PREFACE

Ebola, Zika – What's Next?

The human race has experienced and felt the effects of new infectious diseases for millennia, even well before the discovery of the infectious agents responsible for such diseases. Today, however, despite extraordinary advances to eliminate or lessen the development and spread of infectious disease, their appearance continues—and indeed, it is inevitable. Recent examples of emerging diseases include HIV/AIDS, severe acute respiratory syndrome (SARS), Ebola virus disease, and, most recently, Zika virus infection. Each of these unexpected illnesses has had a global impact on governments, economics, and society, and for Zika, even threatened the 2016 Summer Olympics.

The emergence of infectious diseases like Ebola and Zika is the result of several factors. Realize that more than 60% percent of new human infections originate in, or are transmitted by, wild animals, as is the case for all the diseases mentioned above—AIDS (apes and monkeys to humans), SARS and Ebola (bats [to other animals] to humans), and Zika (monkeys to mosquitoes to humans). Consequently, as human habitation spreads into more remote areas around the world, unknown infectious microbes in wild animals will "jump" to humans as these interacting species make contact. In addition, many of these infectious agents undergo rapid genetic changes, as exemplified by the AIDS and influenza viruses, and they can share genetic information as the influenza virus does every flu season. In some cases, this can make the infection more dangerous.

Adding to these factors is the globalized world we live in today. Airline travel makes an infectious disease outbreak in one corner of the world only a day's plane ride from almost any other destination on the globe. Accordingly, infectious diseases can "pop up" from seemingly nowhere.

The next emerging disease will have a different name and different symptoms from Ebola and Zika, and it will come from another region of the world—but it and others are coming. Therefore, what we can (and must) do is recognize and react to these "infectious events" before they can cause an outbreak or epidemic. We need to be better prepared to deal with these events by managing better the next Ebola- or Zika-like emergence, something that was not done in the most recent Ebola outbreak in West Africa and Zika outbreak in Brazil. Preventing another outbreak/epidemic of a new infectious disease can be accomplished only by aggressive vigilance, continued research for detecting new infectious agents (surveillance tools, diagnostics, drugs, and vaccines), and rapidly deploying these countermeasures.

Each new emerging disease brings unique challenges, forcing the medical community to continually adapt to these ever-shifting threats. The battle against emerging infectious diseases is a continual process in trying to get ahead and stay ahead of the next infectious agent before it can explode on the world scene.

More than likely, you are planning a career in the healthcare field. As such, it is important that you understand how new infectious diseases come about. Therefore, I am excited and honored that you are using and reading this new, eleventh edition of *Fundamentals of Microbiology*. I hope it is very useful in your studies and you come away from your course with a much better appreciation for the role that microorganisms play in the environment as well as with us. 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!

A Concept-Based Curriculum

Fundamentals of Microbiology, Eleventh Edition is written for introductory microbiology courses having an emphasis in the health sciences. It is geared toward students in health and allied health science curricula such as nursing, dental hygiene, medical assistance, sanitary science, and medical laboratory technology. It also will be an asset to students studying food science, agriculture, environmental science, and health administration. In addition, the text provides a firm foundation for advanced programs in biological sciences, as well as medicine, pharmacy, dentistry, and other health professions.

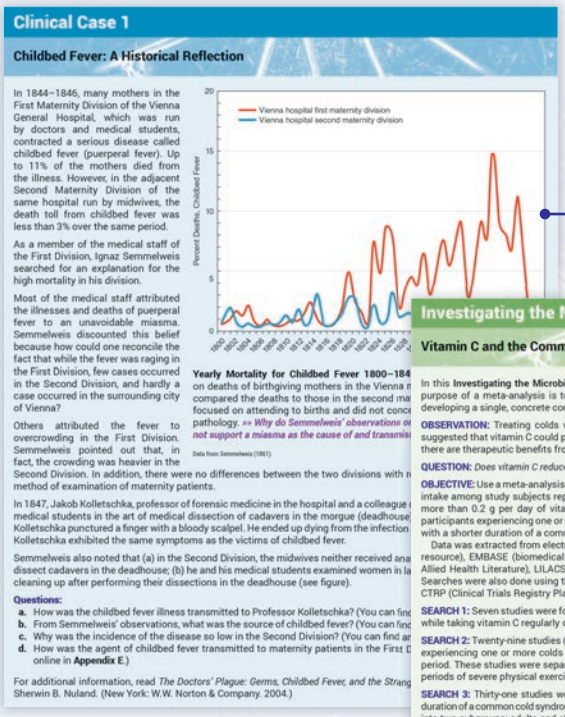
The textbook is divided into seven areas of concentration. Each area reflects the *Concept-Based Microbiology Curriculum Guidelines* as recommended by the American Society for Microbiology.

Overarching Concepts and Fundamental Statements[1]	
Evolution	• Cells, organelles (e.g., mitochondria and chloroplasts), and all major metabolic pathways evolved from early prokaryotic cells. • Mutations and horizontal gene transfer, with the immense variety of microenvironments, have selected for a huge diversity of microorganisms. • Human impact on the environment influences the evolution of microorganisms. • The traditional concept of species is not readily applicable to microbes due to asexual reproduction and the frequent occurrence of horizontal gene transfer. • Evolutionary relatedness of organisms is best reflected in phylogenetic trees.
Cell Structure and Function	• The structure and function of microorganisms have been revealed by the use of microscopy. • Bacteria have unique cell structures that can be targets for antibiotics, immunity, and phage infection. • Bacteria and Archaea have specialized structures that often confer critical capabilities. • While microscopic eukaryotes carry out some of the same processes as bacteria, many of the cellular properties are fundamentally different. • The replication cycles of viruses differ among viruses and are determined by their unique structures and genomes.
Metabolic Pathways	• Bacteria and Archaea exhibit extensive, and often unique, metabolic diversity. • The interactions of microorganisms among themselves and with their environment are determined by their metabolic abilities. • The survival and growth of any microorganism in a given environment depends on its metabolic characteristics. • The growth of microorganisms can be controlled by physical, chemical, mechanical, or biological means.
Information Flow and Genetics	• Genetic variations can impact microbial functions. • Although the central dogma is universal in all cells, the processes of replication, transcription, and translation differ in Bacteria, Archaea, and Eukarya. • The regulation of gene expression is influenced by external and internal molecular cues and/or signals. • The synthesis of viral genetic material and proteins is dependent on host cells. • Cell genomes can be manipulated to alter cell function.
Microbial Systems	• Microorganisms are ubiquitous and live in diverse and dynamic ecosystems. • Most bacteria in nature live in biofilm communities. • Microorganisms and their environment interact with and modify each other. • Microorganisms, cellular and viral, can interact with both human and nonhuman hosts in beneficial, neutral, or detrimental ways.
Impact of Microorganisms	• Microbes are essential for life, as we know it, and the processes that support life. • Microorganisms provide essential models that give us fundamental knowledge about life processes. • Humans use and harness microorganisms and their products. • Because the true diversity of microbial life is largely unknown, its effects and potential benefits have not been fully explored.

[1] Merkel, S. 2012. The Development of Curricular Guidelines for Introductory Microbiology That Focus On Understanding. J Microbiol Biol Educ 13323810.1128/ jmbe.v13i1.36323653779357730 6 http://dx.doi.org/10.1128/jmbe.v13i1.363

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.


Clinical Case 1

Childbed Fever: A Historical Reflection

In 1844–1846, many mothers in the First Maternity Division of the Vienna General Hospital, which was run by doctors and medical students, contracted a serious disease called childbed fever (puerperal fever). Up to 11% of the mothers died from the illness. However, in the adjacent Second Maternity Division of the same hospital run by midwives, the death toll from childbed fever was less than 3% over the same period.

As a member of the medical staff of the First Division, Ignaz Semmelweis searched for an explanation for the high mortality in his division.

Most of the medical staff attributed the illnesses and deaths of puerperal fever to an unavoidable miasma. Semmelweis discounted this belief because how could one reconcile the fact that while the fever was raging in the First Division, few cases occurred in the Second Division, and hardly a case occurred in the surrounding city of Vienna?

Others attributed the fever to overcrowding in the First Division. Semmelweis pointed out that, in fact, the crowding was heavier in the Second Division. In addition, there were no differences between the two divisions with r method of examination of maternity patients.

In 1847, Jakob Kolletschka, professor of forensic medicine in the hospital and a colleague medical students in the art of medical dissection of cadavers in the morgue (deadhouse Kolletschka punctured a finger with a bloody scalpel. He ended up dying from the infection Kolletschka exhibited the same symptoms as the victims of childbed fever.

Semmelweis also noted that (a) in the Second Division, the midwives neither received ana dissect cadavers in the deadhouse; (b) he and his medical students examined women in la cleaning up after performing their dissections in the deadhouse (see figure).

Questions:

a. How was the childbed fever illness transmitted to Professor Kolletschka? (You can find
b. From Semmelweis' observations, what was the source of childbed fever? (You can find
c. Why was the incidence of the disease so low in the Second Division? (You can find ar
d. How was the agent of childbed fever transmitted to maternity patients in the First D online in **Appendix E**.)

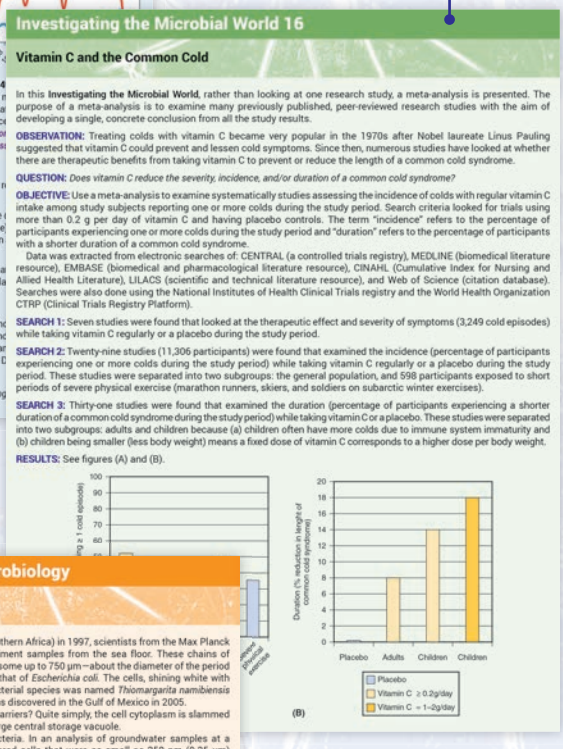
For additional information, read *The Doctors' Plague: Germs, Childbed Fever, and the Strang* Sherwin B. Nuland. (New York: W.W. Norton & Company. 2004.)

Vienna hospital first maternity division
Vienna hospital second maternity division
Percent Deaths, Childbed Fever

Yearly Mortality for Childbed Fever 1800–184
on deaths of birthgiving mothers in the Vienna
compared the deaths to those in the second ma
focused on attending to births and did not conc
pathology. »» *Why do Semmelweis' observations o*
not support a miasma as the cause of and transmis

Data from Semmelweis (1861).

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.


Investigating the Microbial World 16

Vitamin C and the Common Cold

In this **Investigating the Microbial World**, rather than looking at one research study, a meta-analysis is presented. The purpose of a meta-analysis is to examine many previously published, peer-reviewed research studies with the aim of developing a single, concrete conclusion from all the study results.

OBSERVATION: Treating colds with vitamin C became very popular in the 1970s after Nobel laureate Linus Pauling suggested that vitamin C could prevent and lessen cold symptoms. Since then, numerous studies have looked at whether there are therapeutic benefits from taking vitamin C to prevent or reduce the length of a common cold syndrome.

QUESTION: *Does vitamin C reduce the severity, incidence, and/or duration of a common cold syndrome?*

OBJECTIVE: Use a meta-analysis to examine systematically studies assessing the incidence of colds with regular vitamin C intake among study subjects reporting one or more colds during the study period. Search criteria looked for trials using more than 0.2 g per day of vitamin C and having placebo controls. The term "incidence" refers to the percentage of participants experiencing one or more colds during the study period and "duration" refers to the percentage of participants with a shorter duration of a common cold syndrome.

Data was extracted from electronic searches of: CENTRAL (a controlled trials registry), MEDLINE (biomedical literature resource), EMBASE (biomedical and pharmacological literature resource), CINAHL (Cumulative Index for Nursing and Allied Health Literature), LILACS (scientific and technical literature resource), and Web of Science (citation database). Searches were also done using the National Institutes of Health Clinical Trials registry and the World Health Organization CTRP (Clinical Trials Registry Platform).

SEARCH 1: Seven studies were found that looked at the therapeutic effect and severity of symptoms (3,249 cold episodes) while taking vitamin C regularly or a placebo during the study period.

SEARCH 2: Twenty-nine studies (11,306 participants) were found that examined the incidence (percentage of participants experiencing one or more colds during the study period) while taking vitamin C regularly or a placebo during the study period. These studies were separated into two subgroups: the general population, and 598 participants exposed to short periods of severe physical exercise (marathon runners, skiers, and soldiers on subarctic winter exercises).

SEARCH 3: Thirty-one studies were found that examined the duration (percentage of participants experiencing a shorter duration of a common cold syndrome during the study period) while taking vitamin C or a placebo. These studies were separated into two subgroups: adults and children because (a) children often have more colds due to immune system immaturity and (b) children being smaller (less body weight) means a fixed dose of vitamin C corresponds to a higher dose per body weight.

RESULTS: See figures (A) and (B).

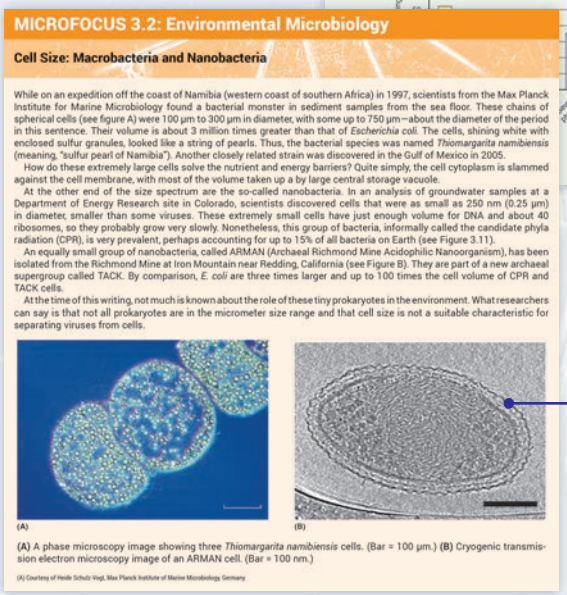
Duration (%) reduction in lenght of common cold episode

Placebo
Adults
Children
Children

Placebo
Vitamin C ≥ 0.2g/day
Vitamin C = 1–2g/day

(B)

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.


MICROFOCUS 3.2: Environmental Microbiology

Cell Size: Macrobacteria and Nanobacteria

While on an expedition off the coast of Namibia (western coast of southern Africa) in 1997, scientists from the Max Planck Institute for Marine Microbiology found a bacterial monster in sediment samples from the sea floor. These chains of spherical cells (see figure A) were 100 µm to 300 µm in diameter, with some up to 750 µm—about the diameter of the period in this sentence. Their volume is about 3 million times greater than that of *Escherichia coli*. The cells, shining white with enclosed sulfur granules, looked like a string of pearls. Thus, the bacterial species was named *Thiomargarita namibiensis* (meaning, "sulfur pearl of Namibia"). Another closely related strain was discovered in the Gulf of Mexico in 2005.

How do these extremely large cells solve the nutrient and energy barriers? Quite simply, the cell cytoplasm is slammed against the cell membrane, with most of the volume taken up a by large central storage vacuole.

At the other end of the size spectrum are the so-called nanobacteria. In an analysis of groundwater samples at a Department of Energy Research site in Colorado, scientists discovered cells that were as small as 250 nm (0.25 µm) in diameter, smaller than some viruses. These extremely small cells have just enough volume for DNA and about 40 ribosomes, so they probably grow very slowly. Nonetheless, this group of bacteria, informally called the candidate phyla radiation (CPR), is very prevalent, perhaps accounting for up to 15% of all bacteria on Earth (see Figure 3.11).

An equally small group of nanobacteria, called ARMAN (Archaeal Richmond Mine Acidophilic Nanoorganism), has been isolated from the Richmond Mine at Iron Mountain near Redding, California (see Figure B). They are part of a new archaeal supergroup called TACK. By comparison, *E. coli* are three times larger and up to 100 times the cell volume of CPR and TACK cells.

At the time of this writing, not much is known about the role of these tiny prokaryotes in the environment. What researchers can say is that not all prokaryotes are in the micrometer size range and that cell size is not a suitable characteristic for separating viruses from cells.

(A)

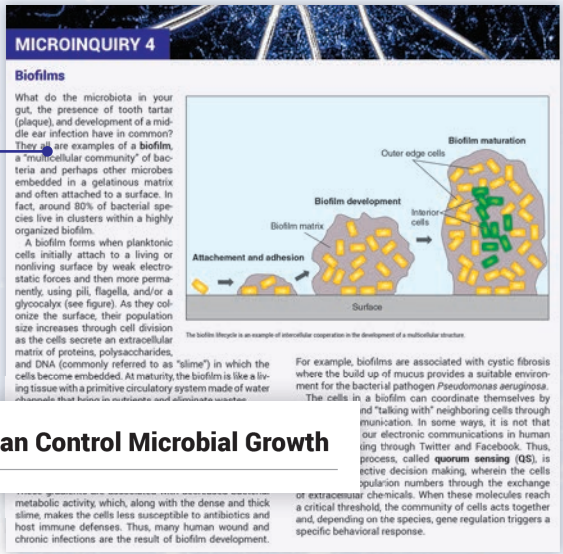
(B)

(A) A phase microscopy image showing three *Thiomargarita namibiensis* cells. (Bar = 100 µm.) **(B)** Cryogenic transmission electron microscopy image of an ARMAN cell. (Bar = 100 nm.)

(A) Courtesy of Heide Schulz-Vogt, Max Planck Institute of Marine Microbiology, Germany.

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

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



MICROINQUIRY 4

Biofilms

What do the microbiota in your gut, the presence of tooth tartar (plaque), and development of a middle ear infection have in common? They all are examples of a **biofilm**, a "multicellular community" of bacteria and perhaps other microbes embedded in a gelatinous matrix and often attached to a surface. In fact, around 80% of bacterial species live in clusters within a highly organized biofilm.

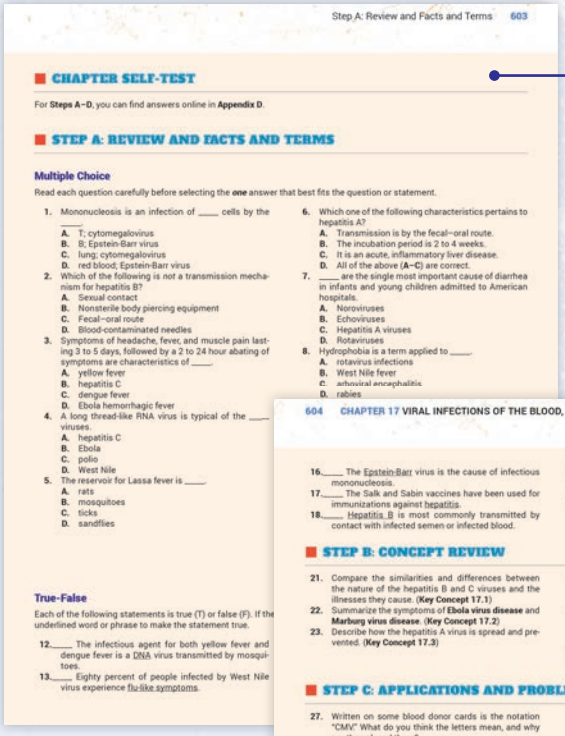
A biofilm forms when planktonic cells initially attach to a living or nonliving surface by weak electrostatic forces and then more permanently, using pili, flagella, and/or a glycocalyx (see figure). As they colonize the surface, their population size increases through cell division as the cells secrete an extracellular matrix of proteins, polysaccharides, and DNA (commonly referred to as "slime") in which the cells become embedded. At maturity, the biofilm is like a living tissue with a primitive circulatory system made of water channels that bring in nutrients and eliminate wastes.

The biofilm lifecycle is an example of intercellular cooperation in the development of a multicellular structure.

For example, biofilms are associated with cystic fibrosis where the build up of mucus provides a suitable environment for the bacterial pathogen *Pseudomonas aeruginosa*. The cells in a biofilm can coordinate themselves by [illegible] and "talking with" neighboring cells through [illegible]munication. In some ways, it is not that [illegible] our electronic communications in human [illegible]ing through Twitter and Facebook. Thus, [illegible] process, called **quorum sensing** (**QS**), is [illegible]ective decision making, wherein the cells [illegible]opulation numbers through the exchange [illegible] of extracellular chemicals. When these molecules reach a critical threshold, the community of cells acts together and, depending on the species, gene regulation triggers a specific behavioral response.

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 9.4 **A Variety of Chemical Agents Can Control Microbial Growth**



CHAPTER SELF-TEST

For **Steps A–D**, you can find answers online in **Appendix D**.

STEP A: REVIEW AND FACTS AND TERMS

Multiple Choice

Read each question carefully before selecting the **one** answer that best fits the question or statement.

1. Mononucleosis is an infection of ____ cells by the ____.
   A. T; cytomegalovirus
   B. B; Epstein-Barr virus
   C. lung; cytomegalovirus
   D. red blood; Epstein-Barr virus
2. Which of the following is *not* a transmission mechanism for hepatitis B?
   A. Sexual contact
   B. Nonsterile body piercing equipment
   C. Fecal–oral route
   D. Blood-contaminated needles
3. Symptoms of headache, fever, and muscle pain lasting 3 to 5 days, followed by a 2 to 24 hour abating of symptoms are characteristics of ____.
   A. yellow fever
   B. hepatitis C
   C. dengue fever
   D. Ebola hemorrhagic fever
4. A long thread-like RNA virus is typical of the ____ viruses.
   A. hepatitis C
   B. Ebola
   C. polio
   D. West Nile
5. The reservoir for Lassa fever is ____.
   A. rats
   B. mosquitoes
   C. ticks
   D. sandflies
6. Which one of the following characteristics pertains to hepatitis A?
   A. Transmission is by the fecal–oral route.
   B. The incubation period is 2 to 4 weeks.
   C. It is an acute, inflammatory liver disease.
   D. All of the above (**A–C**) are correct.
7. ____ are the single most important cause of diarrhea in infants and young children admitted to American hospitals.
   A. Noroviruses
   B. Echoviruses
   C. Hepatitis A viruses
   D. Rotaviruses
8. Hydrophobia is a term applied to ____.
   A. rotavirus infections
   B. West Nile fever
   C. arboviral encephalitis
   D. rabies

True-False

Each of the following statements is true (T) or false (F). If the underlined word or phrase to make the statement true.

12. ____ The infectious agent for both yellow fever and dengue fever is a DNA virus transmitted by mosquitoes.
13. ____ Eighty percent of people infected by West Nile virus experience flu-like symptoms.

16. ____ The Epstein-Barr virus is the cause of infectious mononucleosis.
17. ____ The Salk and Sabin vaccines have been used for immunizations against hepatitis.
18. ____ Hepatitis B is most commonly transmitted by contact with infected semen or infected blood.
19. ____ One of the most important causes of diarrhea in infants and young children admitted to hospitals is the Epstein-Barr virus.
20. ____ Filoviruses are long, thread-like viruses that cause hemorrhagic fevers and include the marburgvirus.

STEP B: CONCEPT REVIEW

21. Compare the similarities and differences between the nature of the hepatitis B and C viruses and the illnesses they cause. (**Key Concept 17.1**)
22. Summarize the symptoms of **Ebola virus disease** and **Marburg virus disease**. (**Key Concept 17.2**)
23. Describe how the hepatitis A virus is spread and prevented. (**Key Concept 17.3**)
24. Explain why rotavirus infections are so deadly in children and describe how noroviruses are transmitted. (**Key Concept 17.3**)
25. Describe the outcome to someone who has been bitten by a rabid animal and recommend treatment if **rabies** symptoms have not yet appeared. (**Key Concept 17.4**)
26. Explain how the polioviruses cause disease and identify the two types of **polio** vaccines. (**Key Concept 17.4**)

STEP C: APPLICATIONS AND PROBLEM SOLVING

27. Written on some blood donor cards is the notation "CMV." What do you think the letters mean, and why are they placed there?
28. Sicilian barbers are renowned for their skill and dexterity with razors (and sometimes their singing voices). French researchers studied a group of 37 Sicilian barbers and found that 14 had antibodies against hepatitis C, despite never having been sick with the disease. By comparison, when a random group of 50 blood donors was studied, none had the antibodies. As an epidemiologist, what might account for the high incidence of exposure to hepatitis C among these barbers?
29. As a state health inspector, you suggest all restaurant workers should be immunized with the hepatitis A vaccine. Why would restaurant owners agree or disagree with your idea?
30. An epidemiologist notes that India has a high rate of dengue fever but a very low rate of yellow fever. What might be the cause of this anomaly?

STEP D: QUESTIONS FOR THOUGHT AND DISCUSSION

31. Health authorities panicked when an outbreak of Ebola hemorrhagic disease occurred among imported macaques in a quarantine facility in Reston, Virginia, in 1989. What sparks such a dramatic response when a disease like Ebola virus disease breaks out?
32. A diagnostic test has been developed to detect hepatitis C in blood intended for transfusion purposes. Obviously, if the test is positive, the blood is not used. However, there is a lively controversy as to whether the blood donor should be informed of the positive result. What is your opinion? Why?
33. In the southwestern United States, abundant rain and a mild winter often bring conditions that encourage a burgeoning rodent population. Under these circumstances, what viral disease would health officials anticipate and what precautions should they give residents?
34. Disney World and 20 swampy counties in Florida use "sentinel chickens" strategically placed on the grounds to detect any signs of viral encephalitis. Why do you suppose they use chickens? Why are Disney World and many Florida counties particularly susceptible to outbreaks of viral encephalitis? What recommendations might be offered to tourists if the disease broke out?

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 three 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: Applications and Problems** are questions requiring students to reason critically through a problem of practical significance.
- **Step C: Questions for Thought and Discussion** encourage students to use the text to resolve thought-provoking problems with contemporary relevance.

Chapter-By-Chapter Revisions

Each chapter of *Fundamentals of Microbiology, Eleventh Edition* has been carefully and thoroughly revised. In addition, new information pertinent to nursing and allied health has been included, 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 Clinical Case study
- Modified MicroInquiry feature
- Two new and one revised and updated MicroFocus feature
- Chapter Self-Test redesigned

Chapter 2 The Chemical Building Blocks of Life

- 16 figures modified for clarity
- 2 new figures
- Chapter Self-Test redesigned

Chapter 3 Concepts and Tools for Studying Microorganisms

- New discussion on the importance of cell size
- New MicroFocus feature on very small cells
- More basic information on eukaryotic organelles
- New text material on endosymbiosis
- New Microinquiry feature on microbial identification
- Chapter Self-Test redesigned

Chapter 4 Structure and Organization of Prokaryotic Cells

- New MicroInquiry feature on biofilms
- New information on bacterial cell compartments
- Chapter Self-Test redesigned

Chapter 5 Microbial Growth and Nutrition

- New information on biofilm growth
- New and revised MicroFocus features
- New section on chemical factors influencing microbial growth
- Chapter Self-Test redesigned

Chapter 6 Microbial Metabolism

- Revised MicroInquiry feature
- New clinical case
- Revised section on cellular respiration
- Revised section on metabolic diversity
- Chapter Self-Test redesigned

Chapter 7 Microbial Genetics

- New information on bacterial genomes
- New information on organelle DNA
- Revised section on mutations
- Chapter Self-Test redesigned

Chapter 8 Gene Transfer, Genetic Engineering, and Genomics

- New Clinical Case study
- Added discussion on bioethics in biotechnology
- Several new figures
- Chapter Self-Test redesigned

Chapter 9 Control of Microorganisms: Physical Methods and Chemical Agents

- New Investigating the Microbial World
- Chapter Self-Test redesigned

Chapter 10 Control of Microorganisms: Antimicrobial Drugs and Superbugs

Formerly Chapter 24

- New Investigating the Microbial World box on antibiotic resistance
- Chapter Self-Test redesigned

Chapter 11 Airborne Bacterial Diseases

- Expanded discussion of the human respiratory microbiome
- Revised material on pertussis and tuberculosis
- Revised tables
- Chapter Self-Test redesigned

Chapter 12 Foodborne and Waterborne Bacterial Diseases

- New MicroFocus feature on probiotics
- Expanded discussion of the human gut microbiome
- New figures on oral health
- Revised tables
- Chapter Self-Test redesigned

Chapter 13 Soilborne and Arthropod-borne Bacterial Diseases

- New MicroFocus feature on insect bites
- Updated discussion of Lyme disease
- New figures on arthropod-borne diseases
- Chapter Self-Test redesigned

Chapter 14 Sexually Transmitted and Contact Transmitted Bacterial Diseases

- New MicroFocus box about rosacea
- New information on the human microbiome
- New figures and art
- Chapter Self-Test redesigned

Chapter 15 The Viruses and Virus-Like Agents

- New information of giant viruses
- New figures and art
- Chapter Self-Test redesigned

Chapter 16 Viral Infections of the Respiratory Tract and Skin

- New figures on virus families
- New Investigating the Microbial World feature
- New figure on recent mumps outbreaks
- Chapter Self-Test redesigned

Chapter 17 Viral Infections of the Blood, Lymphatic, Gastrointestinal, and Nervous Systems

- New chapter introduction (on Zika virus infection)
- New MicroInquiry feature
- Coverage of Zika virus infection
- Updated material on Ebola virus disease
- Updated material on yellow fever and dengue fever
- Chapter Self-Test redesigned

Chapter 18 Eukaryotic Microorganisms: The Fungi

- New material on the fungal mycobiome
- New figures
- Chapter Self-Test redesigned

Chapter 19 Eukaryotic Microorganisms: The Parasites

- New Clinical Case study
- Chapter Self-Test redesigned

Chapter 20 The Host-Microbe Relationship and Epidemiology

- New tables
- Several figures redesigned
- Narrative reorganized
- Chapter Self-Test redesigned

Chapter 21 Resistance and the Immune System: Innate Immunity

- New tables
- New figure for inflammation
- Chapter Self-Test redesigned

Chapter 22 Resistance and the Immune System: Adaptive Immunity

- Revised figures
- Chapter Self-Test redesigned

Chapter 23 Immunity and Serology

- Two MicroFocus features revised
- Chapter Self-Test redesigned

Chapter 24 Immunization and Serology

- Update on AIDS
- New figures
- Chapter Self-Test redesigned

Chapter 25 Applied and Industrial Microbiology

- Chapter material organized around food spoilage, food preservation, and industrial uses of microbes in food production (fermentation)
- Chapter Self-Test redesigned

Chapter 26 Environmental Microbiology

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

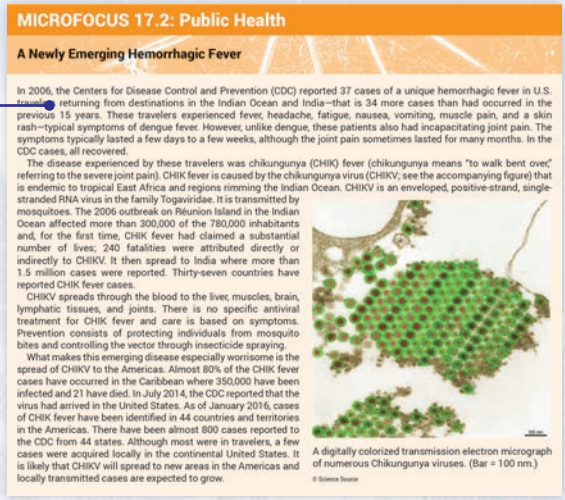
- New chapter opener
- Chapter material organized around water pollution, water and sewage treatment, and microbial roles in biogeochemical recycling in the environment
- Chapter Self-Test redesigned

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 xi for the complete list of Public Health boxes.



MICROFOCUS 17.2: Public Health

A Newly Emerging Hemorrhagic Fever

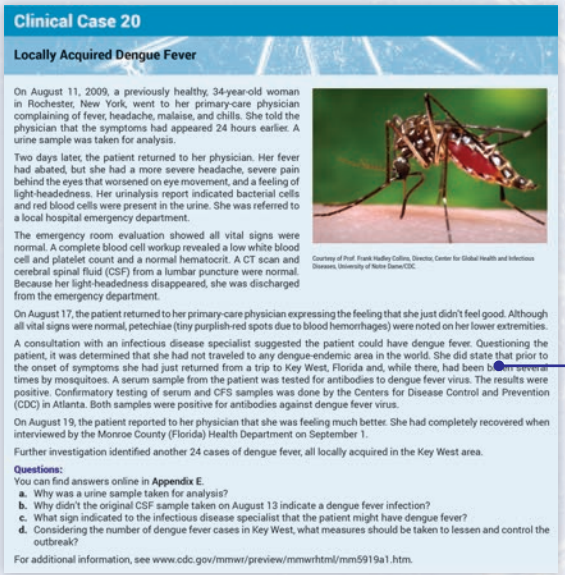
In 2006, the Centers for Disease Control and Prevention (CDC) reported 37 cases of a unique hemorrhagic fever in U.S. travelers returning from destinations in the Indian Ocean and India—that is 34 more cases than had occurred in the previous 15 years. These travelers experienced fever, headache, fatigue, 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). CHIK fever is caused by the chikungunya virus (CHIKV; see the accompanying figure) that is endemic to tropical East Africa and regions rimming the Indian Ocean. CHIKV is an enveloped, positive-strand, single-stranded RNA virus in the family Togaviridae. 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. Thirty-seven countries have reported CHIK fever cases.

CHIKV spreads through the blood to the liver, muscles, brain, lymphatic tissues, and joints. There is no specific antiviral treatment for CHIK fever and care is based on symptoms. 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. Almost 80% of the CHIK fever cases have occurred in the Caribbean where 350,000 have been infected and 21 have died. In July 2014, the CDC reported that the virus had arrived in the United States. As of January 2016, cases of CHIK fever have been identified in 44 countries and territories in the Americas. There have been almost 800 cases reported to the CDC from 44 states. Although most were in travelers, a few cases were acquired locally in the continental United States. It is likely that CHIKV will spread to new areas in the Americas and locally transmitted cases are expected to grow.

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



Clinical Case 20

Locally Acquired Dengue Fever

On August 11, 2009, 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 that the symptoms had appeared 24 hours earlier. A urine sample was taken for analysis.

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.

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.

On August 17, 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.

A consultation with an infectious disease specialist suggested the patient could have dengue fever. Questioning the patient, it was determined that 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 and, while there, 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 CFS samples was done by the Centers for Disease Control and Prevention (CDC) in Atlanta. Both samples were positive for antibodies against dengue fever virus.

On August 19, 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.

Further investigation identified another 24 cases of dengue fever, all locally acquired in the Key West area.

Questions:
You can find answers online in **Appendix E**.

a. Why was a urine sample taken for analysis?
b. Why didn't the original CSF sample taken on August 13 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?

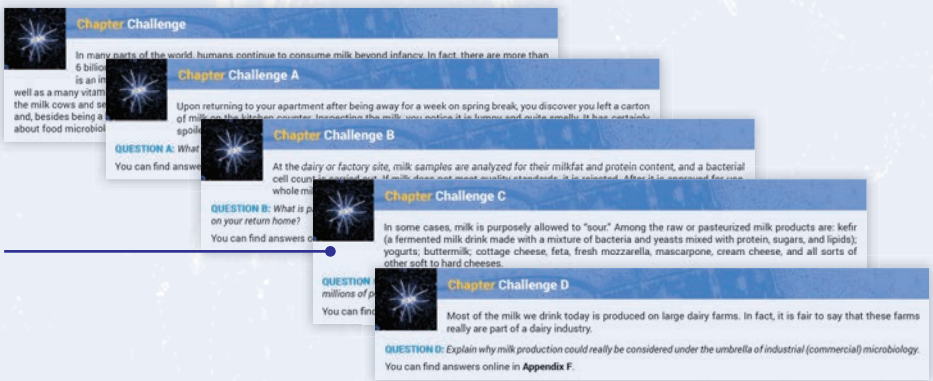
For additional information, see www.cdc.gov/mmwr/preview/mmwrhtml/mm5919a1.htm.

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 x for the complete list of Clinical Cases.

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.



Chapter Challenge

In many parts of the world, humans continue to consume milk beyond infancy. In fact, there are more than 6 billio

Chapter Challenge A

Upon returning to your apartment after being away for a week on spring break, you discover you left a carton of

Chapter Challenge B

At the dairy or factory site, milk samples are analyzed for their milkfat and protein content, and a bacterial cell coun

Chapter Challenge C

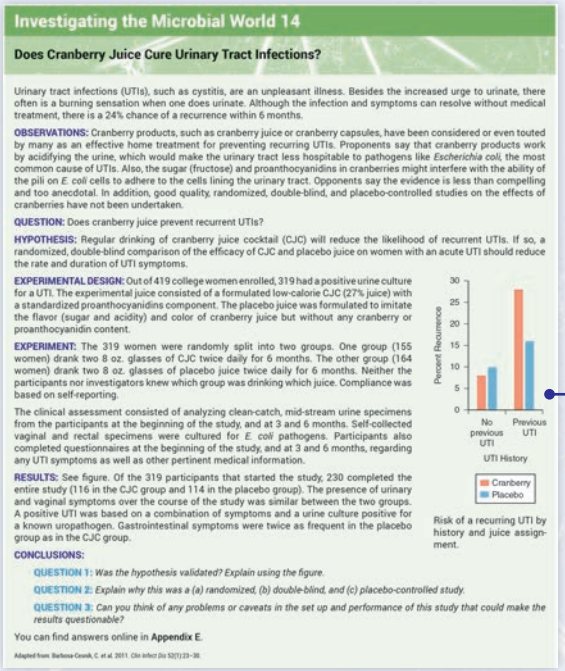
In some cases, milk is purposely allowed to "sour." Among the raw or pasteurized milk products are: kefir (a fermented milk drink made with a mixture of bacteria and yeasts mixed with protein, sugars, and lipids); yogurts; buttermilk; cottage cheese, feta, fresh mozzarella, mascarpone, cream cheese, and all sorts of other soft to hard cheeses.

Chapter Challenge D

Most of the milk we drink today is produced on large dairy farms. In fact, it is fair to say that these farms really are part of a dairy industry.

QUESTION D: Explain why milk production could really be considered under the umbrella of industrial (commercial) microbiology.

You can find answers online in **Appendix F**.



Investigating the Microbial World 14

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: Cranberry products, such as cranberry juice or cranberry capsules, have been considered or even touted by many as an effective home treatment for preventing recurring UTIs. 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 might 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, 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.

Risk of a recurring UTI by history and juice assignment.

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?*

You can find answers online in **Appendix E**.

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

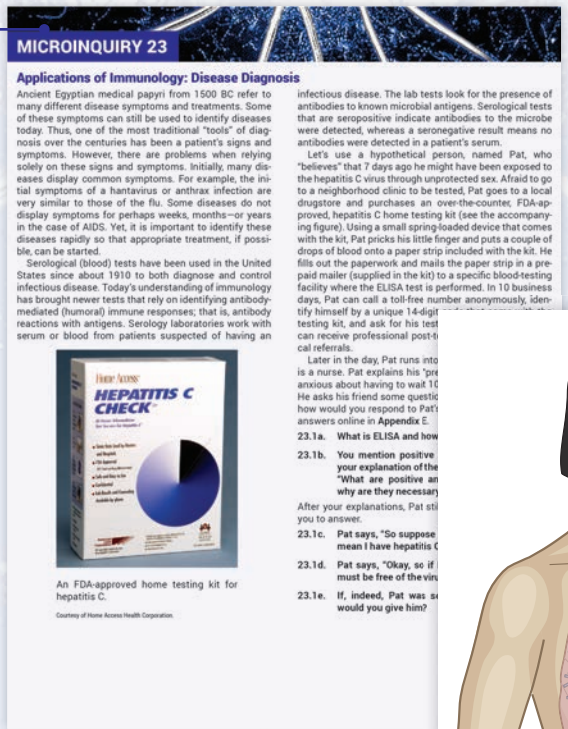
INVESTIGATING THE MICROBIAL WORLD (IMW) introduces students to real world science. Although most students will not be entering the research field, the nursing and allied health arenas require that they have a familiarity with how science is done. The examples in each chapter vary from basic to applied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

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 he or she has mastered the material, but also strengthen his or her 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.

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.



MICROINQUIRY 23

Applications of Immunology: Disease Diagnosis

Ancient Egyptian medical papyri from 1500 BC refer to many different disease symptoms and treatments. Some of these symptoms can still be used to identify diseases today. Thus, one of the most traditional "tools" of diagnosis over the centuries has been a patient's signs and symptoms. However, there are problems when relying solely on these signs and symptoms. Initially, many diseases display common symptoms. For example, the initial symptoms of a hantavirus or anthrax infection are very similar to those of the flu. Some diseases do not display symptoms for perhaps weeks, months—or years in the case of AIDS. Yet, it is important to identify these diseases rapidly so that appropriate treatment, if possible, can be started.

Serological (blood) tests have been used in the United States since about 1910 to both diagnose and control infectious disease. Today's understanding of immunology has brought newer tests that rely on identifying antibody-mediated (humoral) immune responses; that is, antibody reactions with antigens. Serology laboratories work with serum or blood from patients suspected of having an infectious disease. The lab tests look for the presence of antibodies to known microbial antigens. Serological tests that are seropositive indicate antibodies to the microbe were detected, whereas a seronegative result means no antibodies were detected in a patient's serum.

Let's use a hypothetical person, named Pat, who "believes" that 7 days ago he might have been exposed to the hepatitis C virus through unprotected sex. Afraid to go to a neighborhood clinic to be tested, Pat goes to a local drugstore and purchases an over-the-counter, FDA-approved, hepatitis C home testing kit (see the accompanying figure). Using a small spring-loaded device that comes with the kit, Pat pricks his little finger and puts a couple of drops of blood onto a paper strip included with the kit. He fills out the paperwork and mails the paper strip in a prepaid mailer (supplied in the kit) to a specific blood-testing facility where the ELISA test is performed. In 10 business days, Pat can call a toll-free number anonymously, identify himself by a unique 14-digit [illegible] testing kit, and ask for his test [illegible] can receive professional post-[illegible] cal referrals.

Later in the day, Pat runs into [illegible] is a nurse. Pat explains his "pre[illegible] anxious about having to wait 10 [illegible] He asks his friend some questio[illegible] how would you respond to Pat's [illegible] answers online in **Appendix E**.

23.1a. **What is ELISA and how**

23.1b. **You mention positive [illegible] your explanation of the [illegible] "What are positive an[illegible] why are they necessary**

After your explanations, Pat sti[illegible] you to answer.

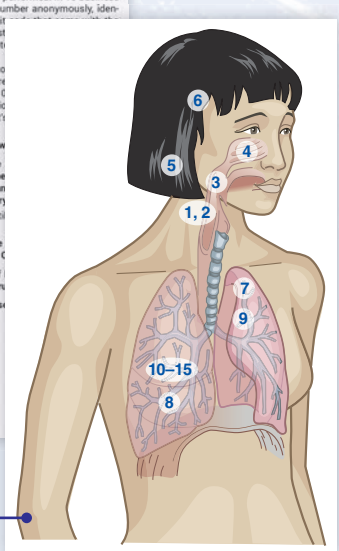
23.1c. **Pat says, "So suppose [illegible] mean I have hepatitis C**

23.1d. **Pat says, "Okay, so if [illegible] must be free of the viru[illegible]**

23.1e. **If, indeed, Pat was s[illegible] would you give him?**

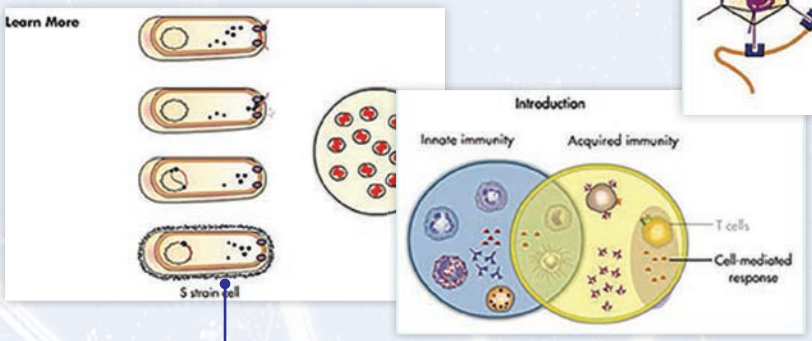
An FDA-approved home testing kit for hepatitis C.

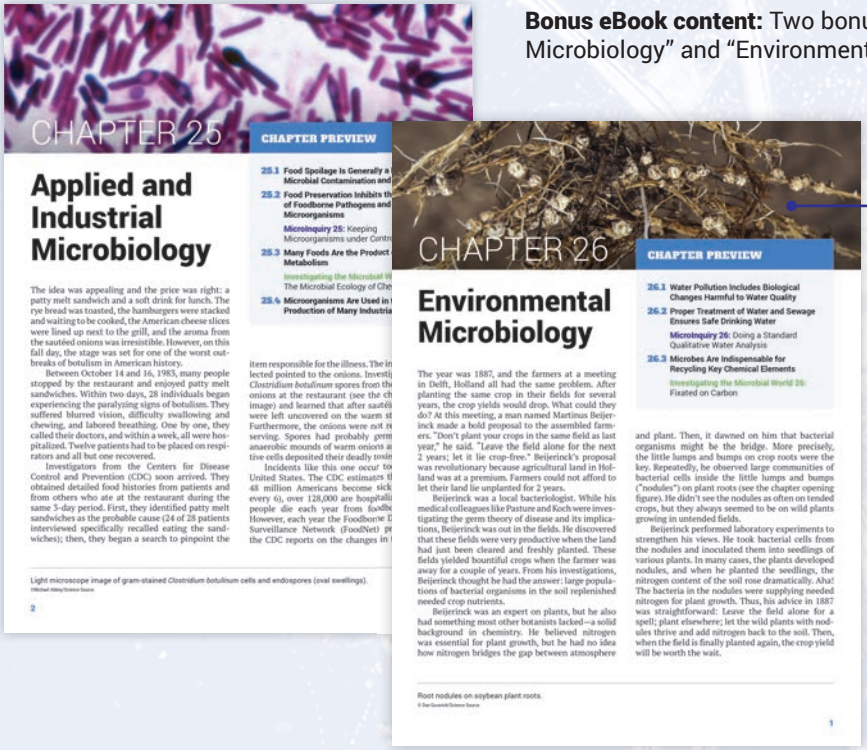
Courtesy of Home Access Health Corporation.



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 online Appendices D, E, and F (accessible with access card).

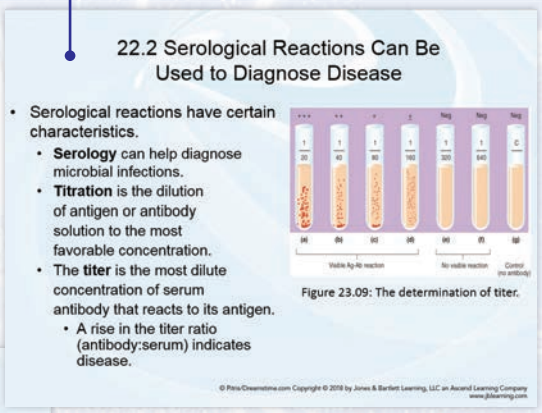
TEACHING TOOLS

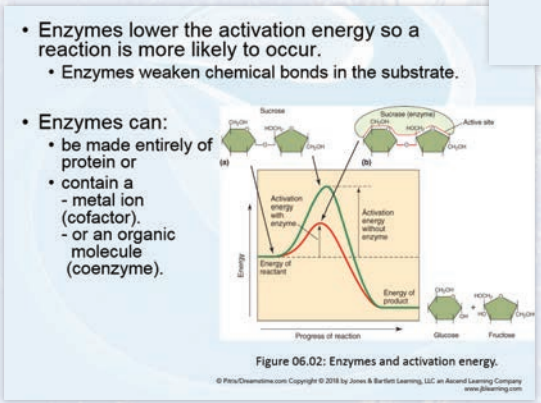
Jones & Bartlett Learning also has an array of supportive materials for instructors. Additional information and review copies of any of the following items are available through your Jones & Bartlett sales representative or by going to http://www.jblearning.com.

The **PowerPoint Lecture Outline** presentation package provides lecture notes and images for each chapter of the text. Instructors with Microsoft PowerPoint software can customize the outlines, art, and order of presentation.

The **Image Bank in PowerPoint format** provides images of 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 copy individual images or tables into your existing lecture presentations, test and quizzes, or other classroom materials.

An **Unlabeled Art Image Bank in PowerPoint format** provides selected images from the text with the labels removed so you can easily integrate them into your lectures, assignments, or exams.

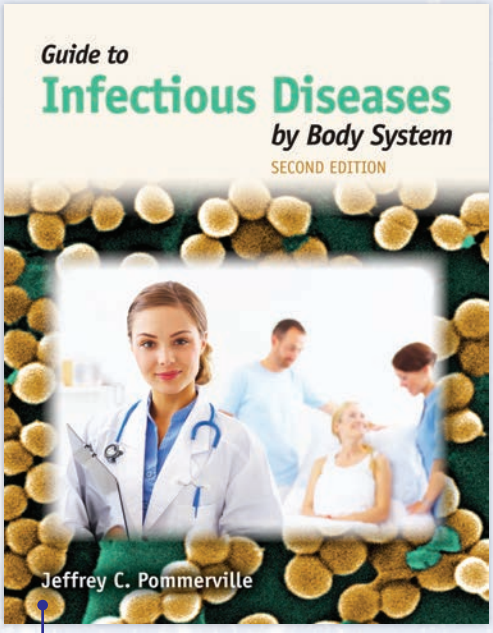




The **Instructor's Manual**, provided as a text file, includes an Instructional Overview, Instructional Objectives, Key Terms and Concepts, Chapter Teaching Points and Tips, and Essay Questions.

A robust **Test Bank**, including hundreds of assessment questions, is available.

Infectious Diseases: The *Guide to Infectious Diseases by Body Systems, 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: *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.

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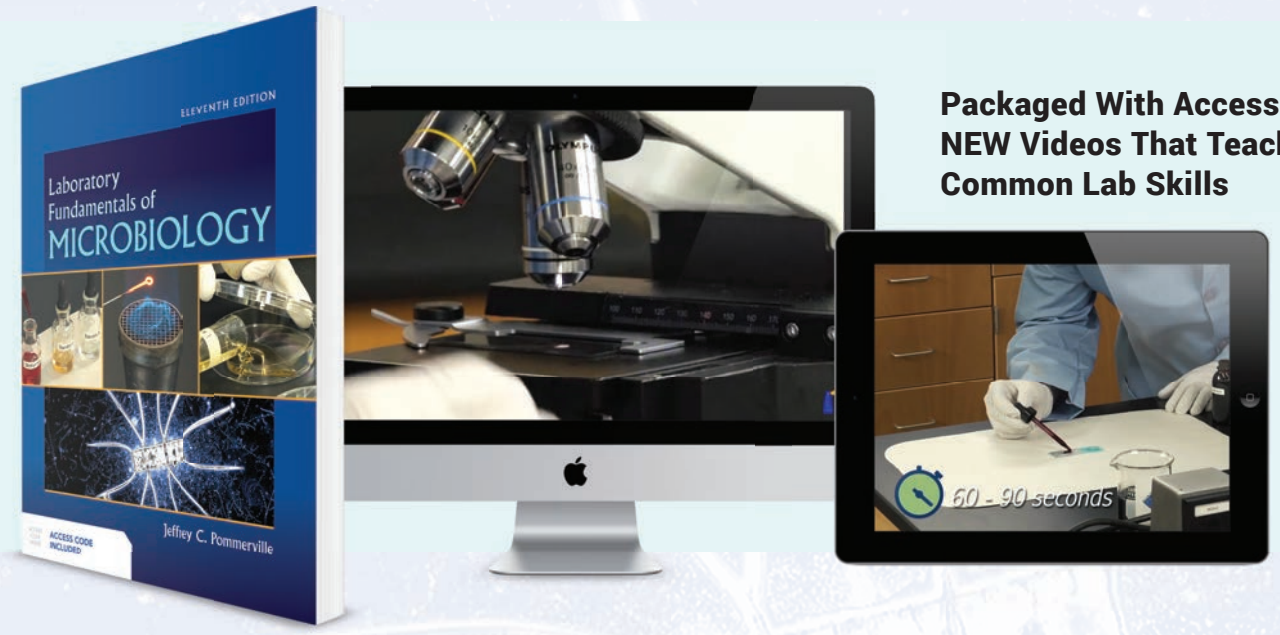

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IMViC: Voges-Proskauer Test
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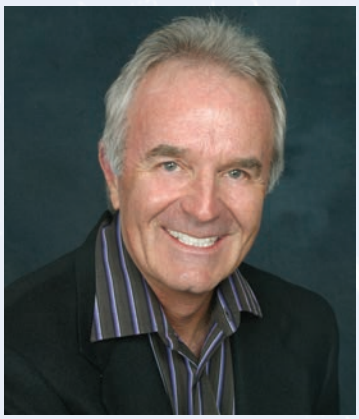
ACKNOWLEDGMENTS

It takes a team of experts to put together a new edition of *Fundamentals of Microbiology*. Moreover, when the team members at Jones & Bartlett Learning are very talented professionals, my work is made easier. I wish to thank Executive Editor, Matthew Kane, who has been my "go to" person when I have had questions or I have needed guidance. As always, my Associate Editor, Audrey Schwinn, has coordinated the textbook revision with conductor-like control. Nancy Hoffmann, Senior Development Editor at Ascend Learning/Jones & Bartlett Learning, brought a new and dynamic leadership to the development of this edition. At the production end, my Production Editor, Dan Stone, managed the assembly process expertly. Jamey O'Quinn, Rights and Media Specialist, was super at locating new photos to illustrate the pages, and Troy Liston managed the revisions to the art program.

Throughout all my years of teaching at universities and colleges, I have had great fortune of working with great colleagues and outstanding students. My students 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 a 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 Community College
Glendale, AZ

ABOUT THE AUTHOR



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 those desires would come true—as a high school baseball player my batting average was miserable (but I was a good defensive fielder), I hated the astronomy correspondence course I took in high school, 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 B.S. in biology and stayed on to pursue a Ph.D. 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!

Moving to Texas A&M University, I spent 8 years in teaching and research—and telling Aggie jokes. Toward the end of this time, 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. I was project director and lead principal investigator for a National Science Foundation grant to improve student outcomes in science through changes in curriculum and pedagogy. This culminated in my being honored with the Gustav Ohaus Award (College Division) for Innovations in Science Teaching from the National Science Teachers Association.

For 6 years I was the Perspectives Editor for the *Journal of Microbiology and Biology Education*, the education research journal of the American Society for Microbiology (ASM). I have been co-chair for the ASM Conference for Undergraduate Educators and chair of the Undergraduate Education Division of ASM. My dedication to teaching and mentoring students has been recognized by an Outstanding Instructor Award at Glendale Community College and, nationally, 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 unlimited opportunities will come your way. And, hey, who knows—maybe that '66 Corvette could be in my garage yet.

Dedication

This is the fifth edition of *Fundamentals of Microbiology* that I have authored. Over these 14 years, I have spent countless months revising and updating the text, often unintentionally neglecting time that should be spent with my wife. Therefore, I dedicate this eleventh edition of the textbook to my wife, Yvonne. She always has supported my passion for teaching and has encouraged me to push forward throughout the textbook revision, often providing valuable and constructive suggestions. Thanks for your support and encouragement, and enduring love through the years.

Reviewers for the *Eleventh 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.

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. 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 are also 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 that you understand 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, Eleventh 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 4.4 Most Prokaryotic

The **cell envelope** is a complex structure that forms the two "wrappings"—the cell wall and the cell membrane—around the cell cytoplasm. The cell envelope helps protect the integrity of the cell. However, the cell wall is relatively porous to the diffusion of substances, so the cell membrane controls the transport of nutrients and metabolic products into and out of the cell.

The Bacterial Cell Wall Is a Tough and Protective External Shell

A key feature of most prokaryotic cells is the **cell wall**. By covering the entire cell surface, the cell wall acts as an exoskeleton to provide structural integrity to the cell and, along with the cytoplasmic cytoskeleton, to provide cell shape. The cell wall also anchors other molecules (i.e., pili and flagella) that extend out from the cell surface.

The cell wall prevents the cell from expanding and bursting due to the high osmotic forces pushing against the cell membrane. Most microbes live in an environment where there are more dissolved materials inside the cell than outside. The **hypertonic** condition in the cytoplasm means water diffuses inward, accounting for the increased osmotic pressure. Without a cell wall, the cell would rupture through a process called **osmotic lysis** (FIGURE 4.9).

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 though 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 "Protein Synthesis," 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)?

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

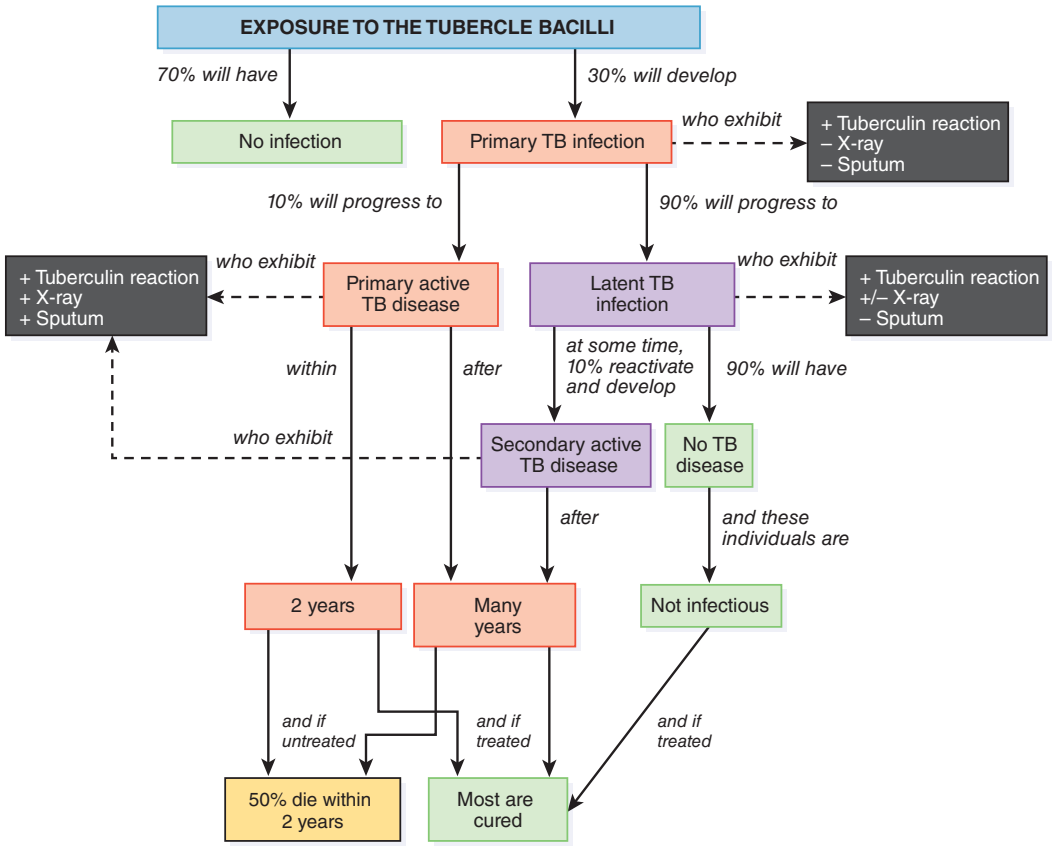

FIGURE 11.17 A Concept Map for Tuberculosis. The stages of tuberculosis infection and disease are shown. ("+" or "–" represents positive or negative test results.) *»» How does TB infection differ from active TB disease?*

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 often awesome world of microorganisms.

—Dr. P
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