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.

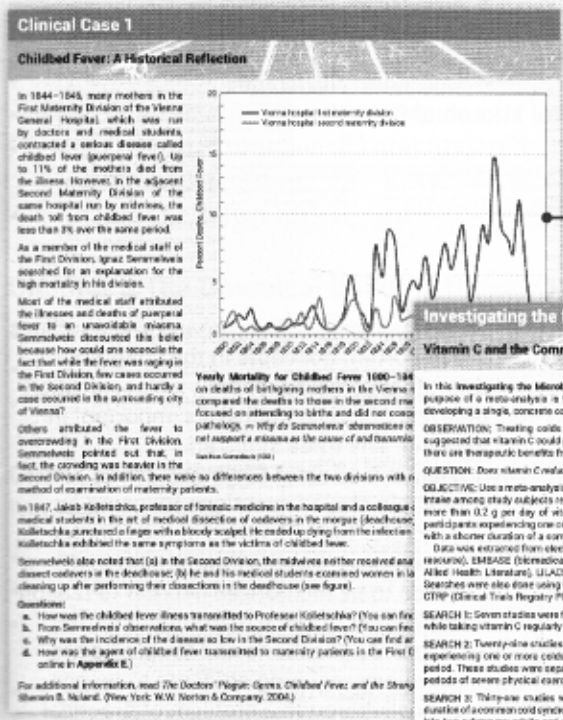
Overarching Concepts and Fundamental Statements[1]

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.v13i1.36323653779357306 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

In 1847, Jakob Kolletschka, professor of forensic medicine in the hospital and a colleague

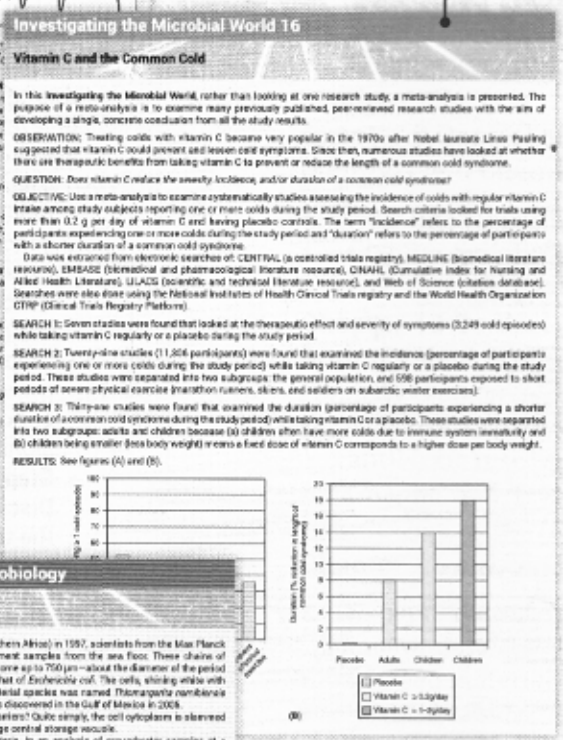
Semmelweis also noted that (a) in the Second Division, the midwives neither received ana

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 fin
c. Why was the incidence of the disease so low in the Second Division? (You can find a
d. How was the agent of childbed fever transmitted to maternity patients in the First D

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

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).

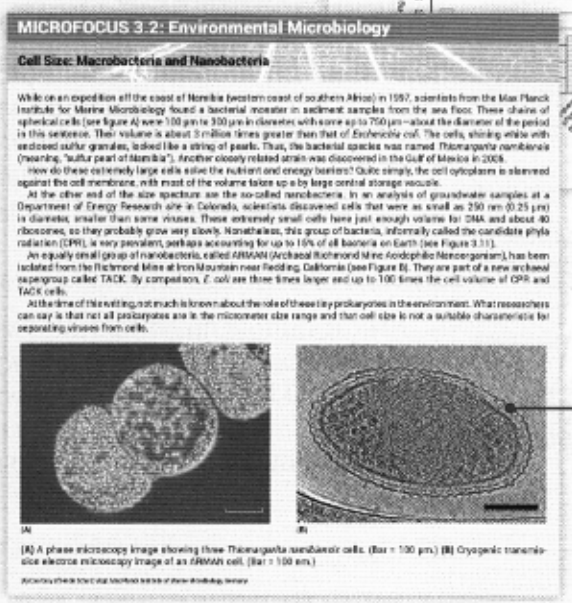
SEARCH 1: Seven studies were found that looked at the therapeutic effect and severity of symptoms (3,249 cold episodes) while taking vitamin C regularly or a placebo during the study period.

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).

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 5 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 2009.

How do these extremely large cells solve the nutrient and energy barriers? Quite simply, the cell cytoplasm is stationed 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 3.31).

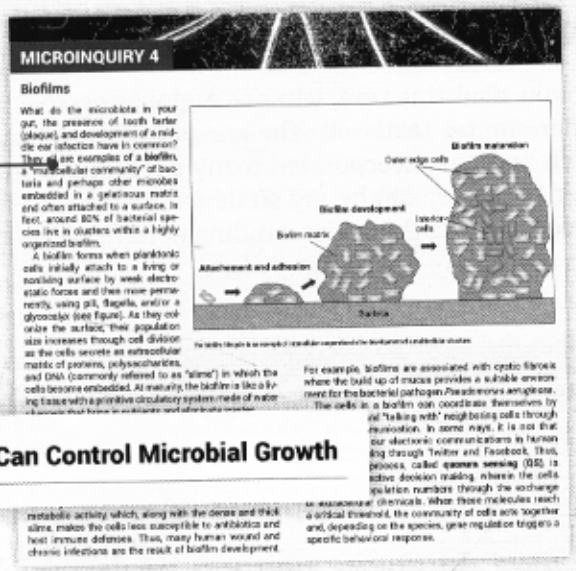
An equally small group of nanobacteria, called ARMAN (Archaeal Richmond Mine Acidophilic Nanoorganism), has been isolated from the Richmond Mine at Iron Mountain near Redding, California (see Figure B). They are part of a new archaeal supergroup called TACK. By comparison, *E. coli* are three times larger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

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

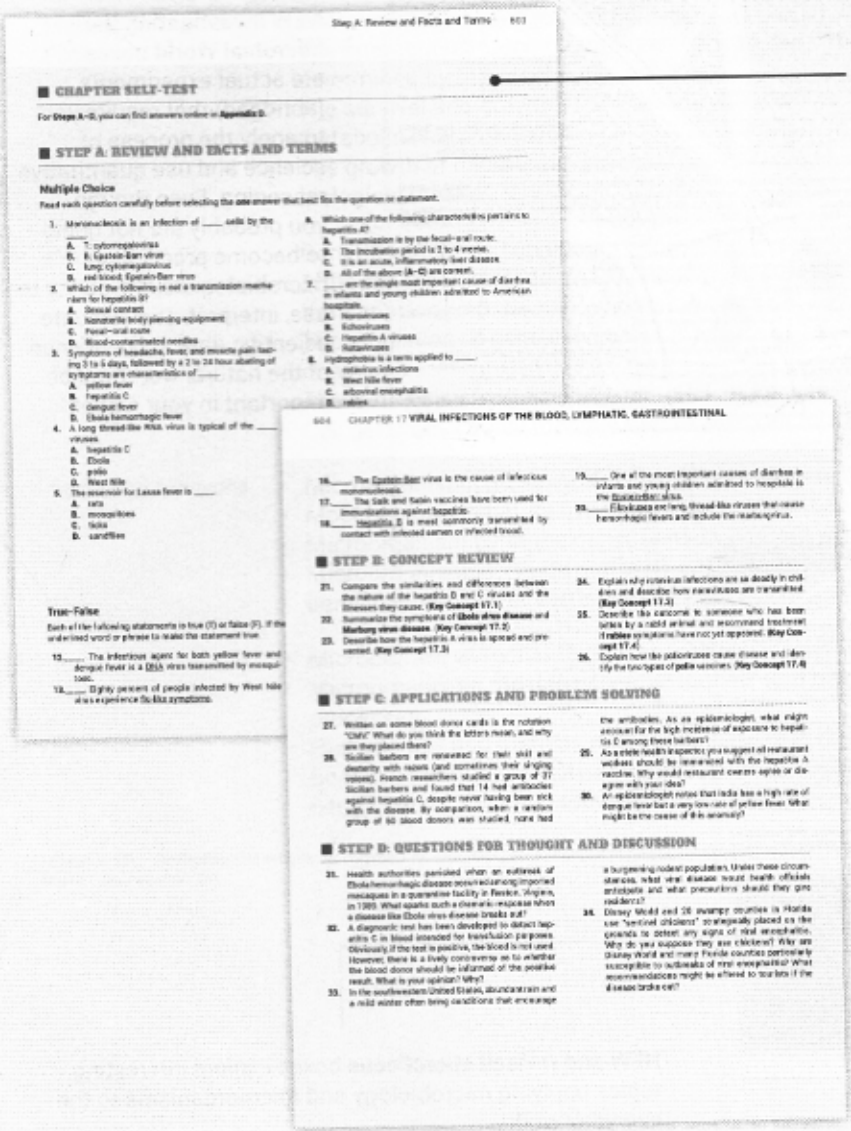
metabolic activity which, along with the dense and thick slime, makes the cells less susceptible to antibiotics and host immune defenses. Thus, many human wound and chronic infections are the result of biofilm development.

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] "talking with" neighboring cells through communication. In some ways, it is not that [illegible] electronic communications in human [illegible] through Twitter and Facebook. Thus, [illegible] process, called **quorum sensing** (QS), is [illegible] active decision making, wherein the cells [illegible] population numbers through the exchange [illegible] 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


Step A: Review and Facts and Terms 603

CHAPTER SELF-TEST

For Steps A–B, 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. Norseviruses
   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 is false, make the statement true.

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

604 CHAPTER 17 VIRAL INFECTIONS OF THE BLOOD, LYMPHATIC, GASTROINTESTINAL

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 Norwalk 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 rotaviruses are transmitted. (Key Concept 17.3)
25. Describe this symptoms 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 poliovirizes 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 60 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 southeastern 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 26 swamp counties in Florida use "sentinel chickens" strategically placed as the grounds to detect any signs of viral encephalitis. Why do you suppose they are 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