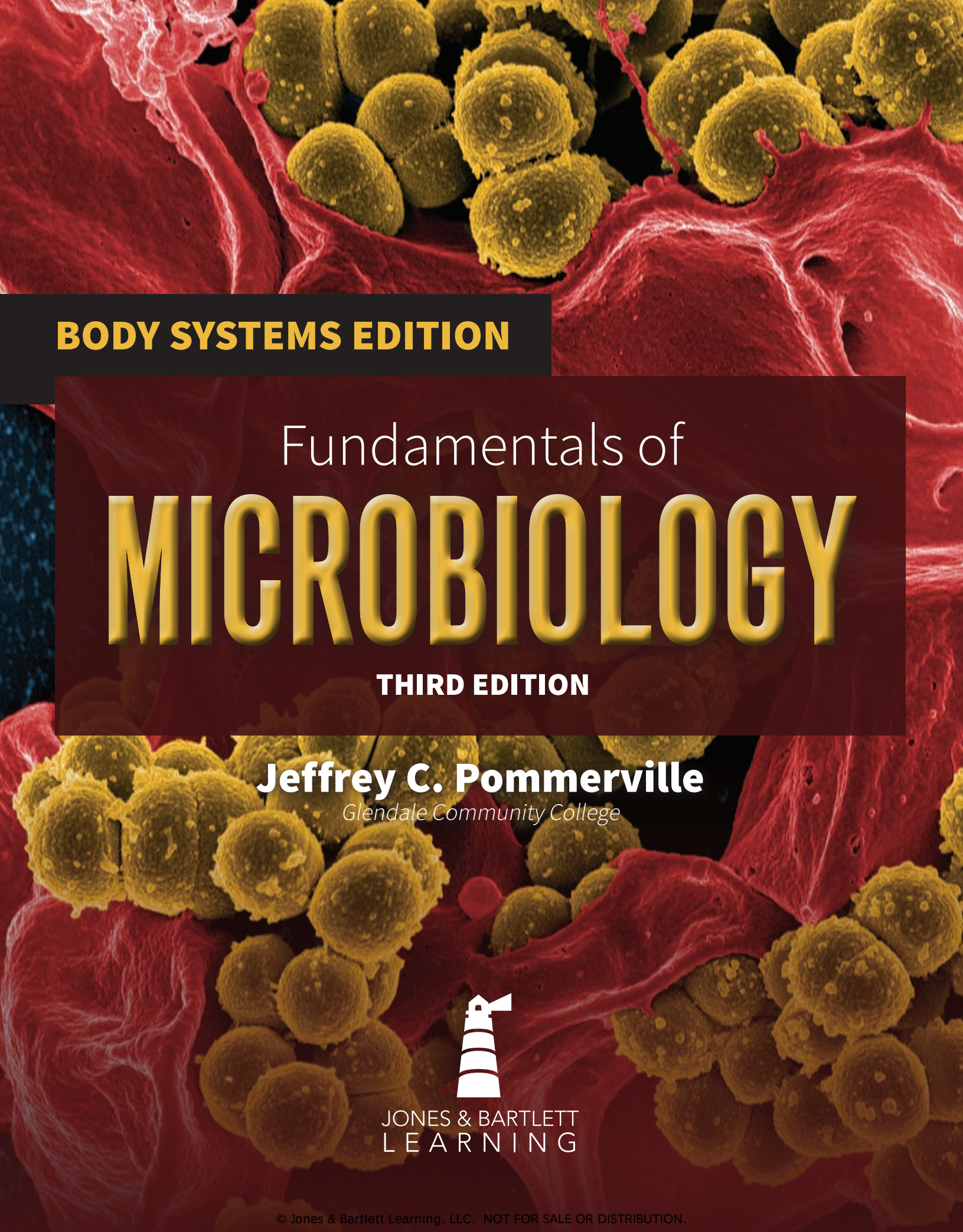

BODY SYSTEMS EDITION

Fundamentals of MICROBIOLOGY

THIRD EDITION

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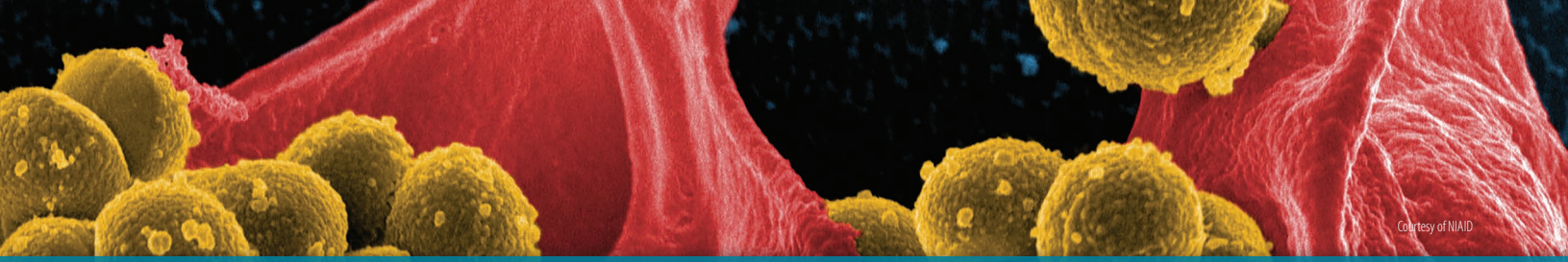

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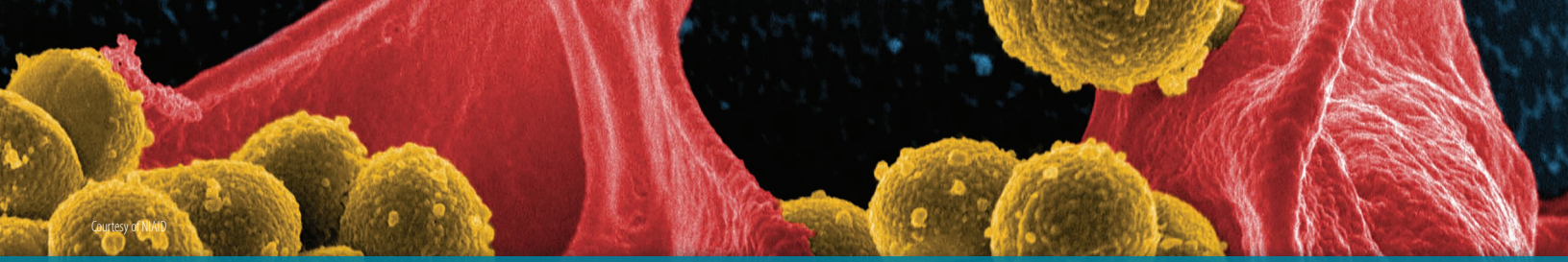

CONTENTS


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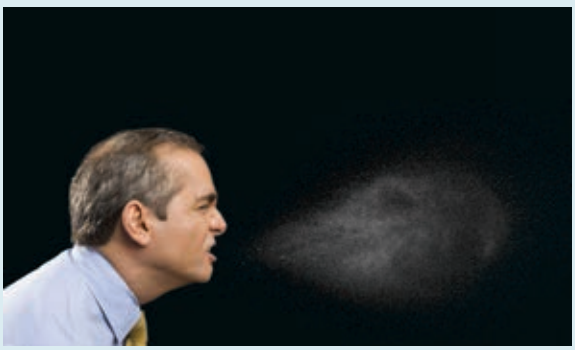

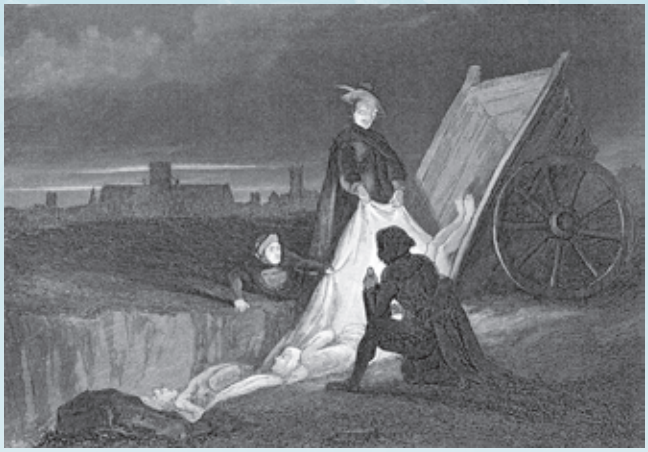

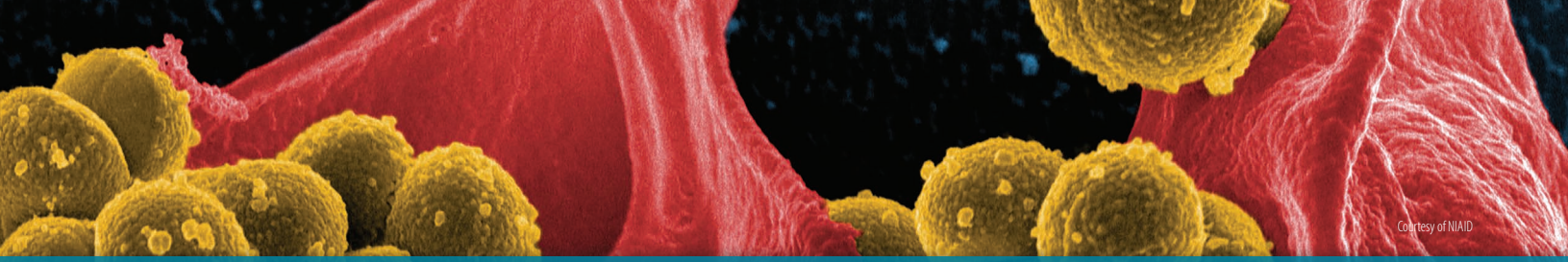
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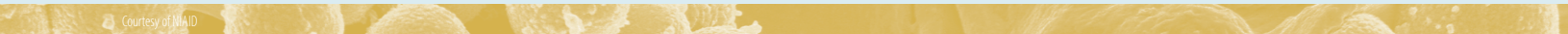
INDEX OF BOXED FEATURES

CLINICAL CASE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INVESTIGATING THE MICROBIAL WORLD

MICROINQUIRY

MICROBIOLOGY PATHWAYS

MICROFOCUS

Biotechnology

Environmental Microbiology

Clinical Microbiology

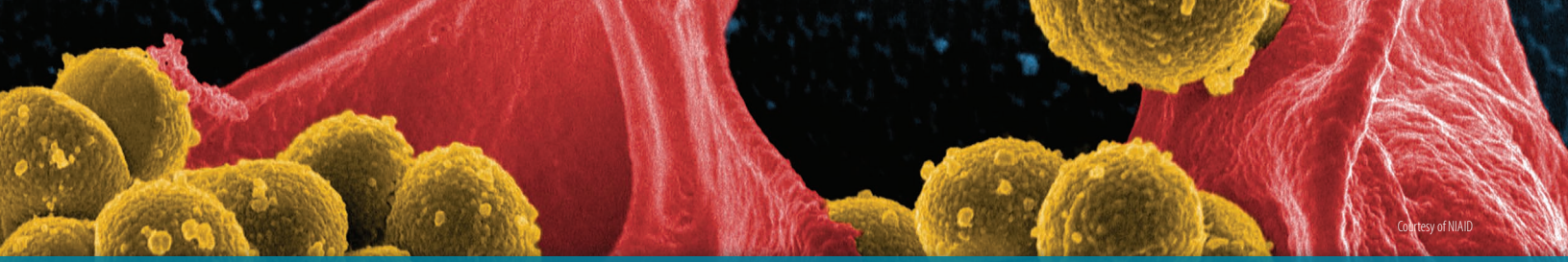
Public Health

History

Evolution

Tools

Being Skeptical



PREFACE

GOOD HEALTH MEANS BEING AN AMIABLE HOST

If you are hosting a party, you want to make sure your home is inviting to your guests. When the guests arrive, they tend to spread out through your home, with many typically finding the kitchen to be an inviting spot. The same holds true for your body. Each of us is home and host to an enormous community of long term guests, specifically microbes known as the human microbiome. And just as guests at a party usually far outnumber the hosts, the cells composing the microbiome outnumber our own human cells by at least 10 to 1. Of these microbial guests, the vast majority find the gut to be a very inviting spot.

You also make your party inviting by serving your guests food and drink. But suppose you only served vegan foods. Most of the meat-eating guests would shy away. Similarly, if you only had salami and roast beef, the vegans would draw back. In fact, depending on what foods you serve, guests may actually leave your party.

Well, the same holds true for your gut. Depending on your diet, your microbiome can change rapidly. More importantly, the change can have more serious consequences than some friends leaving your party. For example, if a group of individuals on their "normal" diet is switched to a diet rich in grains, fruits, and vegetables, there is a rapid rise in the number of bacteria producing chemicals known to reduce chronic inflammation in the digestive tract that is associated with inflammatory bowel diseases such as Crohn's disease and ulcerative colitis.

Alternatively, if another group is switched to a high meat, egg, and cheese diet, their gut microbiome changes within 24 hours, but in the long term to one linked with an increased risk of the chronic inflammatory conditions mentioned above. So, like the party, to be an amiable host to all your gut microbes, perhaps maintaining a varied diet—not overly animal dominated—is one very important factor to maintaining good health.

Ten years ago, few scientists and health experts would have predicted microbes had this ability to directly affect our health in beneficial and harmful ways. In fact, today we now know our human microbiome plays even more roles in our health and represents just one of the updated topics in this textbook that makes microbiology one of the most exciting and interesting sciences. It also shows why it is important for you, as a student of microbiology and a current/future healthcare professional, to understand the basics of microbiology and the means by which microbes can keep us healthy or make us more susceptible to disease.

Having taught microbiology for over 25 years, I know students going into nursing or an allied health field can struggle with some areas of science and biology, depending on their background. Importantly, this textbook is designed to be easily approachable by students with and without a strong biology background. To facilitate your studies and coordinate it with class material, I developed a "learning design" format for the textbook (described below) to make reading easier, studying more efficient, and learning uncomplicated. The design allows you to better evaluate your learning and provides you with the tools needed to probe your understanding—that is, chapter learning aids and assessment drills to evaluate your progress. Realize a prepared student knows her or his mastery before an exam—not as a result of the exam!

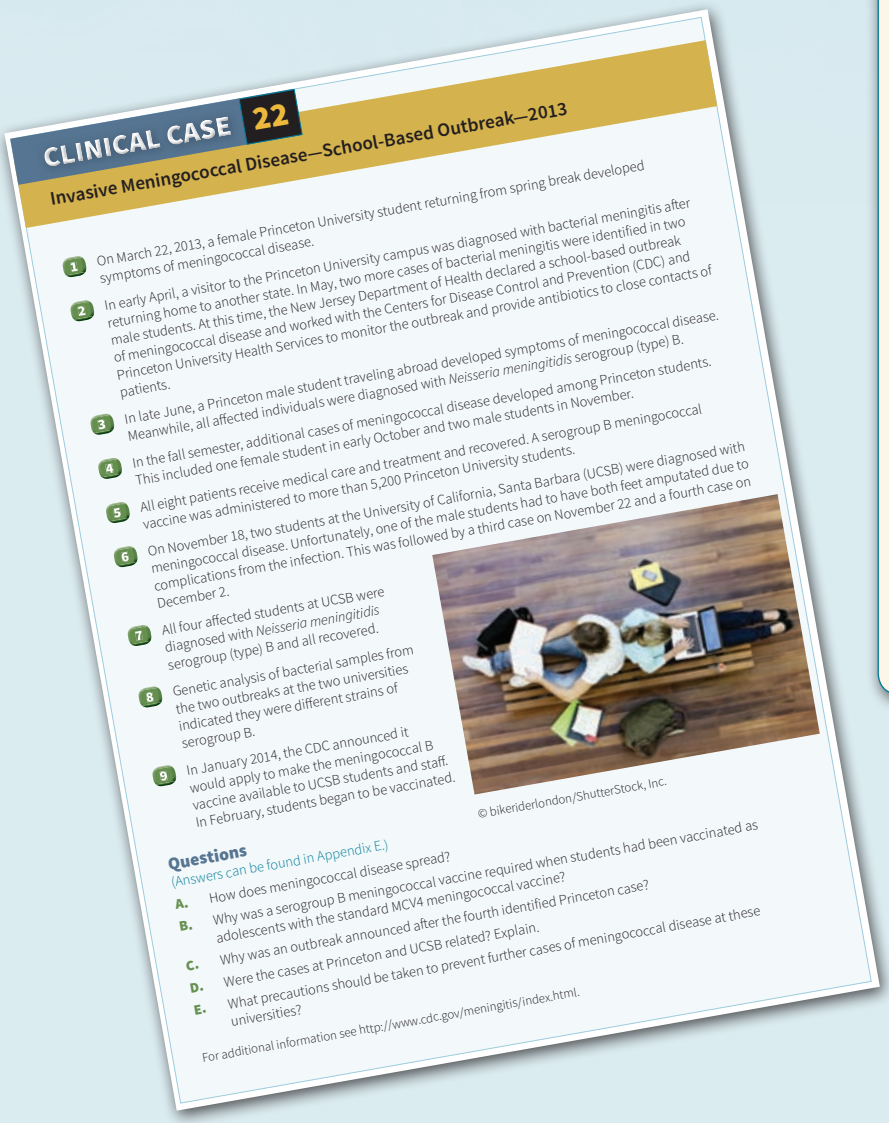
I am excited and honored that you are using and reading this new, third edition of *Fundamentals of Microbiology: Body Systems Edition*. I hope it is very useful in your studies and also enjoyable to read. Always take time to read the sidebars (MicroFocus boxes) whether they are assigned or not. They will help in your overall microbiology experience and the realization that microorganisms do rule the world!

WHAT'S NEW IN THIS EDITION

When you read this text, you get a global perspective on microbiology and infectious disease as found in no other similar textbook. The current edition has been updated with the latest scientific and education research, and has

incorporated many suggestions made by my colleagues, by emails received from microbiology instructors, and by my students. Along with these revisions, the visual aspects of the text have been improved to make the understanding of difficult concepts more approachable and the figures more engaging. What's new? Here is a summary list.

- **NEW** and revised **Clinical Cases** are embedded in all the chapters to help you understand pathogens by presenting contemporary human disease scenarios, many originally reported by the Centers for Disease Control and Prevention.



CLINICAL CASE 22

Invasive Meningococcal Disease—School-Based Outbreak—2013

1. On March 22, 2013, a female Princeton University student returning from spring break developed symptoms of meningococcal disease.
2. In early April, a visitor to the Princeton University campus was diagnosed with bacterial meningitis after returning home to another state. In May, two more cases of bacterial meningitis were identified in two male students. At this time, the New Jersey Department of Health declared a school-based outbreak of meningococcal disease and worked with the Centers for Disease Control and Prevention (CDC) and Princeton University Health Services to monitor the outbreak and provide antibiotics to close contacts of patients.
3. In late June, a Princeton male student traveling abroad developed symptoms of meningococcal disease. Meanwhile, all affected individuals were diagnosed with *Neisseria meningitidis* serogroup (type) B.
4. In the fall semester, additional cases of meningococcal disease developed among Princeton students. This included one female student in early October and two male students in November.
5. All eight patients receive medical care and treatment and recovered. A serogroup B meningococcal vaccine was administered to more than 5,200 Princeton University students.
6. On November 18, two students at the University of California, Santa Barbara (UCSB) were diagnosed with meningococcal disease. Unfortunately, one of the male students had to have both feet amputated due to complications from the infection. This was followed by a third case on November 22 and a fourth case on December 2.
7. All four affected students at UCSB were diagnosed with *Neisseria meningitidis* serogroup (type) B and all recovered.
8. Genetic analysis of bacterial samples from the two outbreaks at the two universities indicated they were different strains of serogroup B.
9. In January 2014, the CDC announced it would apply to make the meningococcal B vaccine available to UCSB students and staff. In February, students began to be vaccinated.

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Questions
(Answers can be found in Appendix E.)

A. How does meningococcal disease spread?
B. Why was a serogroup B meningococcal vaccine required when students had been vaccinated as adolescents with the standard MCV4 meningococcal vaccine?
C. Why was an outbreak announced after the fourth identified Princeton case?
D. Were the cases at Princeton and UCSB related? Explain.
E. What precautions should be taken to prevent further cases of meningococcal disease at these universities?

For additional information see http://www.cdc.gov/meningitis/index.html.

- **NEW Chapter Challenges** provide stimulating activities to extend your thinking beyond the basic concepts and ideas presented in each chapter. They will help you develop the critical thinking skills needed for your future career in nursing or an allied health field.

CHAPTER CHALLENGE

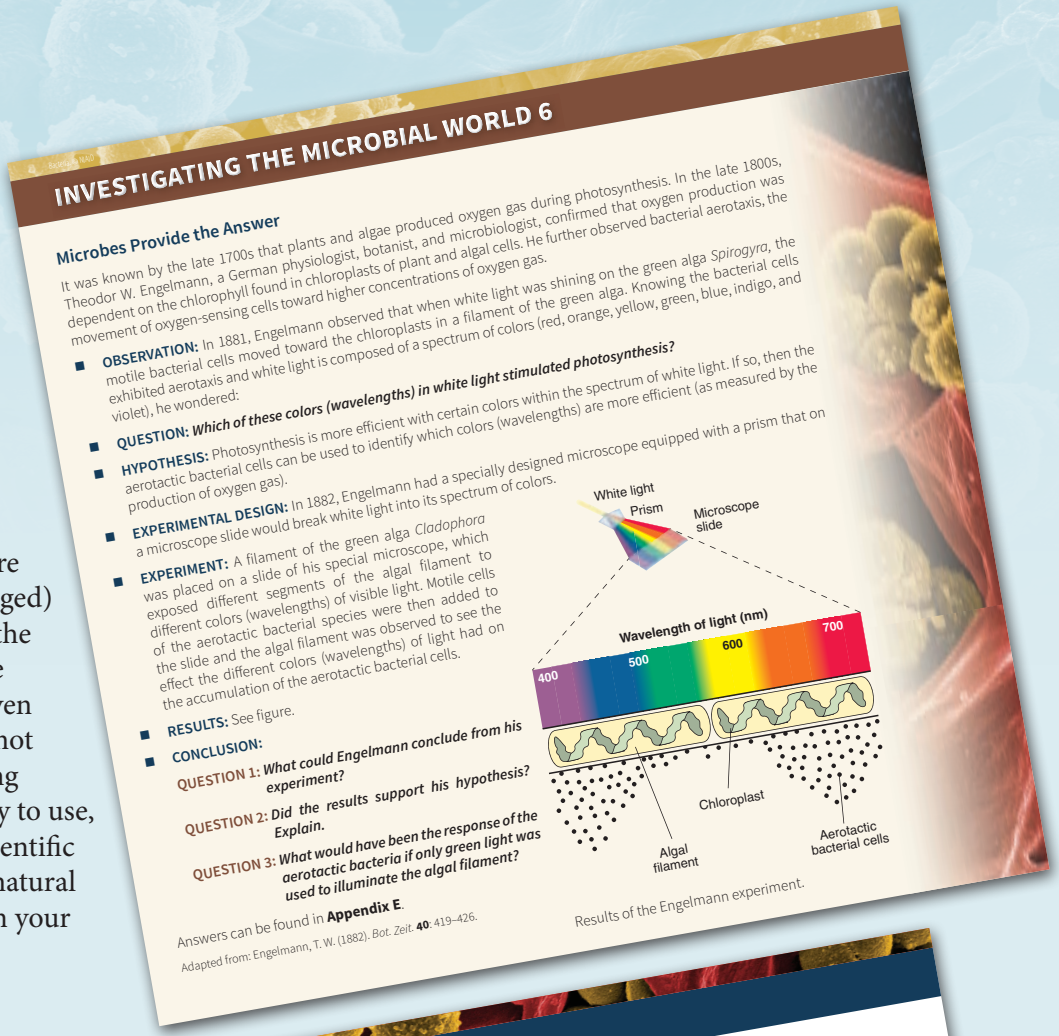
Viruses are often described as being on the edge of life, in some "limboland" between "life" and "nonlife." But on which side of the edge are they? Most biology textbooks use certain emergent properties of life to define something as a living organism. These properties include the ability to:

- Grow and develop
- Reproduce
- Establish a complex organization
- Regulate its internal environment (maintain homeostasis)
- Transform energy (light to chemical; chemical to cellular)
- Respond to the environment
- Evolve by adapting to a changing environment

So, are viruses alive? Let's consider this question as we study the viruses, their structure, and behavior in this chapter.

- **NEW Investigating the Microbial World boxes** are actual experiments (abridged) that require you to apply the process of science and use quantitative reasoning. Even though you probably are not going to become practicing microbiologists, the ability to use, interpret, and evaluate scientific data and evidence of the natural world will be important in your career.

- **NEW** and revised **MicroFocus boxes** explore interesting topics applying microbiology and microorganisms to the everyday world.



INVESTIGATING THE MICROBIAL WORLD 6

Microbes Provide the Answer

It was known by the late 1700s that plants and algae produced oxygen gas during photosynthesis. In the late 1800s, Theodor W. Engelmann, a German physiologist, botanist, and microbiologist, confirmed that oxygen production was dependent on the chlorophyll found in chloroplasts of plant and algal cells. He further observed bacterial aerotaxis, the movement of oxygen-sensing cells toward higher concentrations of oxygen gas.

- **OBSERVATION:** In 1881, Engelmann observed that when white light was shining on the green alga *Spirogyra*, the motile bacterial cells moved toward the chloroplasts in a filament of the green alga. Knowing the bacterial cells exhibited aerotaxis and white light is composed of a spectrum of colors (red, orange, yellow, green, blue, indigo, and violet), he wondered:
- **QUESTION: *Which of these colors (wavelengths) in white light stimulated photosynthesis?***
- **HYPOTHESIS:** Photosynthesis is more efficient with certain colors within the spectrum of white light. If so, then the aerotactic bacterial cells can be used to identify which colors (wavelengths) are more efficient (as measured by the production of oxygen gas).
- **EXPERIMENTAL DESIGN:** In 1882, Engelmann had a specially designed microscope equipped with a prism that on a microscope slide would break white light into its spectrum of colors.
- **EXPERIMENT:** A filament of the green alga *Cladophora* was placed on a slide of his special microscope, which exposed different segments of the algal filament to different colors (wavelengths) of visible light. Motile cells of the aerotactic bacterial species were then added to the slide and the algal filament was observed to see the effect the different colors (wavelengths) of light had on the accumulation of the aerotactic bacterial cells.
- **RESULTS:** See figure.
- **CONCLUSION:**

QUESTION 1: ***What could Engelmann conclude from his experiment?***

QUESTION 2: ***Did the results support his hypothesis? Explain.***

QUESTION 3: ***What would have been the response of the aerotactic bacteria if only green light was used to illuminate the algal filament?***

Answers can be found in **Appendix E**.

Adapted from: Engelmann, T. W. (1882). Bot. Zeit. **40**: 419–426.

Results of the Engelmann experiment.

MICROFOCUS 23.2: Public Health

A Newly Emerging Hemorrhagic Fever

In 2006, the Centers for Disease Control and Prevention (CDC) reported 37 cases of a unique hemorrhagic fever in U.S. travelers returning from destinations in the Indian Ocean and India—that is 34 more cases than had occurred in the previous 15 years. These travelers experienced fever, headache, fatigue, nausea, vomiting, muscle pain, and a skin rash—typical symptoms of dengue fever. However, unlike dengue, these patients also had incapacitating joint pain. The symptoms typically lasted a few days to a few weeks, although the joint pain sometimes lasted for many months. In the CDC cases, all recovered.

The disease experienced by these travelers was chikungunya (CHIK) fever (chikungunya means "to walk bent over," referring to the severe joint pain) caused by the disease. CHIK fever is caused by the chikungunya virus (CHIKV), a single-stranded (+ strand), enveloped RNA virus of the Togaviridae endemic to tropical East Africa and regions rimming the Indian Ocean. It is transmitted by mosquitoes. The 2006 outbreak on Réunion Island in the Indian Ocean affected more than 300,000 of the 780,000 inhabitants and, for the first time, CHIK fever had claimed a substantial number of lives; 240 fatalities were attributed directly or indirectly to CHIKV. It then spread to India where more than 1.5 million cases were reported. Today, more than 37 countries have reported CHIK fever cases (see map).

CHICKV spreads through the blood to the liver, muscles, brain, lymphatic tissues, and joints. There is no specific antiviral treatment for CHIK fever, so prevention consists of protecting individuals from mosquito bites and controlling the vector through insecticide spraying.

What makes this emerging disease especially worrisome is the spread of CHIKV to the Americas. In December 2013, the first case of CHIK fever was reported in the Caribbean. And it continues to spread. As of September 19, 2014, cases of Chikungunya fever have been identified in 34 countries or territories in the Caribbean, Central America, South America, and North America. There have been almost 730,000 suspected cases and nearly 11,000 laboratory-confirmed cases.

It is likely that the virus will continue to spread to new areas in the Americas through infected people and mosquitoes. In fact, the mosquitoes capable of transmitting CHIKV are found throughout much of the Americas, including parts of the United States. Because most people in these regions of the Americas are not immune, they can be infected and, through blood meals by female mosquitoes, infected individuals can spread the disease to more humans. By the time you read this, CHIK fever will certainly have spread in the U.S.

A digitally-colorized transmission electron micrograph of numerous Chikungunya viruses. (Bar = 100 nm.)

Courtesy of Cynthia Goldsmith, James A. Comer, and Barbara Johnson/CDC

- **NEW** and revised **MicroInquiry boxes** allow you to investigate (usually interactively) some important aspect of the chapter being studied.

MICROINQUIRY 22

The Last Push to Polio Eradication?

A global effort to eradicate polio began in the 1988 as the Global Polio Eradication Initiative. Stimulated by the recent success in eradicating smallpox from the globe and polio from the Americas in 1979, the World Health Organization, Rotary International, the Centers for Disease Control and Prevention, and UNICEF spearheaded the effort to rid the world by 2000 of a virus responsible for the majority of paralysis and disability in children. Although this goal was not met, significant progress was made. By 2000, annual reports of polio cases had fallen by more than 99%, to fewer than 1,000. By 2013, only three countries (Afghanistan, Pakistan, and Nigeria) were reporting endemic cases with only 89 cases between January and June of 2014. Thus, the Initiative succeeded in reducing cases through routine immunization of infants with the oral polio vaccine. However, eradication was not completed for several reasons. Remaining reservoirs of naturally occurring wild poliovirus have been difficult to eliminate in the endemic countries. Conflicts and wars have made it hard to move freely through the countries to ensure immunization has been accomplished. In India, the problem has been trying to vaccinate an enormously overcrowded and growing population, where poor sanitation and diarrheal diseases abound.

Basic biology has also hampered efforts to eradicate the virus. A new, circulating vaccine-derived poliovirus has emerged that reverted back to a virulent form similar to the parent strain from which the vaccine was originally produced. Although the outbreaks have been controlled through additional immunization campaigns, the emergence of these new virus strains is worrisome.

For these reasons, and that an increasing number of polio-free areas were becoming reinfected, the stakeholders in the global eradication of polio launched the Strategic Plan 2010–2012 for eradicating wild polio virus. Unfortunately, that plan did not reach its goal so a new Polio Eradication and Endgame Strategic Plan 2013–2018 has been developed to eradicate all types of polio disease simultaneously—both due to wild poliovirus and due to vaccine-derived polioviruses. Confidence in the plan appears high as global leaders and philanthropists have pledged over 75% of the $5.5 billion needed over these six years to accomplish the goal. An encouraging sign was announced in early 2014 when India, considered the most challenging place to attempt polio eradication, marked its third anniversary without a reported polio case. Hopefully, the new Strategic Plan 2013–2018 will soon bring the end to another devastating human disease.

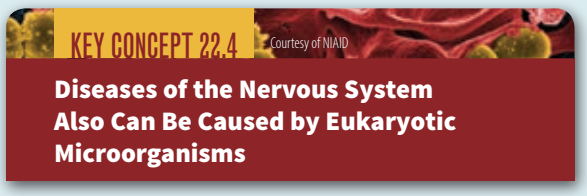
Discussion Point

According to the Polio Eradication and Endgame Strategic Plan 2013–2018, $5.5 billion is needed to finally eradicate polio by 2018. What might happen if it is not eradicated and immunizations were to stop? What does it say about potential future immunization campaigns for eradicating other diseases if this polio initiative fails?

Global Polio Cases, 2013. Cases are limited to three endemic countries (Nigeria, Pakistan, and Afghanistan and outbreaks in neighboring countries (Cameroon, Ethiopia, Somalia, Kenya, and Syria) due to importation.

Source: WHO; http://www.polioeradication.org/Dataandmonitoring.aspx.

- **NEW Key Concept** organization presents section statements identifying the important concepts in the upcoming section and alerts you to the significance of that written material.



KEY CONCEPT 22.4

Courtesy of NIAID

Diseases of the Nervous System Also Can Be Caused by Eukaryotic Microorganisms

- **NEW Chapter Self-Test** organization outlines the important concepts in the chapters through Bloom's Taxonomy, a classification of levels of intellectual skills important in learning. The four steps are:
  - **Step A: Review of Facts and Terms** are multiple-choice questions focusing on concrete "facts" learned in the chapter. Let's face it, there is information that needs to be memorized in order to reason critically.
  - **Step B: Concept Review** contains questions covering the major concepts in each chapter.
  - **Step C: Applications and Problems** are questions requiring students to reason critically through a problem of practical significance.
  - **Step D: Questions for Thought and Discussion** encourage students to use the text to resolve thought-provoking problems with contemporary relevance.

9. **Type IV cellular hypersensitivity** involves no antibodies, but is an exaggeration of cell-mediated immunity based in T lymphocytes. **Contact dermatitis** and **infection allergies** are manifestations of this hypersensitivity.

18.3 Autoimmune Disorders and Transplantation Are Immune Responses to "Self"

10. **Autoimmune disorders** can occur through defects in **clonal deletion**, **clonal anergy**, or **regulatory T-cell activity**. Human heredity, as well as access to **privileged sites** and **antigenic mimicry**, also can trigger an autoimmune response. (Fig. 18.14)
11. Four types of grafts or transplants can be performed: **autografts**, **isografts**, **allografts**, and **xenografts**. Allografts are the most common. Rejection of grafts or transplants involves cytotoxic T cells and antibodies. The graft also can be rejected by immune cells in the graft that reject the recipient (**graft-versus-host reaction**).
12. Prevention of rejection is strengthened by using immunosuppressive agents, including antimetabolites, immune cell inhibitors, anti-inflammatory drugs, and monoclonal antibodies.

18.4 Immunodeficiency Disorders Can Be Inherited or Acquired

13. **Immunodeficiency disorders** may be congenital (**primary immunodeficiencies**) or acquired later in life (**secondary immunodeficiencies**).
14. **AIDS** (**acquired immunodeficiency syndrome**) is the final stage of the HIV (human immunodeficiency virus) infection. HIV infects and destroys CD4 T cells, eventually leading to an inability of the immune system to fend off opportunistic diseases. Transmission is through blood, blood products, contaminated needles, or unprotected sexual intercourse. Many **antiretroviral drugs** are available to slow the progression of disease. (Figs. 18.19, 18.20)

CHAPTER SELF-TEST

For **STEPS A–D**, answers to questions and problems can be found in **Appendix D**.

STEP A: REVIEW OF FACTS AND TERMS

Multiple Choice

Read each question carefully, then select the ***one*** answer that best fits the question or statement.

1. All the following are types of immediate hypersensitivities except _____.
   A. asthma
   B. contact dermatitis
   C. food allergies
   D. hay fever
2. Systemic anaphylaxis is characterized by _____.
   A. contraction of smooth muscles
   B. a red rash
   C. blood poisoning
   D. hives
3. Which of the following is NOT a type I hypersensitivity?
   A. Food allergies
   B. Contact dermatitis
   C. Allergic rhinitis
   D. Exercise-induced allergies
4. The early response in asthma is due to _____ activity.
   A. cytotoxic T cell
   B. basophil
   C. T_H2 cell and NK cell
   D. dendritic cells

STEP B: CONCEPT REVIEW

26. Summarize the events occurring in and the role of humoral immunity in **type I hypersensitivities**. (**Key Concept 1**)
27. Explain the initiation and outcomes of **systemic anaphylaxis**. (**Key Concept 1**)
28. Distinguish between the different forms of **atopic disease**. (**Key Concept 1**)
29. Compare **asthma** to other forms of type I hypersensitivities. (**Key Concept 1**)
30. Discuss the reasons why allergies develop. (**Key Concept 1**)
31. Identify the therapies and treatments available for type I hypersensitivities. (**Key Concept 1**)
32. Summarize the characteristics of **type II hypersensitivity** and its relationship to blood transfusions and **hemolytic disease of the newborn**. (**Key Concept 2**)
33. Summarize the characteristics of **type III hypersensitivity** and its relationship to **serum sickness** and the **Arthus reaction**. (**Key Concept 2**)
34. Summarize the characteristics of **type IV hypersensitivity** and its relationship to **infection allergies** and **contact dermatitis**. (**Key Concept 2**)
35. Identify the ways in which an **autoimmune disease** can arise. (**Key Concept 3**)
36. Describe the immunological reasons why **organ transplants** are rejected and list the four types of grafts (transplants). (**Key Concept 3**)
37. Assess the usefulness of **immunosuppressive drugs** by transplant patients. (**Key Concept 3**)
38. Contrast **primary** and **secondary immunodeficiencies** and list several primary disorders and their accompanying immunological deficiencies. (**Key Concept 3**)
39. Diagram how the **human immunodeficiency virus** (**HIV**) infects a cell and identify the prevention and treatment methods used for **HIV disease** and **AIDS**. (**Key Concept 4**)

STEP C: APPLICATIONS AND PROBLEMS

40. During war and under emergency conditions, a soldier whose blood type is O donates blood to save the life of a fellow soldier with type B blood. The soldier lives, and after the war becomes a police officer. One day he is called to donate blood to a brother officer who has been wounded and finds that it is his old friend from the war. He gladly rolls up his sleeve and prepares for the transfusion. Should it be allowed to proceed? Why?
41. Coming from the anatomy lab, you notice your hands are red and raw and have begun peeling in several spots. This was your third period of dissection. What is happening to your hands, and what could be causing the condition? How will you solve the problem?
42. "He had a history of nasal congestion, swelling of his eyes, and difficulty breathing through his nose. He gave a history of blowing his nose frequently, and the congestion was so severe during the spring he had difficulty running." The person in this description is former President Bill Clinton, and the writer is an allergist from Little Rock, Arkansas. What condition (technically known as allergic rhinitis) is probably being described?

STEP D: QUESTIONS FOR THOUGHT AND DISCUSSION

43. As part of an experiment, one animal is fed a raw egg while a second animal is injected intravenously with a raw egg. Which animal is in greater danger? Why?
44. A woman is having the fifth injection in a weekly series of hay fever shots. Shortly after leaving the allergist's office, she develops a flush on her face, itching sensations of the skin, and shortness of breath. She becomes dizzy, then faints. What is taking place in her body, and why has it not happened after the first four injections?
45. You may have noted that brothers and sisters are allowed to be organ donors for one another, but a person cannot always donate to his or her spouse. Many people feel bad about being unable to help a loved one in time of need. How might you explain to someone in such a situation the basis for becoming an organ donor and why it may be impossible to serve as one?
46. The immune system is normally provides protection against disease. This chapter, however, seems to indicate that the immune system is responsible for numerous afflictions. Even the title is "Immune Disorders." Does this mean the immune system should be given a new name? On the other hand, is it possible all these afflictions are actually the result of the body's attempts to protect itself? Finally, why can the phrase "immune disorder" be considered an oxymoron?
47. In many diseases, the immune system overcomes the infectious agent, and the person recovers. In other diseases, the infectious agent overcomes the immune system, and death follows. Compare this broad overview of disease and resistance to what is taking place with AIDS, and explain why AIDS is probably unlike any other disease encountered in medicine.

CHAPTER-BY-CHAPTER REVISIONS

Each chapter of *Fundamentals of Microbiology: Body Systems Edition, Third Edition* has been carefully and thoroughly revised. In addition, new information pertinent to nursing and allied health has been added, while many figures and tables have been updated, revised, and/or reorganized for clarity. Here are the major changes to each chapter.

Chapter 1 Microbiology: Then and Now

- New introduction highlighting the microbial world
- Revised material on model systems
- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- Two new and one revised and updated MicroFocus feature
- One new photo, one new figure
- One figure revised for clarity

Chapter 2 The Chemical Building Blocks of Life

- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- New Investigating the Microbial World box
- One new photo
- One figure revised for clarity

Chapter 3 Concepts and Tools for Studying Microorganisms

- Rewritten section of classification
- Revised section on microbial identification
- Improved visual presentation of microscopy
- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- One MicroFocus feature revised and updated
- Four new photos
- One figure revised for clarity

Chapter 4 Structure of Bacterial and Archaeal Cells

- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- Two new MicroFocus features

Chapter 5 Microbial Growth and Nutrition

- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- One new and two revised MicroFocus features
- One new photo
- Four figures revised for clarity

Chapter 6 Microbial Metabolism

- Revised sections on cellular respiration and alternative energy sources
- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- New Investigating the Microbial World box

CHAPTER CHALLENGE

What do a termite's gut, a cow's rumen, and the warm, waterlogged soil in a rice paddy have in common? They all produce substantial amounts of methane (CH_4) gas. In Africa, Australia, and South America, there are large areas inhabited by mound-building termites whose mounds can be up to 9 meters tall. The methane gas produced from the termites in these mounds contributes some 5% of the atmospheric methane. Methane produced from ruminant livestock, like dairy cattle, goats, and sheep, is currently estimated to contribute 16% of the atmosph
However, rice production currently
approximately 20% of global methane
methane release from these three "n
account for more than 40% of the met
emitted every day into the atmospher
methane gas coming from? You have p
guessed—microbes! Still, how do ter
rumens, and waterlogged rice patty so
methane gas? Let's uncover the reason

CHAPTER CHALLENGE D

Hopefully you have figured out the chapter challenge. The reason all these animal and soil "environments" were producing methane gas was because the environments are highly anaerobic. The breakdown of cellulose (the polysaccharide) to glucose requires the anaerobes to use a different final electron acceptor to generate ATP through anaerobic respiration. For some of these microbes, especially the archaeal members, carbonate is the final electron acceptor, forming ATP and methane gas as a final end product.

Question D:
As a last step, use Figure 6.17 to trace the microorganism metabolism that these anaerobic microbes possess. Where do you end up?

Answers can be found in **Appendix F**.

Courtesy of NIAID

Chapter 7 Microbial Genetics

- Revised section on DNA replication
- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- New Investigating the Microbial World box
- New Clinical Case box
- Two MicroFocus features revised
- Five figures revised for clarity

Chapter 8 Gene Transfer, Genetic Engineering, and Genomics

- Revised section on conjugation
- More concise coverage of genetic engineering and its uses
- Revised section on comparative genomics with more information on microbial forensics
- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- Six figures revised for clarity and two updated
- One new table

Chapter 9 Control of Microorganisms: Physical and Chemical Methods

- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- One new figure and two figures revised for clarity

Chapter 10 Antimicrobial Drugs and Superbugs

Formerly Chapter 24

- Completely revised and updated material on antibiotics, including the CRE and NDM superbugs
- Chapter Self-Test redesigned
- New Chapter Challenge with five follow up challenges
- New Investigating the Microbial World box
- One new and two revised MicroFocus features
- Two new photos, three new figures
- Seven figures revised for clarity and four tables revised

Chapter 11 Microbial Systematics and the Domains Bacteria and Archaea

- Material on microbial systematics shortened
- Improved coverage of mutations and horizontal gene transfer
- Chapter Self-Test redesigned

TABLE 8.3 Some of the Therapeutic Products of Biotechnology and Their Functions

Product	Function
Replacement Proteins and Hormones	
Factors VII, VIII, IX	Replace clotting factors missing in hemophiliacs
Growth hormone (HGH)	Replaces missing hormone in people with short stature
Insulin	Treatment of insulin-dependent diabetes
Therapeutic Proteins, Hormones, and Enzymes	
Epidermal growth factor (hEGF)	Promotes wound healing
Granulocyte colony stimulating factor (hG-CSF)	Used to stimulate white blood cell production in cancer and AIDS patients
Interferon-alpha (IFN-α)	Used with other antiviral agent to fight viral infections and some cancers
Tissue plasminogen activator (TPA)	Dissolves blood clots; prevents blood clotting after heart attacks and strokes
DNase I	Treatment of cystic fibrosis

- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- One new MicroFocus feature
- One new figure and two figures revised for clarity

Chapter 12 Eukaryotic Microorganisms: The Protists, Fungi, and Helminths

- Revised material on the classification of the protists
- Condensed coverage of fungal classification
- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- New Investigating the Microbial World box
- One new photo
- Five figures revised for clarity and one table revised

Chapter 13 The Viruses and Virus-Like Agents

- Improved coverage of the history of virology
- Amended coverage of virus replication
- Updated coverage of viruses and cancer
- Chapter Self-Test redesigned

- New Chapter Challenge with five follow up challenges
- New Investigating the Microbial World box
- Four MicroFocus features revised
- One new figure and seven figures revised for clarity

Chapter 14 Infection and Disease

- Reorganized sections on the stages and progression of infectious disease
- Updated and revised information on epidemiology
- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- One new and two revised and updated MicroFocus features
- Seven figures revised for clarity and two updated
- Two new tables

Chapter 15 Resistance and the Immune System: Introduction and Innate Immunity

- Material on the white bloods cells restructured
- Complement coverage simplified

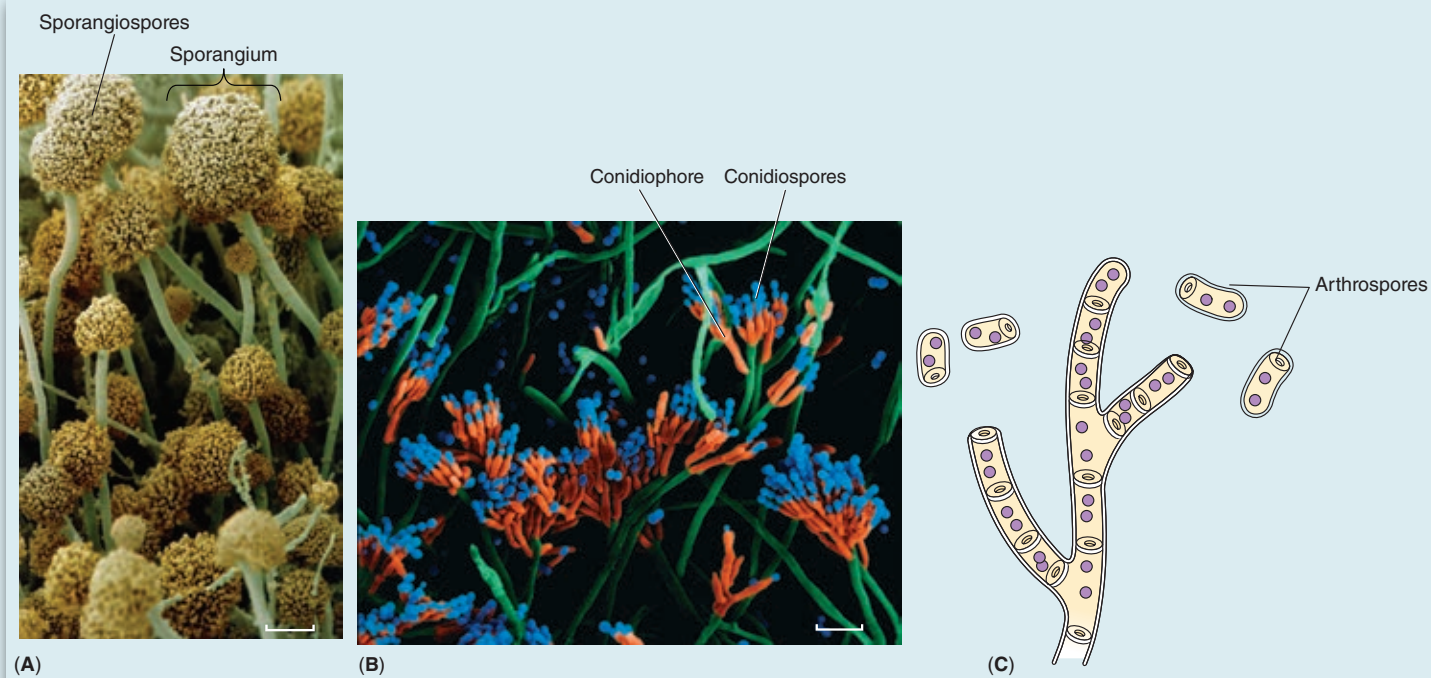


FIGURE 12.11 **Fungal Fruiting Bodies. (A)** A false-color scanning electron micrograph of sporangia of the common bread mold *Rhizopus.* Each round sporangium contains thousands of sporangiospores. (Bar = 20 μm.) **(B)** A false-color scanning electron micrograph of conidiophores and conidia in *Penicillium roqueforti.* (Bar = 20 μm.) **(C)** Some fungi produce arthrospores by simple fragmentation of the hyphae. **Why must fungal spores be elevated on the tips of hyphae?**

- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- New Investigating the Microbial World box
- One MicroFocus feature revised
- One new figure and three figures revised for clarity

Chapter 16 Resistance and the Immune System: Adaptive Immunity

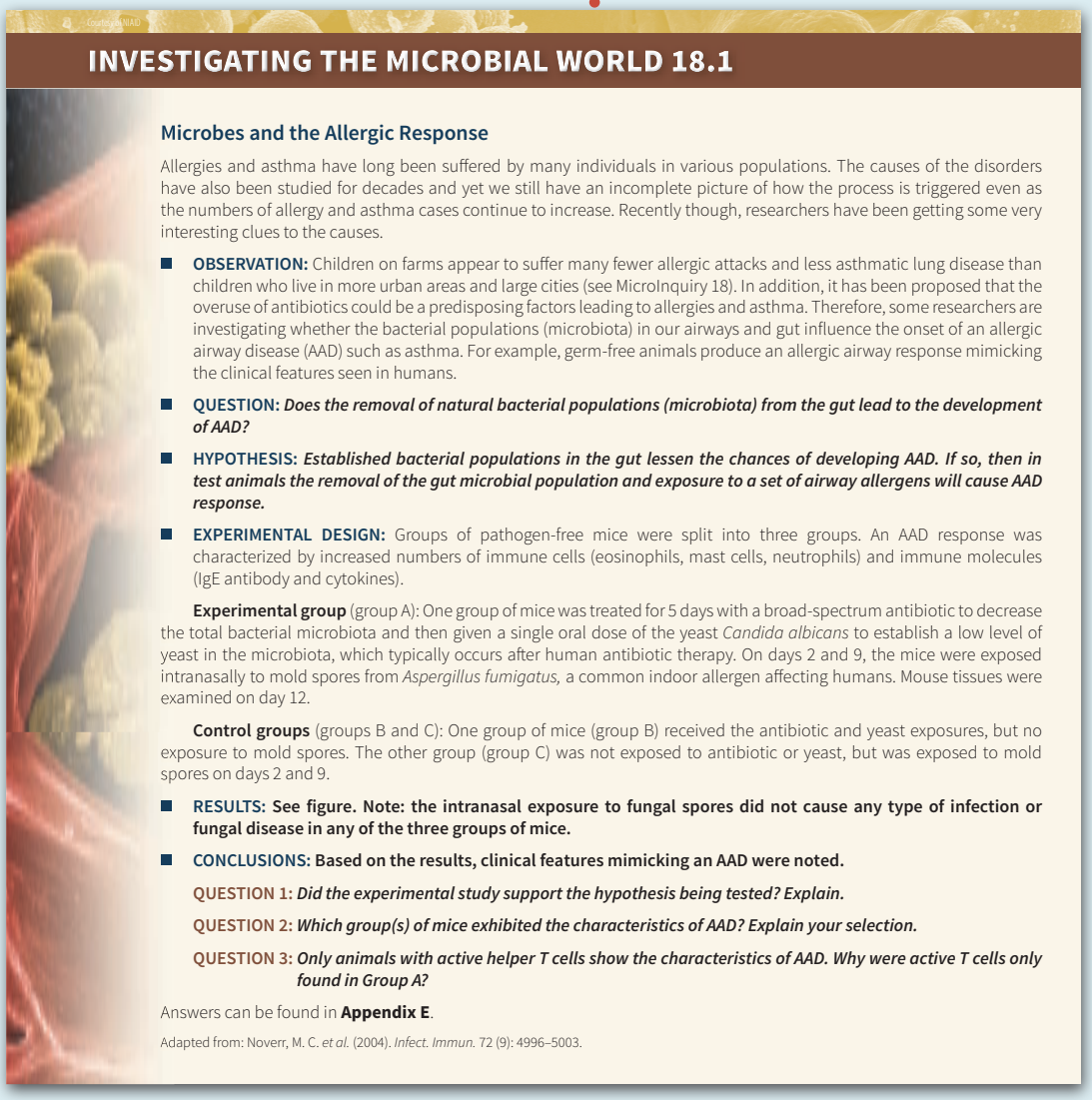
- Improved coverage of cell-mediated immunity
- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- Six figures revised

Chapter 17 Immunity and Serology

- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- Two MicroFocus features revised
- One new photo
- Five figures revised and two updated
- One table updated

Chapter 18 Immune Disorders and AIDS

- Improved coverage of hypersensitivities
- Updated coverage of AIDS
- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box



INVESTIGATING THE MICROBIAL WORLD 18.1

Microbes and the Allergic Response

Allergies and asthma have long been suffered by many individuals in various populations. The causes of the disorders have also been studied for decades and yet we still have an incomplete picture of how the process is triggered even as the numbers of allergy and asthma cases continue to increase. Recently though, researchers have been getting some very interesting clues to the causes.

- **OBSERVATION:** Children on farms appear to suffer many fewer allergic attacks and less asthmatic lung disease than children who live in more urban areas and large cities (see MicroInquiry 18). In addition, it has been proposed that the overuse of antibiotics could be a predisposing factors leading to allergies and asthma. Therefore, some researchers are investigating whether the bacterial populations (microbiota) in our airways and gut influence the onset of an allergic airway disease (AAD) such as asthma. For example, germ-free animals produce an allergic airway response mimicking the clinical features seen in humans.
- **QUESTION:** ***Does the removal of natural bacterial populations (microbiota) from the gut lead to the development of AAD?***
- **HYPOTHESIS:** ***Established bacterial populations in the gut lessen the chances of developing AAD. If so, then in test animals the removal of the gut microbial population and exposure to a set of airway allergens will cause AAD response.***
- **EXPERIMENTAL DESIGN:** Groups of pathogen-free mice were split into three groups. An AAD response was characterized by increased numbers of immune cells (eosinophils, mast cells, neutrophils) and immune molecules (IgE antibody and cytokines).

Experimental group (group A): One group of mice was treated for 5 days with a broad-spectrum antibiotic to decrease the total bacterial microbiota and then given a single oral dose of the yeast *Candida albicans* to establish a low level of yeast in the microbiota, which typically occurs after human antibiotic therapy. On days 2 and 9, the mice were exposed intranasally to mold spores from *Aspergillus fumigatus,* a common indoor allergen affecting humans. Mouse tissues were examined on day 12.

Control groups (groups B and C): One group of mice (group B) received the antibiotic and yeast exposures, but no exposure to mold spores. The other group (group C) was not exposed to antibiotic or yeast, but was exposed to mold spores on days 2 and 9.

- **RESULTS: See figure. Note: the intranasal exposure to fungal spores did not cause any type of infection or fungal disease in any of the three groups of mice.**
- **CONCLUSIONS: Based on the results, clinical features mimicking an AAD were noted.**

QUESTION 1: ***Did the experimental study support the hypothesis being tested? Explain.***

QUESTION 2: ***Which group(s) of mice exhibited the characteristics of AAD? Explain your selection.***

QUESTION 3: ***Only animals with active helper T cells show the characteristics of AAD. Why were active T cells only found in Group A?***

Answers can be found in **Appendix E**.

Adapted from: Noverr, M. C. *et al.* (2004). *Infect. Immun.* 72 (9): 4996–5003.

- One new MicroFocus feature
- Revised MicroInquiry box
- One new figure and five figures revised for clarity

Chapter 19 Infectious Diseases Affecting the Skin and Eyes

- Enhanced coverage of the skin microbiome
- More concise coverage of skin diseases caused by bacteria, viruses, fungi, and parasites
- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box
- One MicroFocus feature revised
- Seven new photos
- One figure revised for clarity and five tables revised

Chapter 20 Infectious Diseases Affecting the Respiratory System

- Updated information on the respiratory microbiome
- New discussion of pertussis outbreaks
- Updated information on flu virus types and transmission
- Updated information on MERS
- Chapter Self-Test redesigned
- New Chapter Challenge with five follow up challenges
- New Investigating the Microbial World box
- Two new and three revised and updated MicroFocus features
- Revised and updated MicroInquiry box
- Two new photos and three new figures
- Five figures revised and two tables revised and updated

Chapter 21 Infectious Diseases Affecting the Digestive System

- Updated information and more discussion on the gut microbiome
- More coverage of *Clostridium difficile* and norovirus infections
- Better coverage of intestinal helminths
- Chapter Self-Test redesigned
- New Chapter Challenge with eight follow up challenges
- New Investigating the Microbial World box
- Two new and one revised MicroFocus feature
- Two new photos, three new figures
- Four figures revised and three tables revised

Chapter 22 Infectious Diseases Affecting the Nervous System

- Updated coverage of meningitis and recent outbreaks
- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- New Investigating the Microbial World box
- New Clinical Case box
- One new and one revised MicroFocus feature
- Two new figures
- Four figures revised and two tables revised

Chapter 23 Cardiovascular, Lymphatic, and Systemic Infectious Diseases

- Updated coverage of emerging hemorrhagic fevers
- Chapter Self-Test redesigned
- New Chapter Challenge with five follow up challenges
- New Investigating the Microbial World box
- One MicroFocus feature revised and updated
- One new photo
- Two figures revised and three tables revised

Chapter 24 Infectious Diseases Affecting the Urinary and Reproductive Systems

- Revised organization of material on urinary tract infections
- Updated material on STDs
- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- New Investigating the Microbial World box

- Three MicroFocus features revised and updated
- Three figures revised and three tables revised

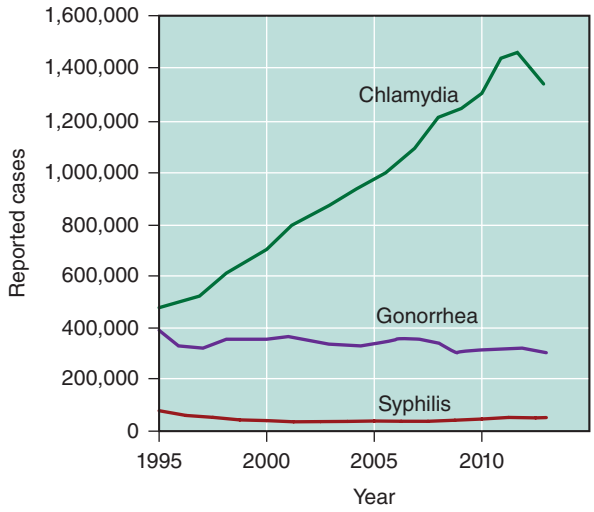


FIGURE 24.8 Incidence of Chlamydia, Gonorrhea, and Syphilis—United States and U.S. Territories, 1995–2013. In 2012, more than 1.4 million cases of chlamydia were reported to the CDC, the largest number of cases ever reported to CDC for any condition.

» Provide a few reasons for the explosive increase in chlamydia infections in comparison to those for gonorrhea and syphilis.

Chapter 25 Allied and Industrial Microbiology

- Chapter material organized around food spoilage, food preservation, and industrial uses of microbes in food production (fermentation)
- Chapter Self-Test redesigned
- New Chapter Challenge with four follow up challenges
- New Investigating the Microbial World box
- One new MicroFocus feature and one MicroFocus feature revised and updated
- Seven new photos, three new figures, and two new tables

Chapter 26 Environmental Microbiology

Chapter completely revised to incorporate some material from previous edition Chapter 27

- Chapter material organized around water pollution, water and sewage treatment, and microbial roles in biogeochemical recycling in the environment
- Chapter Self-Test redesigned
- New Chapter Challenge with three follow up challenges
- New Investigating the Microbial World box

THE STUDENT EXPERIENCE

A GLOBAL PERSPECTIVE

Many decades ago, nursing and allied health students studying microbiology only needed to be concerned about infectious diseases as related to their community or geographic region. Today, with global travel, diseases from halfway around the world can be at our doorstep almost overnight. Therefore, students need a more global perspective of infectious disease and an understanding and familiarity with these diseases, which are presented no better than in this text.

MICROFOCUS features, such as public health articles, provide students with the information and understanding they need. Each article, such as the one about an emerging hemorrhagic fever, provides the background and significance needed for students to be informed and conversant. See page xvii for the complete list of Public Health boxes.

Courtesy of NIAID

MICROFOCUS 23.2: Public Health

A Newly Emerging Hemorrhagic Fever

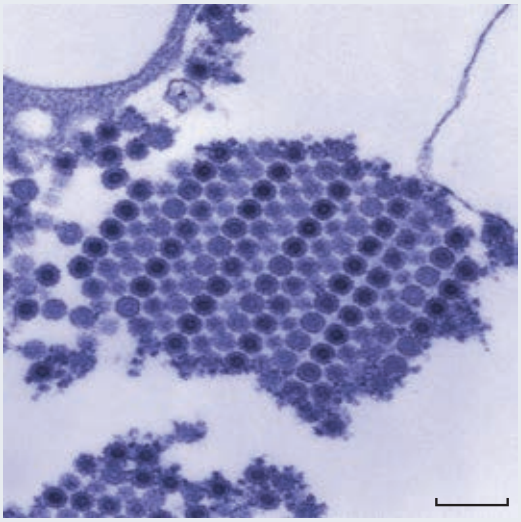
In 2006, the Centers for Disease Control and Prevention (CDC) reported 37 cases of a unique hemorrhagic fever in U.S. travelers returning from destinations in the Indian Ocean and India—that is 34 more cases than had occurred in the previous 15 years. These travelers experienced fever, headache, fatigue, nausea, vomiting, muscle pain, and a skin rash—typical symptoms of dengue fever. However, unlike dengue, these patients also had incapacitating joint pain. The symptoms typically lasted a few days to a few weeks, although the joint pain sometimes lasted for many months. In the CDC cases, all recovered.

The disease experienced by these travelers was chikungunya (CHIK) fever (chikungunya means "to walk bent over," referring to the severe joint pain) caused by the disease. CHIK fever is caused by the chikungunya virus (CHIKV), a single-stranded (+ strand), enveloped RNA virus of the Togaviridae endemic to tropical East Africa and regions rimming the Indian Ocean. It is transmitted by mosquitoes. The 2006 outbreak on Réunion Island in the Indian Ocean affected more than 300,000 of the 780,000 inhabitants and, for the first time, CHIK fever had claimed a substantial number of lives; 240 fatalities were attributed directly or indirectly to CHIKV. It then spread to India where more than 1.5 million cases were reported. Today, more than 37 countries have reported CHIK fever cases (see map).

CHICKV spreads through the blood to the liver, muscles, brain, lymphatic tissues, and joints. There is no specific antiviral treatment for CHIK fever, so prevention consists of protecting individuals from mosquito bites and controlling the vector through insecticide spraying.

What makes this emerging disease especially worrisome is the spread of CHIKV to the Americas. In December 2013, the first case of CHIK fever was reported in the Caribbean. And it continues to spread. As of September 19, 2014, cases of Chikungunya fever have been identified in 34 countries or territories in the Caribbean, Central America, South America, and North America. There have been almost 730,000 suspected cases and nearly 11,000 laboratory-confirmed cases.

It is likely that the virus will continue to spread to new areas in the Americas through infected people and mosquitoes. In fact, the mosquitoes capable of transmitting CHIKV are found throughout much of the Americas, including parts of the United States. Because most people in these regions of the Americas are not immune, they can be infected and, through blood meals by female mosquitoes, infected individuals can spread the disease to more humans. By the time you read this, CHIK fever will certainly have spread in the U.S.



A digitally-colorized transmission electron micrograph of numerous Chikungunya viruses. (Bar = 100 nm.)

Courtesy of Cynthia Goldsmith, James A. Comer, and Barbara Johnson/CDC.

CLINICAL CASES also provide the global experience essential for student achievement and career success. These cases, such as the one on dengue fever, illustrate how a disease originally found in another part of the world has rapidly made it to our doorstep. See page xv for the complete list of Clinical Cases.

CLINICAL CASE 14

Locally Acquired Dengue Fever

Courtesy of Prof. Frank Hadley Collins, Director, Center for Global Health and Infectious Diseases, University of Notre Dame/CDC.

1. A previously healthy, 34-year-old woman in Rochester, New York, went to her primary care physician complaining of fever, headache, malaise, and chills. She told the physician the symptoms had appeared 24 hours earlier. A urine sample was taken for analysis.
2. Two days later, the patient returned to her physician. Her fever had abated but she had a more severe headache, severe pain behind the eyes that worsened on eye movement, and a feeling of light-headedness. Her urinalysis report indicated bacterial cells and red blood cells were present in the urine. She was referred to a local hospital emergency department.
3. The emergency room evaluation showed all vital signs were normal. A complete blood cell workup revealed a low white blood cell and platelet count and a normal hematocrit. A CT scan and cerebral spinal fluid (CSF) from a lumbar puncture were normal. Because her light-headedness disappeared, she was discharged from the emergency department.
4. Four days later, the patient returned to her primary care physician expressing the feeling that she just didn't feel good. Although all vital signs were normal, petechiae (tiny purplish-red spots due to blood hemorrhages) were noted on her lower extremities.
5. A consultation with an infectious disease specialist suggested the patient could have dengue fever. Questioning the patient, it was evident she had not traveled to any dengue-endemic area in the world. She did state that prior to the onset of symptoms she had just returned from a trip to Key West, Florida. While there, she had been bitten several times by mosquitoes. A serum sample from the patient was tested for antibodies to dengue fever virus. The results were positive. Confirmatory testing of serum and CSF samples was done by the Centers for Disease Control and Prevention (CDC) in Atlanta. Both samples were positive for antibodies against dengue fever virus.
6. Two days later the patient reported to her physician that she was feeling much better. She had completely recovered when interviewed by the Monroe County (Florida) Health Department on September 1.
7. Further investigation identified another 24 cases of dengue fever, all locally acquired in the Key West area.

Questions:
Answers can be found in **Appendix E**.

A. Why was a urine sample taken for analysis?
B. Why didn't the original CSF sample indicate a dengue fever infection?
C. What sign indicated to the infectious disease specialist that the patient might have dengue fever?
D. Considering the number of dengue fever cases in Key West, what measures should be taken to lessen and control the outbreak?

For additional information see http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5919a1.htm.

CHAPTER CHALLENGE

Foodborne illnesses are a major cause of infectious disease in the United States. Every year there are an estimated 48 million foodborne infections, leading to 128,000 hospitalizations and 3,000 deaths. Yet many of us don't think about food safety until we or someone we know gets sick from eating contaminated food or drinking contaminated water. Because everyone is at risk for food poisoning, we need to think about ways we can try to reduce the risk and prevent illnesses of the digestive system. As we describe many of the more common foodborne and waterborne infections, let's try to think of ways to prevent such infections from the farm to the table.

REAL-LIFE APPLICATIONS

Some concepts and ideas in microbiology can be daunting and, at times, abstract to students studying the science. Providing students with real-life examples helps them see the significance of the concept and its application in the real world, be it their local community or worldwide.

CHAPTER CHALLENGES help students connect text material to the outside world while at the same time building their critical thinking skills. For example, foodborne illnesses are a growing concern locally, nationally, and globally. Yes, there are diseases associated with such food infections, but what about the prevention strategies? This and other chapter challenges help students see "beyond the textbook" to the real world.

INVESTIGATING THE MICROBIAL WORLD introduces students to real world science. Although most students will not be entering the research field, the nursing and allied health arenas require that they have a familiarity with how science is done. The examples in each chapter vary from basic to applied science experiments, and as in the IMW on urinary tract infections, often have real world (and personal) implications. See page xv for the complete list of IMW boxes.

INVESTIGATING THE MICROBIAL WORLD 24

Does Cranberry Juice Cure Urinary Tract Infections?

Urinary tract infections (UTIs), such as cystitis, are an unpleasant illness. Besides the increased urge to urinate, there often is a burning sensation when one does urinate. Although the infection and symptoms can resolve without medical treatment, there is a 24% chance of a recurrence within 6 months.

- **OBSERVATIONS:** The cranberry and especially cranberry products, such as cranberry juice or cranberry capsules, have been considered, or even touted, by many as an effective home treatment for UTIs, or to prevent UTIs from recurring. Proponents say that cranberry products work by acidifying the urine, which would make the urinary tract less hospitable to pathogens like *Escherichia coli*, the most common cause of UTIs. Also, the sugar (fructose) and proanthocyanidins in cranberries may interfere with the ability of the pili on *E. coli* cells to adhere to the cells lining the urinary tract. Opponents say the evidence is less than compelling and too anecdotal. In addition, good quality, randomized, double-blind, and placebo-controlled studies on the effects of cranberries have not been undertaken.
- **QUESTION:** ***Does cranberry juice prevent recurrent UTIs?***
- **HYPOTHESIS:** Regular drinking of cranberry juice cocktail (CJC) will reduce the likelihood of recurrent UTIs. If so, then a randomized, double-blind comparison of the efficacy of CJC and placebo juice on women with an acute UTI should reduce the rate and duration of UTI symptoms.
- **EXPERIMENTAL DESIGN:** Out of 419 college women enrolled, 319 had a positive urine culture for a UTI. The experimental juice consisted of a formulated low-calorie CJC (27% juice) with a standardized proanthocyanidins component. The placebo juice was formulated to imitate the flavor (sugar and acidity) and color of cranberry juice but without any cranberry or proanthocyanidin content.
- **EXPERIMENT:** The 319 women were randomly split into two groups. One group (155 women) drank two 8 oz. glasses of CJC twice daily for 6 months. The other group (164 women) drank two 8 oz. glasses of placebo juice twice daily for 6 months. Neither the participants nor investigators knew which group was drinking which juice. Compliance was based on self-reporting.

The clinical assessment consisted of analyzing clean-catch, mid-stream urine specimens from the participants at the beginning of the study, and at 3 and 6 months. Self-collected vaginal and rectal specimens were cultured for *E. coli* pathogens. Participants also completed questionnaires at the beginning of the study, and at 3 and 6 months, regarding any UTI symptoms as well as other pertinent medical information.

- **RESULTS:** See figure. Of the 319 participants that started the study, 230 completed the entire study (116 in the CJC group and 114 in the placebo group). The presence of urinary and vaginal symptoms over the course of the study was similar between the two groups. A positive UTI was based on a combination of symptoms and a urine culture positive for a known uropathogen. Gastrointestinal symptoms were twice as frequent in the placebo group as in the CJC group.

CONCLUSIONS:

QUESTION 1: ***Was the hypothesis validated? Explain using the figure.***

Question 2: ***Explain why this was a (a) randomized, (b) double-blind, and (c) placebo-controlled study.***

QUESTION 3: ***Can you think of any problems or caveats in the set up and performance of this study that could make the results questionable?***

Answers can be found online in **Appendix F**.

Adapted from: Barbosa-Cesnik, C. *et al.* (2011). *Clin Infect Dis* **52** (1):23–30.

Risk of a recurring UTI by history and juice assignment.

Adapted from: Barbosa-Cesnik, C. et al. (2011). Clin. Infect. Dis. 52 (1): 23–30.

PRACTICE THROUGH THINKING AND DISCUSSING

One of the best ways to ensure mastery of a topic is through further thought and conversation. Again, the application to what a student has read will not only indicate if they have mastered the material, but also strengthen their critical thinking skills.

Many of the **MICROINQUIRY BOXES**, such as the one on smallpox, provide an opportunity for students to discuss what they have just read—and may ask for an opinion.

MICROINQUIRY 19

"Should We or Shouldn't We?"

One of the liveliest global debates in microbiology is whether the last remaining stocks of smallpox viruses in Russia and the United States should be destroyed. Here are some of the arguments.

For Destruction

- People are no longer vaccinated, so if the virus should escape the laboratory, a deadly epidemic could ensue.
- The DNA of the virus has been sequenced and many cloned fragments are available for performing research experiments; therefore, the whole virus is no longer necessary.
- The elimination of the remaining stocks of laboratory virus will eradicate the disease and complete the project.
- No epidemic resulting from the theft or accidental release of the virus can occur if the remaining stocks are destroyed.
- If the United States and Russia destroy their smallpox stocks, it will send a message saying biological warfare will not be tolerated.

Against Destruction

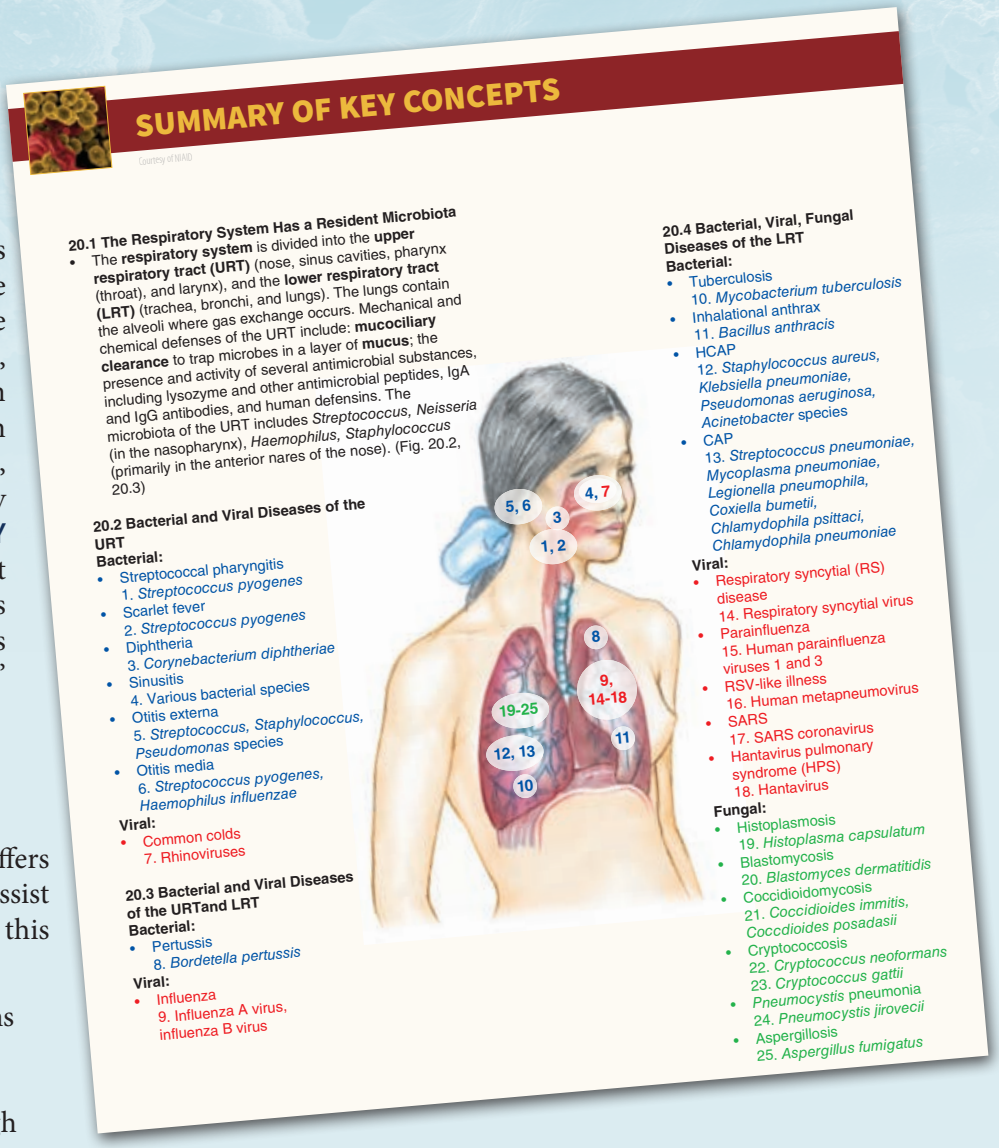
- Future studies of the virus are impossible without the whole virus. Indeed, certain sequences of the viral genome defy deciphering by current laboratory means.
- Insights into how the virus causes disease and affects the human immune system cannot be studied without having the genome and whole virus. The virus research may identify better therapeutic options that can be applied to other infectious diseases.
- Mutated viruses could cause smallpox-like diseases, so continued research on smallpox is necessary in order to be prepared.
- No one actually knows where all the smallpox stocks are located. Smallpox virus stocks may be secretly retained in other labs around the world for bioterrorism purposes, so destroying the stocks may create a vulnerability in protecting the public. Smallpox viruses also may remain active in buried corpses.
- Destroying the virus impairs the scientists' right to perform research, and the motivation for destruction is political, not scientific.
- Today, it is possible to create the smallpox virus from scratch. So why bother to destroy it?
- Because the smallpox virus (vaccinia) may have evolved from camelpox, who is to say that such evolution could not happen again from camelpox?

Discussion Point

Now it's your turn. Can you add any insights to either list? Which argument do you prefer? P.S. In 2011, the World Health Assembly of the World Health Organization (WHO) met to consider again the evidence for retention or destruction of the smallpox stocks. WHO decided to postpone a decision. In 2014, the debate continues.

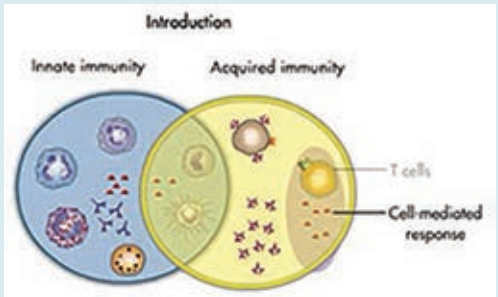
Courtesy of NIAID

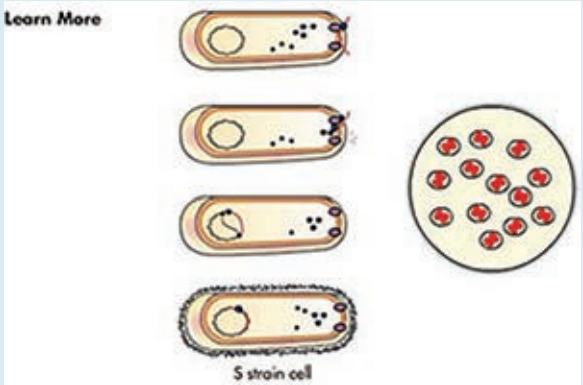
Sometimes the content students are trying to absorb becomes so dense they cannot "see the forest for the trees." Therefore, summary figures, diagrams, and tables can help them see the "forest." In the chapters on infectious diseases of the body systems, such as the one on the respiratory system, each ends with a **SUMMARY MAP** of the agents and diseases of that body system. Although the students may not need to know all the agents and diseases, a common "body map" will help solidify their understanding.

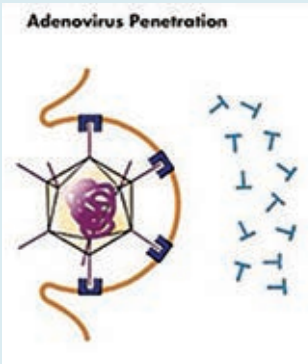


Jones & Bartlett Learning offers an assortment of supplements to assist students in mastering the concepts in this text.

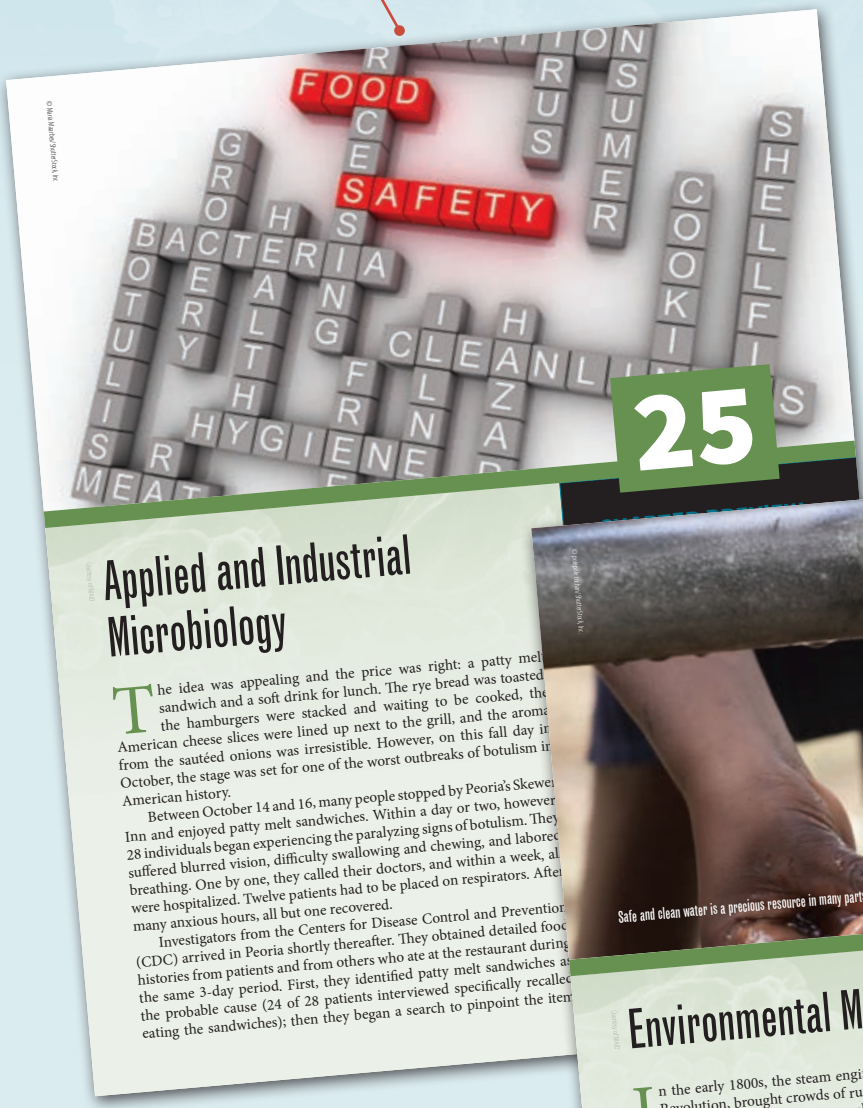
- **Animations:** Engaging animations bring fascinating microbiology phenomena to life! Each animation guides students through microbiology processes and gauges students' progress and understanding with exercises and assessment questions introduced throughout each narrated animation.







- **Bonus eBook content:** Two bonus chapters, "Applied and Industrial Microbiology" and "Environmental Microbiology," are available online.

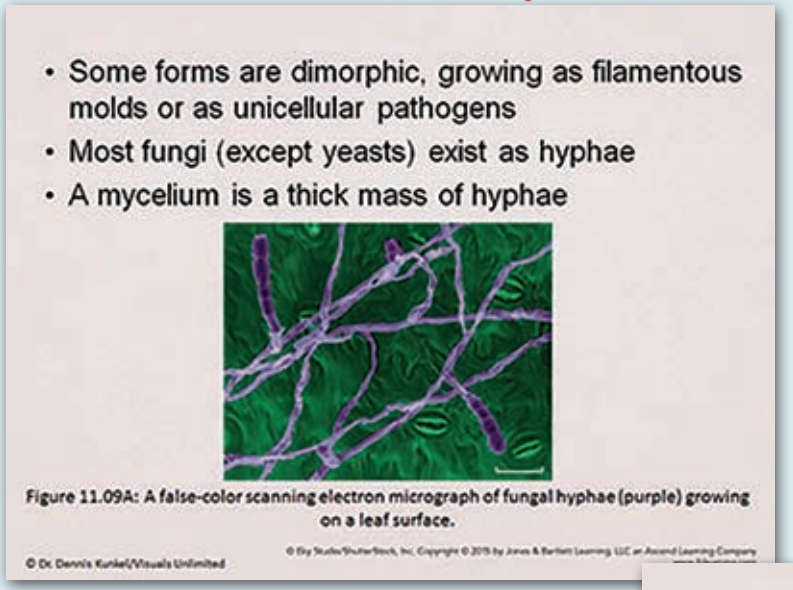


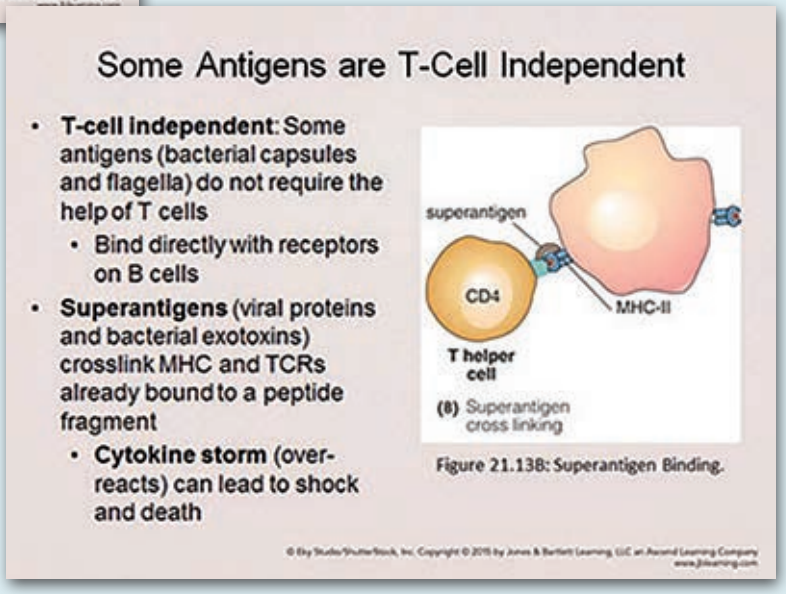
- **Web links:** A variety of weblinks are available that present external website resources to continue your study of microbiology and keep up-to-date on what is happening in the field today.
- **Answer Key:** Answers for the End of Chapter Questions, as well as the questions in the MicroInquiry, Chapter Challenge, Clinical Case, and Investigating the Microbial World feature boxes are available in the book's appendices.

TEACHING TOOLS

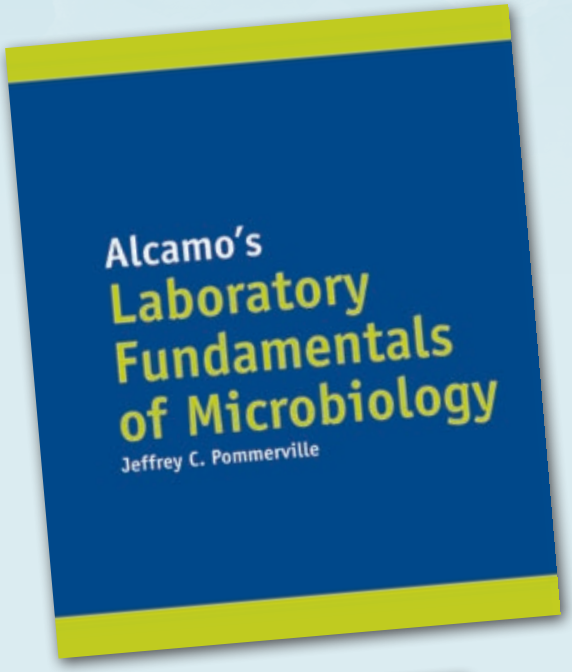
Jones & Bartlett Learning also has an array of support material for instructors. Additional information and review copies of any of the following items are available through your Jones & Bartlett Learning sales representative or by going to www.jblearning.com.

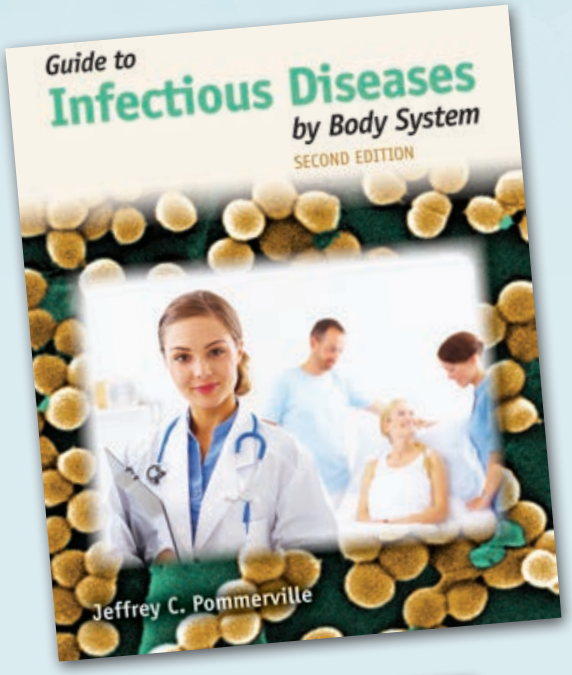
- The *PowerPoint Lecture Outline* presentation package, prepared by Jeff Pommerville, provides lecture notes and images for each chapter of the text. Instructors with the Microsoft PowerPoint software can customize the outlines, art, and order of presentation.
- The *Image Bank* provides the illustrations, photographs, and tables (to which Jones & Bartlett Learning holds the copyright or has permission to reproduce digitally). These images are not for sale or distribution, but you can quickly and easily copy individual images or tables into your existing lecture presentations, test and quizzes, or other classroom materials.
- The *Instructor's Manual*, provided as a text file, includes an Instructional Overview, Instructional Objectives, Key Terms and Concepts, Chapter Teaching Points and Tips, and Essay Questions.
- A robust *Test Bank*, prepared by Justin York of Glendale Community College, including hundreds of assessment questions is available.

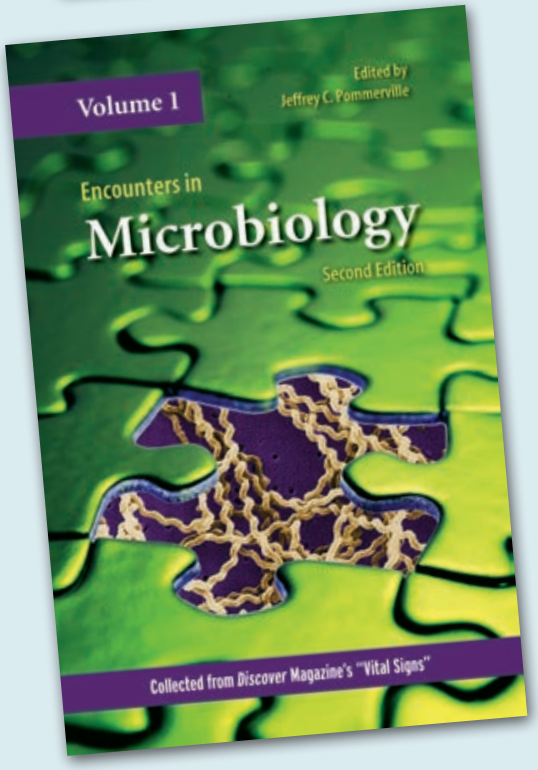


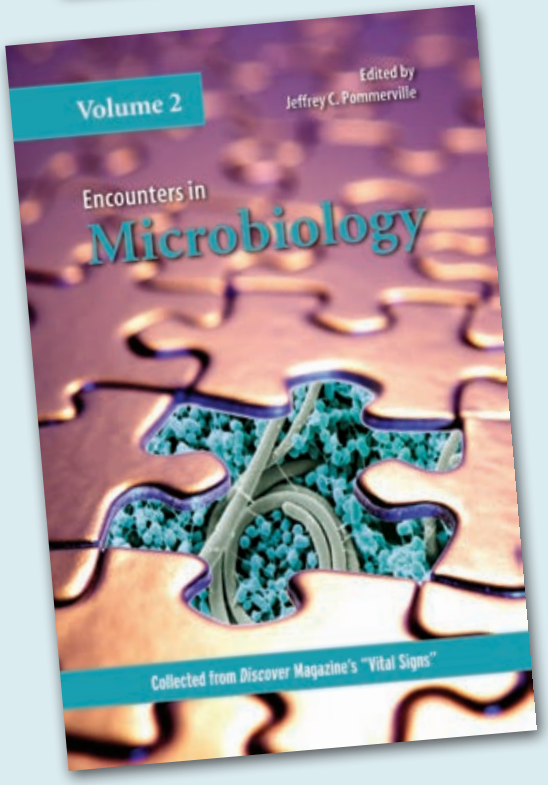


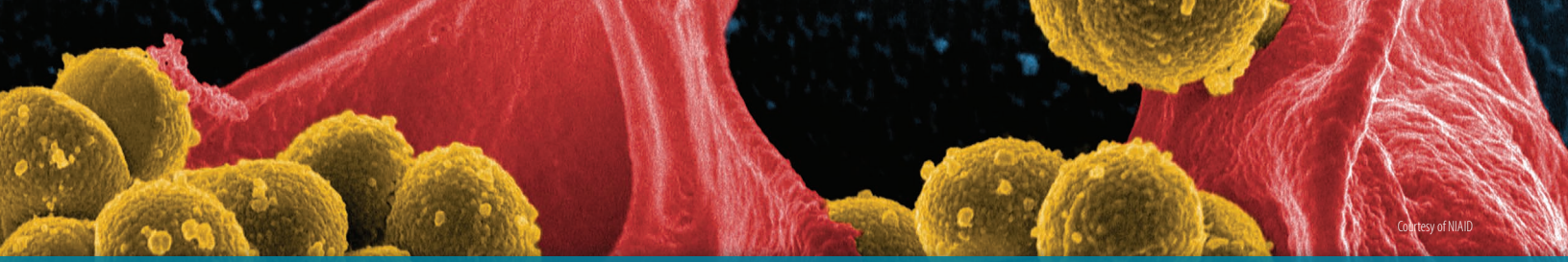
- **Lab manual:** *Alcamo's Laboratory Fundamentals of Microbiology, Tenth Edition*, is a series of over 30 multipart laboratory exercises providing basic training in the handling of microorganisms and reinforcing ideas and concepts described in the textbook.
- **Infectious Diseases:** The *Guide to Infectious Diseases by Body System, Second Edition* is an excellent ancillary tool for learning about microbial diseases. Each of the fifteen body systems units presents a brief introduction to the anatomical system and the bacterial, viral, fungal, or parasitic organism infecting the system.
- **Encounters in Microbiology:** The *Encounters in Microbiology, Volume I, Second Edition*, and *Volume II* bring together "Vital Signs" articles from *Discover* magazine in which health professionals use their knowledge of microbiology in their medical cases.











ACKNOWLEDGMENTS

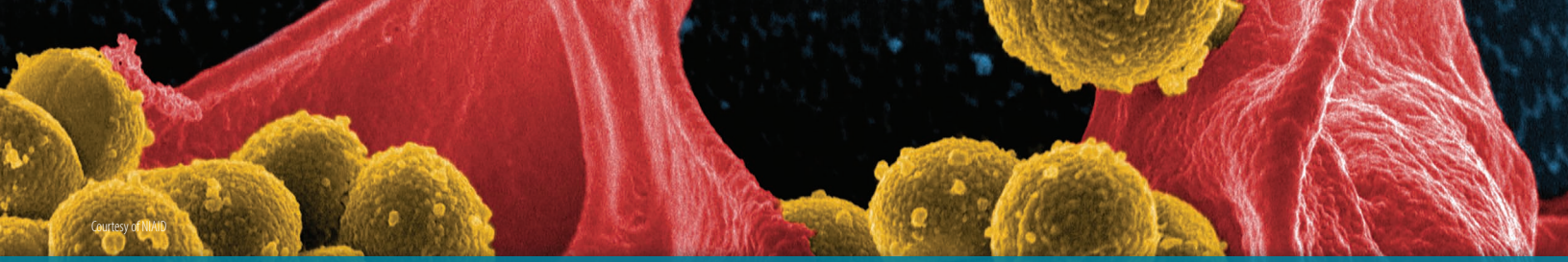
It takes a team of experts to put together a new edition of *Fundamentals of Microbiology: Body System Edition* and the team at Jones & Bartlett Learning are professionals. As Senior Acquisitions Editor, Matthew Kane has been key in coordinating the revision project and is always there to answer my questions and provide guidance. Working on a daily basis with my Editorial Assistant, Audrey Schwinn, has been a pleasure and made the process as smooth as possible. At the production end, my Production Editor, Leah Corrigan, was on top of the project and managed the process skillfully. Lauren Miller, Manager of Photo Research, Rights & Permissions, always found the new photos needed to illustrate the pages. Kristin Parker put together the design format. Shellie Newell did the copyediting and Elizabeth Platt proofread the textbook pages.

Throughout all my years of teaching at universities and colleges, I would not be able to be the instructor I am without the great students I have had the fortune to have in my many classes. They keep me on my toes in the classroom, require me to always be prepared, and let me know when a topic or concept was not conveyed in as clear and understandable way as it could (or should) be. Their suggestions and evaluations have encouraged me to continually assess my instruction, and make it the best it can be. I salute all my former students — and I hope those of you who read this text will let me know what works and what still needs improvement to make your learning effective, enjoyable, and most of all—successful.

Jeff Pommerville
Glendale, AZ

DEDICATION

I dedicate this edition of the book to all my former professors (now emeriti) at the University of California, Santa Barbara (UCSB), especially my PhD mentor Ian K. Ross, who helped me discover the awesome world of biology and microbiology and to all my research mentors (now emeriti) at both UCSB and the University of Georgia, especially Ian, Mel Fuller, and Gary Kochert, who sent me on the adventure of scientific research and discovery. Finally, I want to thank Maria Harper Marinick, now Executive Vice Chancellor and Provost for the Maricopa Community College District, who, as an expert in higher education design and instruction, was my colleague and provided guidance, direction, and friendship as I refocused my career toward science education. To all of you, I am deeply grateful and indebted.


Courtesy of NIAID

ABOUT THE AUTHOR


Courtesy of Dr. Jeffrey Pommerville

Today I am a microbiologist, researcher, and science educator. My plans did not start with that intent. While in high school in Santa Barbara, California, I wanted to play professional baseball, study the stars, and own a '66 Corvette. None of these desires would come true—my batting average was miserable (but I was a good defensive fielder), I hated the astronomy correspondence course I took, and I never bought that Corvette.

I found an interest in biology at Santa Barbara City College. After squeaking through college calculus, I transferred to the University of California at Santa Barbara (UCSB), where I received a BS in biology and stayed on to pursue a PhD degree in the lab of Ian Ross studying cell communication and sexual pheromones in a water mold. After receiving my doctorate in cell and organismal biology, my graduation was written up in the local newspaper as a native son who was a fungal sex biologist—an image that was not lost on my three older brothers!

While in graduate school at UCSB, I rescued a secretary in distress from being licked to death by a German shepherd. Within a year, we were married (the secretary and I). When I finished my doctoral thesis, I spent several years as a postdoctoral fellow at the University of Georgia. Worried that I was involved in too many research projects, a faculty member told me something I will never forget. He said, "Jeff, it's when you can't think of a project or what to do that you need to worry." Well, I have never had to worry!

I then moved on to Texas A&M University, where I spent 8 years in teaching and research—and telling Aggie jokes. Toward the end of this time, after publishing over 30 peer-reviewed papers in national and international research journals, I realized I had a real interest in teaching and education. Leaving the sex biologist nomen behind, I headed farther west to Arizona to join the biology faculty at Glendale Community College, where I continue to teach introductory biology and microbiology.

I have been lucky to be part of several educational research projects and have been honored, along with two of my colleagues, with a Team Innovation of the Year Award by the League of Innovation in the Community Colleges. In 2000, I became project director and lead principal investigator for a National Science Foundation grant to improve student outcomes in science through changes in curriculum and pedagogy. I had a fascinating 3 years coordinating more than 60 science faculty members (who at times were harder to manage than students) in designing and field testing 18 interdisciplinary science units. This culminated with me being honored in 2003 with the Gustav Ohaus Award (College Division) for Innovations in Science Teaching from the National Science Teachers Association.

I am the Perspectives Editor for *Microbiology Education* (now the *Journal of Microbiology and Biology Education*), the education research journal of the American Society for Microbiology (ASM) and in 2004 was co-chair for the ASM Conference for Undergraduate Educators. From 2006 to 2007, I was the chair of Undergraduate Education Division of ASM. In 2006, I was selected as one of four outstanding instructors at Glendale Community College. The culmination of my teaching career came in 2008 when I was nationally recognized by being awarded the Carski Foundation Distinguished Undergraduate Teaching Award for distinguished teaching of microbiology to undergraduate students and encouraging them to subsequent achievement.

I mention all this not to impress, but to show how the road of life sometimes offers opportunities in unexpected and unplanned ways. The key, though, is keeping your "hands on the wheel and your eyes on the prize;" then

Courtesy of NIAID

unlimited opportunities will come your way. With the untimely passing of my friend and professional colleague Ed Alcamo, also the Carski recipient in 2000, I was privileged in 2003 to be offered the opportunity to take over the authorship of *Fundamentals of Microbiology*. It is an undertaking I continue to relish as I (along with the wonderful folks at Jones & Bartlett Learning) try to evolve a new breed of microbiology textbook reflecting the pedagogy change occurring in science classrooms today. And, hey, who knows—maybe that '66 Corvette could be in my garage yet.

Reviewers for the *Third Edition*

As always, it is the input, suggestions, and comments from instructors and students alike that evolve a textbook and make each edition an improvement on its predecessor. I thank everyone from previous editions as well as the reviewers for this edition for their time and effort with the review.

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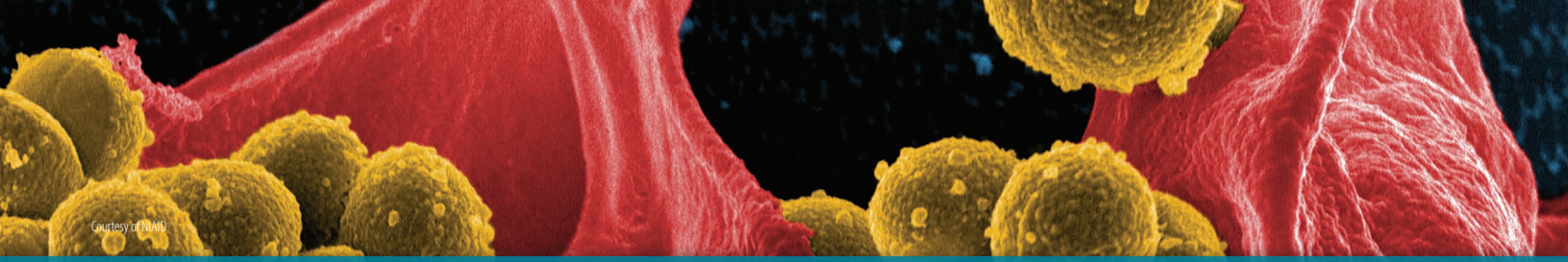


TO THE STUDENT—STUDY SMART

Your success in microbiology and any college or university course will depend on your ability to study effectively and efficiently. Therefore, this textbook was designed with you, the student, in mind. The text's organization will help you improve your learning and understanding and, ultimately, your grades. The learning design concept described in the Preface and illustrated below reflects this organization. Study it carefully, and, if you adopt the flow of study shown, you should be a big step ahead in your preparation and understanding of microbiology—and for that matter any subject you are taking.

Chapter Introduction
What is this chapter about?

Key Concepts
What is important in the section I am about to read?

Concept and Reasoning Checks
Have I understood what I just read?

Summary of Key Concepts
Did I get the main idea?

Are there other materials that will help me master and retain the information?

Student Study Guide
(bundled or sold separately)

CHAPTER AIDS

- Boldface Terms
- Marginal Definitions
- Marginal drawings and chemical structures
- MicroFocus boxes
- MicroInquiry boxes
- Textbook cases
- Figure questions
- Pronouncing organism names
- Summary tables

END-OF-CHAPTER STUDENT ASSESSMENTS

- Learning Objectives
- Self-Test
- Questions for Thought and Discussion
- Applications
- Review

When I was an undergraduate student, I hardly ever read the "To the Student" section (if indeed one existed) in my textbooks because the section rarely contained any information of importance. This one does, so please read on.

In college, I was a mediocre student until my junior year. Why? Mainly because I did not know how to study properly, and, important here, I did not know how to read a textbook effectively. My textbooks were filled with underlined sentences (highlighters hadn't been invented yet!) without any plan on how I would use this "emphasized" information. In fact, most textbooks *assume* you know how to read a textbook properly. I didn't and you might not either.

Reading a textbook is difficult if you are not properly prepared. So that you can take advantage of what I learned as a student and have learned from instructing thousands of students, I have worked hard to make this text user friendly with a reading style that is not threatening or complicated. Still, there is a substantial amount of information to learn and understand, so having the appropriate reading and comprehension skills is critical. Therefore, I encourage you to spend 30 minutes reading this section, as I am going to give you several tips and suggestions for acquiring those skills. Let me show you how to be an active reader. Note: the *Student Study Guide* also contains similar information on how to take notes from the text, how to study, how to take class (lecture) notes, how to prepare for and take exams, and perhaps most important for you, how to manage your time effectively. It all is part of this "learning design," my wish to make you a better student.

BE A PREPARED READER

Before you jump into reading a section of a chapter in this text, prepare yourself by finding the place and time and having the tools for study.

Place. Where are you right now as you read these lines? Are you in a quiet library or at home? If at home, are there any distractions, such as loud music, a blaring television, or screaming kids? Is the lighting adequate to read? Are you sitting at a desk or lounging on the living room sofa? Get where I am going? When you read for an educational purpose—that is, to learn and understand something—you need to maximize the environment for reading. Yes, it should be comfortable but not to the point that you will doze off.

Time. All of us have different times during the day when we perform some skill, be it exercising or reading, the best. The last thing you want to do is read when you are tired or simply not "in tune" for the job that needs to be done. You cannot learn and understand the information if you fall asleep or lack a positive attitude. I have kept the chapters in this text to about the same length so you can estimate the time necessary for each and plan your reading accordingly. If you have done your preliminary survey of the chapter or chapter section, you can determine about how much time you will need. If 40 minutes is needed to read—and comprehend (see below)—a section of a chapter, find the place and time that will give you 40 minutes of uninterrupted study. Brain research suggests that most people's brains cannot spend more than 45 minutes in concentrated, technical reading. Therefore, I have avoided lengthy presentations and instead have focused on smaller sections, each with its own heading. These should accommodate shorter reading periods.

Reading Tools. Lastly, as you read this, what study tools do you have at your side? Do you have a highlighter or pen for emphasizing or underlining important words or phrases? Notice, the text has wide margins, which allow you to make notes or to indicate something that needs further clarification. Do you have a pencil or pen handy to make these notes? Or, if you do not want to "deface" the text, make your notes in a notebook. Lastly, some students find having a ruler is useful to prevent your eyes from wandering on the page and to read each line without distraction.

BE AN EXPLORER BEFORE YOU READ

When you sit down to read a section of a chapter, do some preliminary exploring. Look at the section head and subheadings to get an idea of what is discussed. Preview any diagrams, photographs, tables, graphs, or other visuals used. They give you a better idea of what is going to occur. We have used a good deal of space in the text for these features, so use them to your advantage. They will help you learn the written information and comprehend its meaning. Do not try to understand all the visuals, but try to generate a mental "big picture" of what is to come. Familiarize yourself with any symbols or technical jargon that might be used in the visuals.

The end of each chapter contains a **Summary of Key Concepts** for that chapter. It is a good idea to read the summary before delving into the chapter. That way you

will have a framework for the chapter before filling in the nitty-gritty information.

BE A DETECTIVE AS YOU READ

Reading a section of a textbook is not the same as reading a novel. With a textbook, you need to uncover the important information (the terms and concepts) from the forest of words on the page. So, the first thing to do is read the complete paragraph. When you have determined the main ideas, highlight or underline them. However, I have seen students highlighting the entire paragraph in yellow, including every *a*, *the*, and *and*. This is an example of highlighting before knowing what is important. So, I have helped you out somewhat. Important terms and concepts are in **bold face** followed by the definition (or the definition might be in the margin). So only highlight or underline with a pen essential ideas and key phrases—not complete sentences, if possible. By the way, the important microbiological terms and major concepts also are in the **Glossary** at the back of the text.

What if a paragraph or section has no boldfaced words? How do you find what is important here? From an English course, you may know that often the most important information is mentioned first in the paragraph. If it is followed by one or more examples, then you can backtrack and know what was important in the paragraph. In addition, I have added section "speed bumps" (called **Concept and Reasoning Checks**) to let you test your learning and understanding before getting too far ahead in the material. These checks also are clues to what was important in the section you just read.

BE A REPETITIOUS STUDENT

Brain research has shown that each individual can only hold so much information in short-term memory. If you try to hold more, then something else needs to be removed—sort of like a full computer disk. So that you do not lose any of this important information, you need to transfer it to long-term memory—to the hard drive if you will. In reading and studying, this means retaining the term or concept; so, write it out in your notebook *using your own words.* Memorizing a term does not mean you have learned the term or understood the concept. By actively writing it out in your own words, you are forced to think and actively interact with the information. This repetition reinforces your learning.

BE A PATIENT STUDENT

In textbooks, you cannot read at the speed that you read your e-mail or a magazine story. There are unfamiliar details to be learned and understood—and this requires being a patient, slower reader. Actually, if you are not a fast reader to begin with, as I am, it may be an advantage in your learning process. Identifying the important information from a textbook chapter requires you to *slow down* your reading speed. Speed-reading is of no value here.

KNOW THE WHAT, WHY, AND HOW

Have you ever read something only to say, "I have no idea what I read!" As I've already mentioned, reading a microbiology text is not the same as reading *Sports Illustrated* or *People* magazine. In these entertainment magazines, you read passively for leisure or perhaps amusement. In *Fundamentals of Microbiology, Body Systems Edition,Third Edition,* you must read actively for learning and understanding—that is, for *comprehension*. This can quickly lead to boredom unless you engage your brain as you read—that is, be an active reader. Do this by knowing the *what, why,* and *how* of your reading.

- *What* is the general topic or idea being discussed? This often is easy to determine because the section heading might tell you. If not, then it will appear in the first sentence or beginning part of the paragraph.
- *Why* is this information important? If I have done my job, the text section will tell you why it is important or the examples provided will drive the importance home. These surrounding clues further explain why the main idea was important.
- *How* do I "mine" the information presented? This was discussed under being a detective.

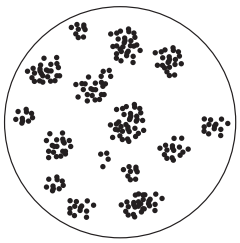
A MARKED UP READING EXAMPLE

So let's put words into action. Below is a passage from the text. I have marked up the passage as if I were a student reading it for the first time. It uses many of the hints and suggestions I have provided. Remember, it is important to read the passage slowly, and concentrate on the main idea (concept) and the special terms that apply.

KEY CONCEPT 21.4

Some Bacterial Pathogens Cause Foodborne Intoxications

A few bacterial species secrete preformed toxins present in food. These foodborne intoxications represent a **noninflammatory gastroenteritis** and involve a brief incubation period and quick resolution.



Staphylococcus aureus

Food Poisoning Can Be the Result of Enterotoxins

Some bacterial species produce **enterotoxins**, which, limited to the intestines (*entero* = "intestine"), are poisons causing vomiting and diarrhea.

Staphylococcal Food Poisoning. Ingestion of a heat-stable exotoxin produced by *Staphylococcus aureus*, a facultatively anaerobic, gram-positive sphere, can cause **staphylococcal food poisoning**. Today, it ranks fourth among reported cases of bacterial foodborne diseases.

Reservoir: The natural host or habitat of a pathogen.

A key reservoir of *S. aureus* in humans is the nose. Thus, an errant sneeze by a food handler may be the source of staphylococcal food contamination. Studies indicate, however, the most common mode of transmission is from boils or abscesses on the skin, which can shed staphylococci into the food product where the

HAVE A DEBRIEFING STRATEGY

After reading the material, be ready to debrief. Verbally summarize what you have learned. This will start moving the short-term information into the long-term memory storage—that is, *retention*. Any notes you made concerning confusing material should be discussed as soon as possible with your instructor. For microbiology, allow time to draw out diagrams. Again, repetition makes for easier learning and better retention.

In many professions, such as sports or the theater, the name of the game is practice, practice, practice. The hints and suggestions I have given you form a skill that requires practice to perfect and use efficiently. Be patient, things will not happen overnight; perseverance and willingness will pay off with practice. You might also check with your college or university academic (or learning) resource center. These folks will have more ways to help you to read a textbook better and to study well overall.

CONCEPT MAPS

In science as well as in other subjects you take at the college or university, there often are concepts that appear abstract or simply so complex that they are difficult to understand. A **concept map** is one tool to help you enhance your abilities to think and learn. Critical reasoning and the ability to make connections between complex, nonlinear information are essential to your studies and career.

Concept maps are a learning tool designed to represent complex or abstract information visually. Neurobiologists and psychologists tell us that the brain's primary function is to take incoming information and interpret it in a meaningful or practical way. They also have found that

the brain has an easier time making sense of information when it is presented in a visual format. Importantly, concept maps not only present the information in "visual sentences," but also take paragraphs of material and present it in an "at-a-glance" format. Therefore, you can use concept maps to

- Communicate and organize complex ideas in a meaningful way
- Aid your learning by seeing connections within or between concepts and knowledge
- Assess your understanding or diagnose misunderstanding

There are many different types of concept maps. The two most used in this textbook are the *process map* or *flow chart* and the *hierarchical map*. The hierarchical map starts with a general concept (the most inclusive word or phrase) at the top of the map and descends downward using more specific, less general words or terms. In several chapters in this textbook process or hierarchical maps are drawn—and you have the opportunity to construct your own hierarchical maps as well.

Concept mapping is the strategy used to produce a concept map. So, let's see how one makes a hierarchical map.

How to Construct a Concept Map

1. Print the central idea (concept or question to be mapped) in a box at the top center of a blank, unlined piece of paper. Use uppercase letters to identify the central idea.
2. Once the concept has been selected, identify the key terms (words or short phrases) that apply to or stem from the concept. Often these may be given to you as a list. If you have read a section of a text, you can extract the terms from that material, as the words are usually boldfaced or italicized.
3. Now, from this list, try to create a hierarchy for the terms you have identified; that is, list them from the most general, most inclusive to the least general, most specific. This ranking may only be approximate and subject to change as you begin mapping.
4. Construct a preliminary concept map. This can be done by writing all of the terms on Post-its®, which can be moved around easily on a large piece of paper. This is necessary as one begins to struggle with the process of building a good hierarchical organization.
5. The concept map connects terms associated with a concept in the following way:
   - The relationship between the concept and the first term(s), and between terms, is connected by an arrow pointing in the direction of the relationship (usually downward or horizontal if connecting related terms).
   - Each arrow should have a label, a very short phrase that explains the relationship with the next term. In the end, each link with a label reads like a sentence.
6. Once you have your map completed, redraw it in a more permanent form. Box in all terms that were on the sticky notes. Remember there may be more than one way to draw a good concept map, and don't be scared off if at first you have some problems mapping; mapping will become more apparent to you after you have practiced this technique a few times using the opportunities given to you in the early chapters of the textbook.
7. Now look at the map and see if it answers the following. Does it:
   - Define clearly the central idea by positioning it in the center of the page?
   - Place all the terms in a logical hierarchy and indicate clearly the relative importance of each term?
   - Allow you to figure out the relationships among the key ideas more easily?
   - Permit you to see all the information visually on one page?
   - Allow you to visualize complex relationships more easily?
   - Make recall and review more efficient?

Example

After reading the section on gene expression, a student makes a list of the terms used and maps the concept. Using the steps outlined above, the student produces the following hierarchical map. Does it satisfy all the questions asked in (7)?

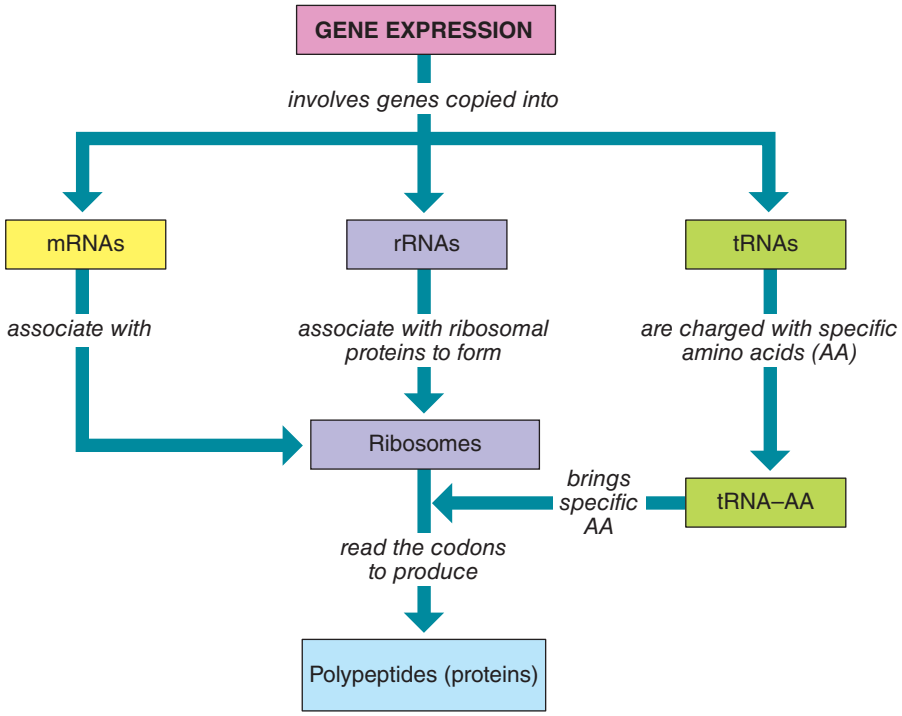


FIGURE 7.14 A Concept Map for Gene Expression. Gene expression is a combination of the transcription and translation processes. **Circle the part of the concept map that represents (a) transcription and (b) translation.**

Practical Uses for Mapping

- **Summarizing textbook readings.** Use mapping to summarize a chapter section or a whole chapter in a textbook. This purpose for mapping is used many times in this text.
- **Summarizing lectures.** Although producing a concept map during the classroom period may not be the best use of the time, making a concept map or maps from the material after class will help you remember the important points and encourage high-level, critical reasoning, which is so important in university and college studies.
- **Reviewing for an exam.** Having concept maps made ahead of time can be a very useful and productive way to study for an exam, particularly if the emphasis of the course is on understanding and applying abstract, theoretical material, rather than on simply reproducing memorized information.
- **Working on an essay.** Mapping also is a powerful tool to use during the early stages of writing a course essay or term paper. Making a concept map before you write the first rough draft can help you see and ensure you have the important points and information you will want to make.

SEND ME A NOTE

In closing, I would like to invite you to write me and let me know what is good about this textbook so I can build on it and what may need improvement so I can revise it. Also, I would be pleased to hear about any news of microbiology in your community, and I'd be happy to help you locate any information not covered in the text.

I wish you great success in your microbiology course. Welcome! Let's now plunge into the wonderful and sometimes awesome world of microorganisms.

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