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Seventh Edition

Microbiology

A Systems Approach

Marjorie Kelly Cowan | Heidi Smith

Mc Graw Hill

SEVENTH EDITION

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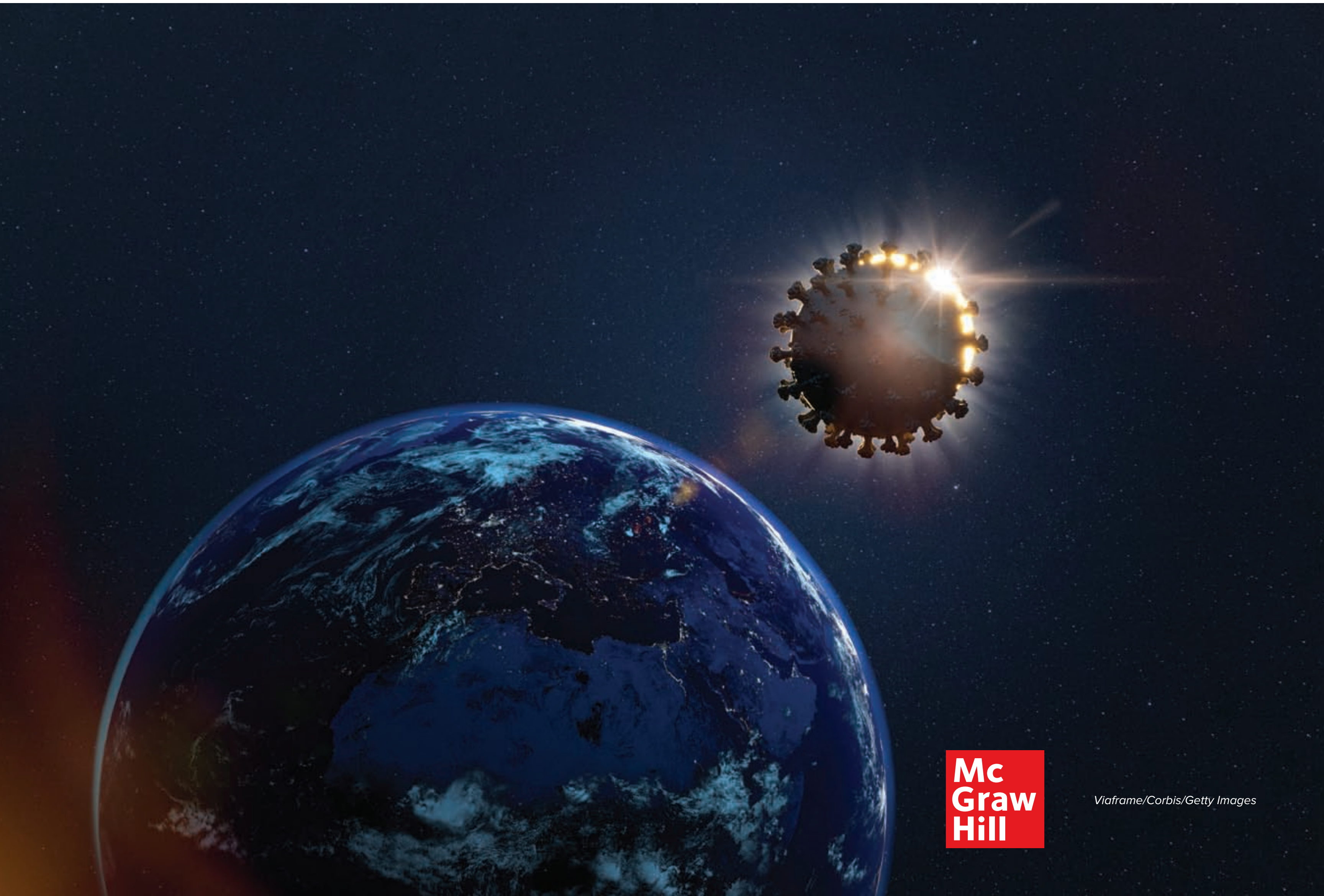

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MICROBIOLOGY

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This book is printed on acid-free paper.

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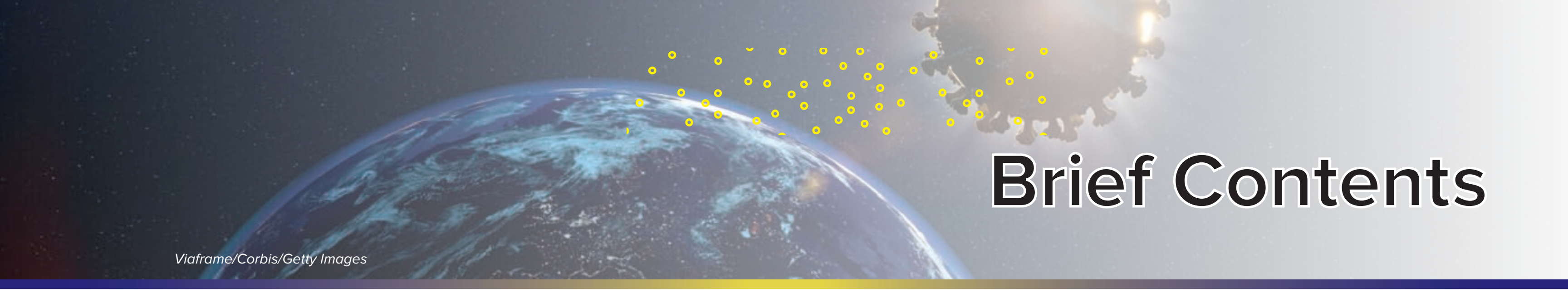

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Brief Contents

About the Authors

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Kelly Cowan has taught microbiology to pre-nursing and allied health students for over 20 years. She received her PhD from the University of Louisville and held postdoctoral positions at the University of Maryland and the University of Groningen in the Netherlands. Her campus, Miami University Middletown, is an open admissions regional campus of Miami University in Ohio. She has also authored over 25 basic research papers with her undergraduate and graduate students. For the past several years, she has turned her focus to studying pedagogical techniques that narrow the gap between under-resourced students and well-resourced students. She is past chair of the American Society for Microbiology's Undergraduate Education committee and past chair of ASM's education division, Division W.

Having a proven educator as an integrated digital author makes a *proven* learning system even better.

We are pleased to have Heidi Smith on the team. Heidi works hand-in-hand with the textbook author, creating online tools that truly complement and enhance the book's content. Because of Heidi, we offer you a robust digital learning program, tied to Learning Outcomes, to enhance your lecture and lab, whether you run a traditional, hybrid, or fully online course.

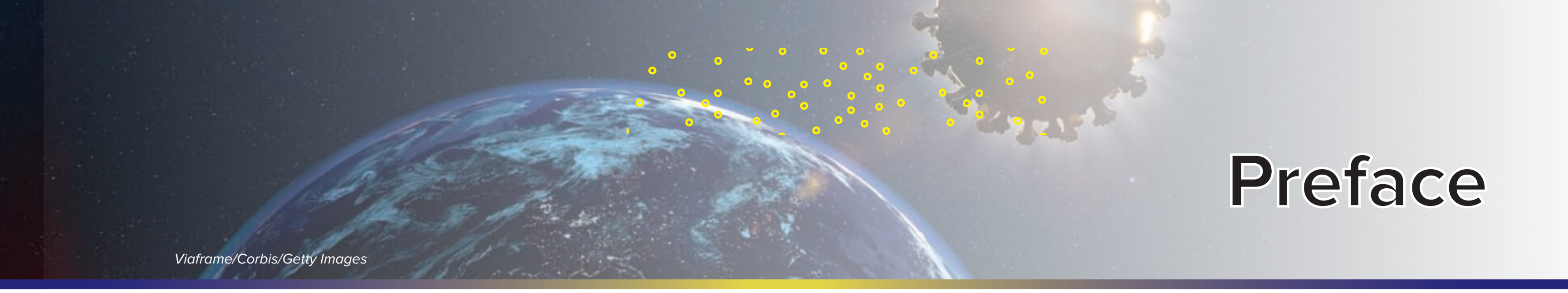
Heidi Smith leads the microbiology department at Front Range Community College in Fort Collins, Colorado. Collaboration with other faculty across the nation, the development and implementation of new digital learning tools, and her focus on student learning outcomes have revolutionized Heidi's face-to-face and online teaching approaches and student performance in her classes. The use of digital technology has given Heidi the ability to teach courses driven by real-time student data and with a focus on active learning and critical thinking activities.

Heidi is an active member of the American Society for Microbiology and participated as a task force member for the development of their Curriculum Guidelines for Undergraduate Microbiology Education. At FRCC, Heidi directs a federal grant program designed to increase student success in transfer and completion of STEM degrees at the local university as well as facilitate undergraduate research opportunities for under-represented students.

Off campus, Heidi spends as much time as she can enjoying the beautiful Colorado outdoors with her husband and four children.

Silver Oaks/McGraw Hill

Heidi Smith / Kelly Cowan



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Preface

Students:

Welcome to the microbial world! I think you will find it fascinating to understand how microbes interact with us and with our environment. The interesting thing is that each of you has already had a lot of experience with microbiology. For one thing, you are thoroughly populated with microbes right now, and much of your own genetic material actually came from viruses and other microbes. And while you have probably had some bad experiences with quite a few microbes in the form of diseases, you have certainly been greatly benefited by them as well.

This book is suited for all kinds of students and doesn't require any prerequisite knowledge of biology or chemistry. If you are interested in entering the health care profession in some way, this book will give you a strong background in the biology of microorganisms without overwhelming you with unnecessary details. Don't worry if you're not in the health professions. As the COVID-19 pandemic has shown us, a grasp of this topic is important for everyone—and it can be attained with this book.

—Kelly Cowan

Instructors
The Power of Connections

A complete course platform

Connect enables you to build deeper connections with your students through cohesive digital content and tools, creating engaging learning experiences. We are committed to providing you with the right resources and tools to support all your students along their personal learning journeys.

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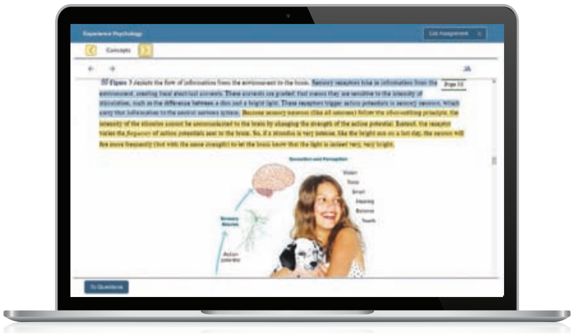

Laptop: Getty Images; Woman/dog: George Doyle/Getty Images

Every learner is unique

In Connect, instructors can assign an adaptive reading experience with SmartBook® 2.0. Rooted in advanced learning science principles, SmartBook 2.0 delivers each student a personalized experience, focusing students on their learning gaps, ensuring that the time they spend studying is time well-spent.
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Affordable solutions, added value

Make technology work for you with LMS integration for single sign-on access, mobile access to the digital textbook, and reports to quickly show you how each of your students is doing. And with our Inclusive Access program, you can provide all these tools at the lowest available market price to your students. Ask your McGraw Hill representative for more information.

Solutions for your challenges

A product isn't a solution. Real solutions are affordable, reliable, and come with training and ongoing support when you need it and how you want it. Visit **supportateverystep.com** for videos and resources both you and your students can use throughout the term.

SUPPORT AT every step

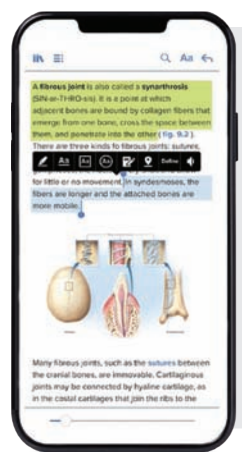
Students
Get Learning that Fits You

Effective tools for efficient studying

Connect is designed to help you be more productive with simple, flexible, intuitive tools that maximize your study time and meet your individual learning needs. Get learning that works for you with Connect.

Study anytime, anywhere

Download the free ReadAnywhere® app and access your online eBook, SmartBook® 2.0, or Adaptive Learning Assignments when it's convenient, even if you're offline. And since the app automatically syncs with your Connect account, all of your work is available every time you open it. Find out more at **mheducation.com/readanywhere**



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"I really liked this app—it made it easy to study when you don't have your text-book in front of you."

- Jordan Cunningham,
Eastern Washington University

Everything you need in one place

Your Connect course has everything you need—whether reading your digital eBook or completing assignments for class—Connect makes it easy to get your work done.

Learning for everyone

McGraw Hill works directly with Accessibility Services Departments and faculty to meet the learning needs of all students. Please contact your Accessibility Services Office and ask them to email accessibility@mheducation.com, or visit **mheducation.com/about/accessibility** for more information.

Digital and Lab Resources for Your Success

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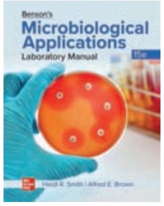
Need a lab manual for your microbiology course? Customize any of these manuals—add your text material—and *Create* your perfect solution!

McGraw Hill offers several lab manuals for the microbiology course. Contact your McGraw Hill learning technology representative for packaging options with any of our lab manuals.

Smith/Brown: *Benson's Microbiological Applications: Laboratory Manual in General Microbiology,* 15th edition (978-1-260-25898-1)



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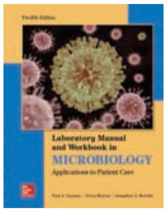
Morello: *Laboratory Manual and Workbook in Microbiology: Applications to Patient Care,* 12th edition (978-1-260-00218-8)



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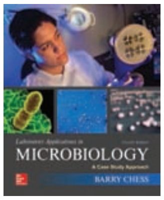
Chess: *Laboratory Applications in Microbiology: A Case Study Approach,* 4th edition (978-1-259-70522-9)



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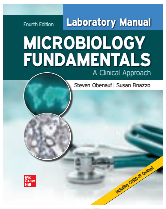
Obenauf/Finazzo: *Microbiology Fundamentals: A Clinical Approach Laboratory Manual,* 4th edition (978-1-260-78609-5)



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Explore our microbiology articles and podcasts dedicated to sharing ideas, best practices, teaching tips and more! https://www.mheducation.com/highered/microbiology.html

NewsFlash brings the real world into your classroom! These activities in Connect tie current news stories to key concepts. After interacting with a contemporary news story, students are assessed on their ability to make the connections between real-life events and course content.

Virtual Labs

Virtual Labs and Lab Simulations

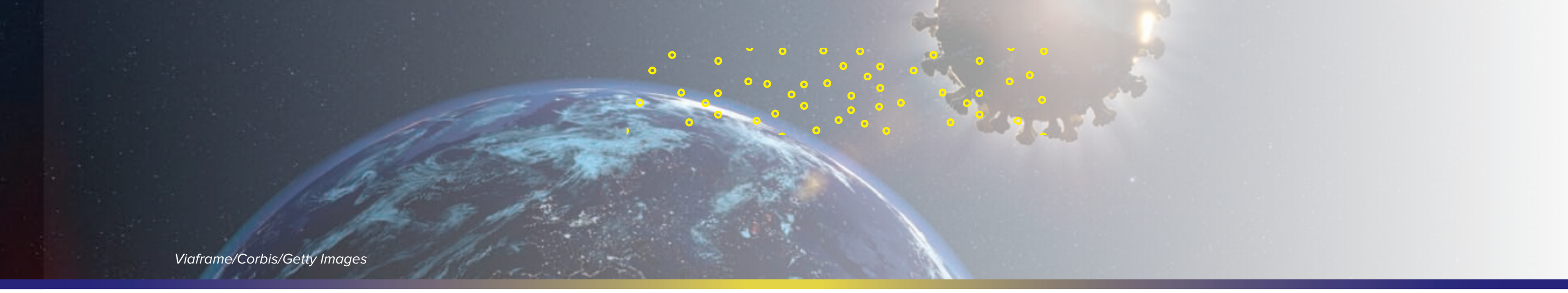
While the biological sciences are hands-on disciplines, instructors are often asked to deliver some of their lab components online: as full online replacements, supplements to prepare for in-person labs, or make-up labs.

These simulations help each student learn the practical and conceptual skills needed, then check for understanding and provide feedback. With adaptive pre-lab and post-lab assessment available, instructors can customize each assignment.

From the instructor's perspective, these simulations may be used in the lecture environment to help students visualize complex scientific processes, such as DNA technology or Gram staining, while at the same time providing a valuable connection between the lecture and lab environments.

Relevancy Modules for Microbiology

With the help of our Relevancy Modules within McGraw Hill Connect, students can see how microbiology actually relates to their everyday lives. For this book, students and instructors can access the Relevancy Modules eBook at no additional cost. Auto-graded assessment questions that correlate to the modules are also available within Connect. Each module consists of videos, an overview of basic scientific concepts, and then a closer look at the application of these concepts to the relevant topic. Some topics include microbiome, immunology, microbes and cancer, fermentation, vaccines, biotechnology, global health, SARS-CoV-2, antibiotic resistance, and several others.



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Prep for Microbiology is designed to get students ready for a forthcoming course by quickly and effectively addressing prerequisite knowledge gaps that may cause problems down the road. This question bank highlights a series of questions, including Fundamentals of Science, Fundamentals of Math and Statistics, Fundamental Skills for the Scientific Laboratory, and Student Success, to give students a refresher on the skills needed to enter and be successful in their course! Prep maintains a continuously adapting learning path individualized for each student, and tailors content to focus on what the student needs to master in order to have a successful start in the new class.

Writing Assignment

Available within Connect and Connect Master, the Writing Assignment tool delivers a learning experience to help students improve their written communication skills and conceptual understanding. As an instructor you can assign, monitor, grade, and provide feedback on writing more efficiently and effectively.

Remote Proctoring & Browser-Locking Capabilities

Remote proctoring and browser-locking capabilities, hosted by Proctorio within Connect, provide control of the assessment environment by enabling security options and verifying the identity of the student.

Seamlessly integrated within Connect, these services allow instructors to control the assessment experience by verifying identification, restricting browser activity, and monitoring student actions.

Instant and detailed reporting gives instructors an at-a-glance view of potential academic integrity concerns, thereby avoiding personal bias and supporting evidence-based claims.

ReadAnywhere®

Read or study when it's convenient for you with McGraw Hill's free ReadAnywhere app. Available for iOS or Android smartphones or tablets, ReadAnywhere gives users access to McGraw Hill tools including the eBook and SmartBook® 2.0 or Adaptive Learning Assignments in Connect. Take notes, highlight, and complete assignments offline—all of your work will sync when you open the app with WiFi access. Log in with your McGraw Hill Connect username and password to start learning—anytime, anywhere!

OLC-Aligned Courses

Implementing High-Quality Online Instruction and Assessment through Preconfigured Courseware

In consultation with the Online Learning Consortium (OLC) and our certified Faculty Consultants, McGraw Hill has created preconfigured courseware using OLC's quality scorecard to align with best practices in online course delivery. This turnkey courseware contains a combination of formative assessments, summative assessments, homework, and application activities, and can easily be customized to meet an individual's needs and course outcomes. For more information, visit https://www.mheducation.com/highered/olc.

Create

Your Book, Your Way

McGraw Hill's Content Collections Powered by Create® is a self-service website that enables instructors to create custom course materials—print and eBooks—by drawing upon McGraw Hill's comprehensive, cross-disciplinary content. Choose what you want from our high-quality textbooks, articles, and cases. Combine it with your own content quickly and easily, and tap into other rights-secured, third-party content such as readings, cases, and articles. Content can be arranged in a way that makes the most sense for your course, and you can include the course name and information as well. Choose the best format for your course: color print, black-and-white print, or eBook. The eBook can be included in your Connect course and is available on the free ReadAnywhere app for smartphone or tablet access as well. When you are finished customizing, you will receive a free digital copy to review in just minutes! Visit McGraw Hill Create—www.mcgrawhillcreate.com—today and begin building!

Test Builder in Connect

Available within Connect, Test Builder is a cloud-based tool that enables instructors to format tests that can be printed,

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administered within a Learning Management System, or exported as a Word document of the test bank. Test Builder offers a modern, streamlined interface for easy content configuration that matches course needs, without requiring a download.

Test Builder allows you to:

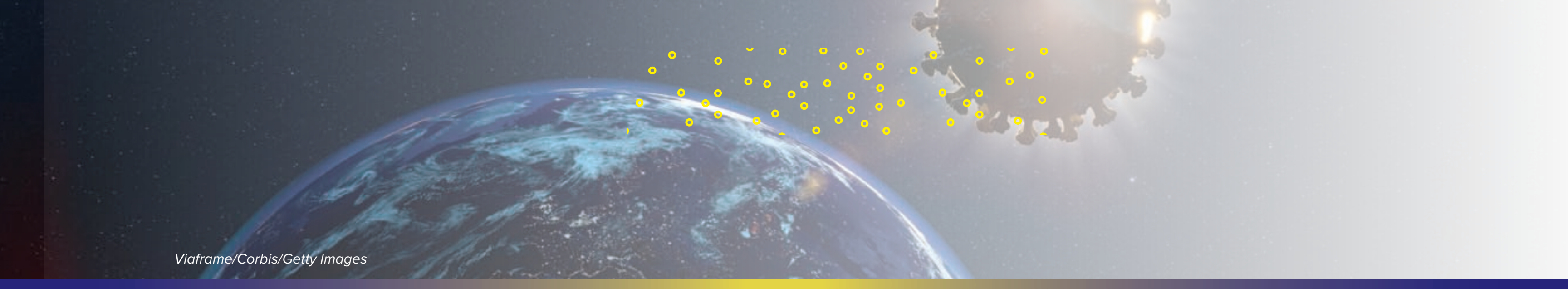
- access all test bank content from a particular title.
- easily pinpoint the most relevant content through robust filtering options.
- manipulate the order of questions or scramble questions and/or answers.
- pin questions to a specific location within a test.
- determine your preferred treatment of algorithmic questions.
- choose the layout and spacing.
- add instructions and configure default settings.

Test Builder provides a secure interface for better protection of content and allows for just-in-time updates to flow directly into assessments.

Tegrity: Lectures 24/7

Tegrity in Connect is a tool that makes class time available 24/7 by automatically capturing every lecture. With a simple one-click start-and-stop process, you capture all computer screens and corresponding audio in a format that is easy to search, frame by frame. Students can replay any part of any class with easy-to-use, browser-based viewing on a PC, Mac, or other mobile device.

Educators know that the more students can see, hear, and experience class resources, the better they learn. In fact, studies prove it. Tegrity's unique search feature helps students efficiently find what they need, when they need it, across an entire semester of class recordings. Help turn your students' study time into learning moments immediately supported by your lecture. With Tegrity, you also increase intent listening and class participation by easing students' concerns about note-taking. Using Tegrity in Connect will make it more likely you will see students' faces, not the tops of their heads.



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Unique Interactive Question Types in Connect Tagged to ASM's Curriculum Guidelines for Undergraduate Microbiology and to Bloom's Taxonomy

- **Case Study:** Case studies come to life in a learning activity that is interactive, self-grading, and assessable. The integration of the cases with videos and animations adds depth to the content, and the use of integrated questions forces students to stop, think, and evaluate their understanding.
- **Media Under The Microscope:** The opening cases in the textbook help students read science articles in the popular media with a critical eye. Questions in Connect are designed to extend these cases in a manner that promotes active student learning, either at home or in the classroom.
- **Concept Maps:** Concept maps allow students to manipulate terms in a hands-on manner in order to assess their understanding of chapter-wide topics. Students become actively engaged and are given immediate feedback, enhancing their understanding of important concepts within each chapter.
- **SmartGrid Questions:** SmartGrid questions replace the traditional end-of-chapter questions, and all of these questions are available for assignment in Connect. These questions were carefully constructed to assess chapter material as it relates to all six concepts outlined in the American Society of Microbiology curriculum guidelines plus the competency of "Scientific Thinking." The questions are cross-referenced with Bloom's taxonomy of learning level. Seven concepts/competencies × three increasing Bloom's levels = a 21-question robust assessment tool.
- **What's the Diagnosis:** Specifically designed for the disease chapters of the text, this is an integrated learning experience designed to assess the student's ability to utilize information learned in the preceding chapters to successfully culture, identify, and treat a disease-causing microbe in a simulated patient scenario. This question type is true experiential learning and allows the students to think critically through a real-life clinical situation.
- **Animations:** Animation quizzes pair our high-quality animations with questions designed to probe student understanding of the illustrated concepts.
- **Animation Learning Modules:** Making use of McGraw Hill's collection of videos and animations, this question type presents an interactive, self-grading, and assessable activity. These modules take a stand-alone, static animation and turn it into an interactive learning experience for your students with real-time remediation.
- **Labeling:** Using the high-quality art from the textbook and other reliable sources, check your students' visual understanding as they practice interpreting figures and learning relationships. Easily edit or remove any label you wish!
- **Classification:** Ask students to organize concepts or structures into categories by placing them in the correct "bucket."
- **Sequencing:** Challenge students to place the steps of a complex process in the correct order.
- **Composition:** Fill in the blanks to practice vocabulary and show a critical understanding of the connections between several different concepts. These exercises may qualify as "writing across the curriculum" activities.

All McGraw Hill Connect content is tagged to Learning Outcomes for each chapter as well as topic, textbook section, Bloom's Level, and ASM Curriculum Guidelines to assist you in customizing assignments and in reporting on your students' performance against these points. This will enhance your ability to assess student learning in your courses by allowing you to align your learning activities to peer-reviewed standards from an international organization.

NCLEX® **Prep Questions:** Sample questions are available in Connect to assign to students.

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Note from the Authors

This Text's Most Important Distinguishing Features:

These are the features we feel most strongly about. They represent proven methods for enabling our students to learn and we have seen them work in the classroom. The Cowan books have always been built around logical and clear organization, a factor that is critical when nonmajors are attempting to learn a science full of new vocabulary and concepts.

- Comprehensive COVID-19 CONTENT. COVID-19 is not just covered in its disease chapter. Most chapters, even the basic science chapters, have COVID-19 content woven in as a dynamic touchstone for basic concepts.
- SYSTEMATIC ORGANIZATION of the disease chapters that groups microbes by the conditions they cause, which is the way our students will encounter diseases in the clinic.
- A new stand-alone chapter on EPIDEMIOLOGY, the importance of which has been made clear by the COVID-19 pandemic.
- OPENING CASES that teach students how to read science articles in the popular media with a critical eye.
- MICROBIOME findings in all 25 chapters—in form of Microbiome Insight boxes as well as in the text. This reinforces how game-changing the microbiome findings are.
- STUDY SMARTER: BETTER TOGETHER in each chapter that provides guidance for students' group study, either in person or online. No instructor intervention required. Research shows that well-structured group study particularly benefits under-resourced learners and students with lower levels of reading ability.
- SMARTGRIDS in each chapter. The usual end-of-chapter questions are dramatically reformatted into a 21-question grid that cross-references questions by their Bloom's level and the six core concepts of microbiology (plus the competency of scientific literacy) as identified by the American Society for Microbiology.
- CLEAN, uncluttered, and predictable sequence of chapter content. Again, this is extremely helpful to our less-prepared students.
- CONNECT UPDATES
  - CRITICAL THINKING applied through higher Bloom's level questions added to the Connect Question Bank.
  - SMARTBOOK LEARNING RESOURCES added based on heat map results showing areas where students struggle the most. Help when they need it and where they need it.
  - Ready-to-implement ACTIVE LEARNING opportunities available in every chapter in the form of case studies, scientific article reviews, and other interactive question types.

—Kelly Cowan
—Heidi Smith

Capturing Students' Attention and Learning

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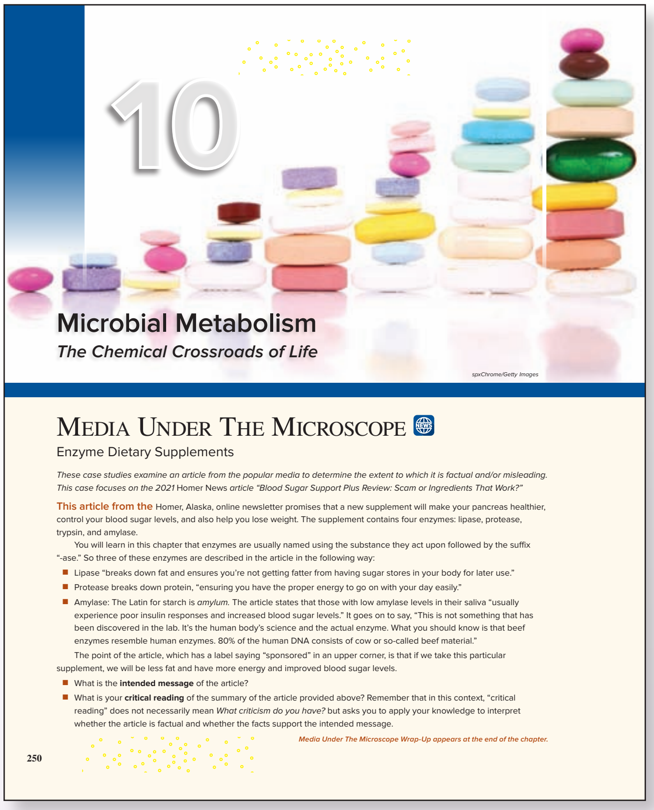
Chapter Opening Case Files That Teach Students How to Judge Popular Media Articles About Science!

Each chapter opens with a revolutionary kind of case study. Titled "Media Under The Microscope," these are summaries of actual news items about microbiology topics. Students are walked through the steps of judging the relative accuracy of the popular media stories. Chapter by chapter, they learn how to critically assess the journalistic accounts. They encounter the principles of causation vs. correlation, biological plausibility, and the importance of not overstating experimental results. It is a critical need among the public today, and this textbook addresses it.



10

Microbial Metabolism

The Chemical Crossroads of Life

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MEDIA UNDER THE MICROSCOPE

Enzyme Dietary Supplements

These case studies examine an article from the popular media to determine the extent to which it is factual and/or misleading. This case focuses on the 2021 Homer News *article "Blood Sugar Support Plus Review: Scam or Ingredients That Work?"*

This article from the Homer, Alaska, online newsletter promises that a new supplement will make your pancreas healthier, control your blood sugar levels, and also help you lose weight. The supplement contains four enzymes: lipase, protease, trypsin, and amylase.

You will learn in this chapter that enzymes are usually named using the substance they act upon followed by the suffix "-ase." So three of these enzymes are described in the article in the following way:

- Lipase "breaks down fat and ensures you're not getting fatter from having sugar stores in your body for later use."
- Protease breaks down protein, "ensuring you have the proper energy to go on with your day easily."
- Amylase: The Latin for starch is *amylum.* The article states that those with low amylase levels in their saliva "usually experience poor insulin responses and increased blood sugar levels." It goes on to say, "This is not something that has been discovered in the lab. It's the human body's science and the actual enzyme. What you should know is that beef enzymes resemble human enzymes. 80% of the human DNA consists of cow or so-called beef material."

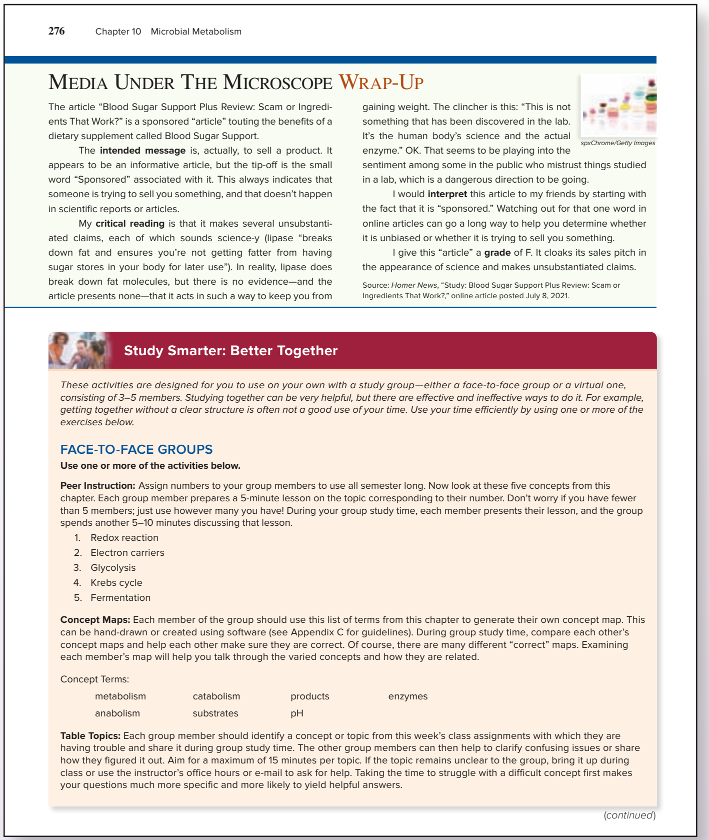
The point of the article, which has a label saying "sponsored" in an upper corner, is that if we take this particular supplement, we will be less fat and have more energy and improved blood sugar levels.

- What is the **intended message** of the article?
- What is your **critical reading** of the summary of the article provided above? Remember that in this context, "critical reading" does not necessarily mean *What criticism do you have?* but asks you to apply your knowledge to interpret whether the article is factual and whether the facts support the intended message.

Media Under The Microscope Wrap-Up appears at the end of the chapter.

250

Active learning activities are assignable in Connect to extend these case files in or outside of the classroom.



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MEDIA UNDER THE MICROSCOPE WRAP-UP

The article "Blood Sugar Support Plus Review: Scam or Ingredients That Work?" is a sponsored "article" touting the benefits of a dietary supplement called Blood Sugar Support.

The **intended message** is, actually, to sell a product. It appears to be an informative article, but the tip-off is the small word "Sponsored" associated with it. This always indicates that someone is trying to sell you something, and that doesn't happen in scientific reports or articles.

My **critical reading** is that it makes several unsubstantiated claims, each of which sounds science-y (lipase "breaks down fat and ensures you're not getting fatter from having sugar stores in your body for later use"). In reality, lipase does break down fat molecules, but there is no evidence—and the article presents none—that it acts in such a way to keep you from gaining weight. The clincher is this: "This is not something that has been discovered in the lab. It's the human body's science and the actual enzyme." OK. That seems to be playing into the sentiment among some in the public who mistrust things studied in a lab, which is a dangerous direction to be going.

spxChrome/Getty Images

I would **interpret** this article to my friends by starting with the fact that it is "sponsored." Watching out for that one word in online articles can go a long way to help you determine whether it is unbiased or whether it is trying to sell you something.

I give this "article" a **grade** of F. It cloaks its sales pitch in the appearance of science and makes unsubstantiated claims.

Source: *Homer News*, "Study: Blood Sugar Support Plus Review: Scam or Ingredients That Work?," online article posted July 8, 2021.

Study Smarter: Better Together

These activities are designed for you to use on your own with a study group—either a face-to-face group or a virtual one, consisting of 3–5 members. Studying together can be very helpful, but there are effective and ineffective ways to do it. For example, getting together without a clear structure is often not a good use of your time. Use your time efficiently by using one or more of the exercises below.

FACE-TO-FACE GROUPS

Use one or more of the activities below.

Peer Instruction: Assign numbers to your group members to use all semester long. Now look at these five concepts from this chapter. Each group member prepares a 5-minute lesson on the topic corresponding to their number. Don't worry if you have fewer than 5 members; just use however many you have! During your group study time, each member presents their lesson, and the group spends another 5–10 minutes discussing that lesson.

1. Redox reaction
2. Electron carriers
3. Glycolysis
4. Krebs cycle
5. Fermentation

Concept Maps: Each member of the group should use this list of terms from this chapter to generate their own concept map. This can be hand-drawn or created using software (see Appendix C for guidelines). During group study time, compare each other's concept maps and help each other make sure they are correct. Of course, there are many different "correct" maps. Examining each member's map will help you talk through the varied concepts and how they are related.

Concept Terms:

metabolism	catabolism	products	enzymes
anabolism	substrates	pH	

Table Topics: Each group member should identify a concept or topic from this week's class assignments with which they are having trouble and share it during group study time. The other group members can then help to clarify confusing issues or share how they figured it out. Aim for a maximum of 15 minutes per topic. If the topic remains unclear to the group, bring it up during class or use the instructor's office hours or e-mail to ask for help. Taking the time to struggle with a difficult concept first makes your questions much more specific and more likely to yield helpful answers.

(continued)

Photo: Caia Image/Image Source

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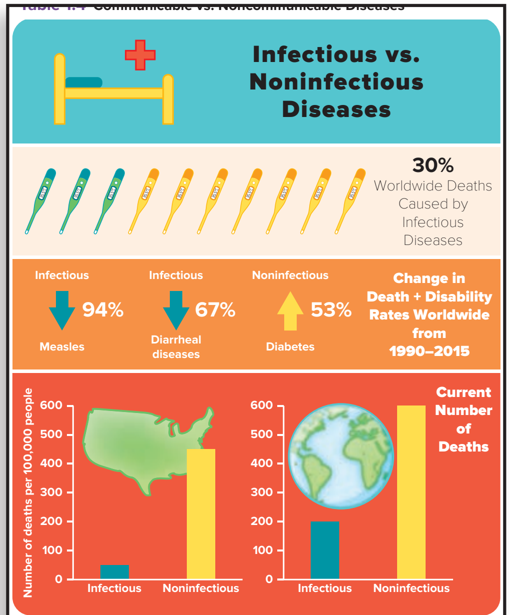
Infographics for the Way Students Consume Data

Students have always had difficulty reading figures and graphs. Savvy data designers on the Internet have come up with a format that attracts their eyes and makes complex concepts and data more palatable to them. And more palatable means that they spend time absorbing the information.



Source: Data from the World Health Organization and from the Institute for Health Metrics and Evaluation,

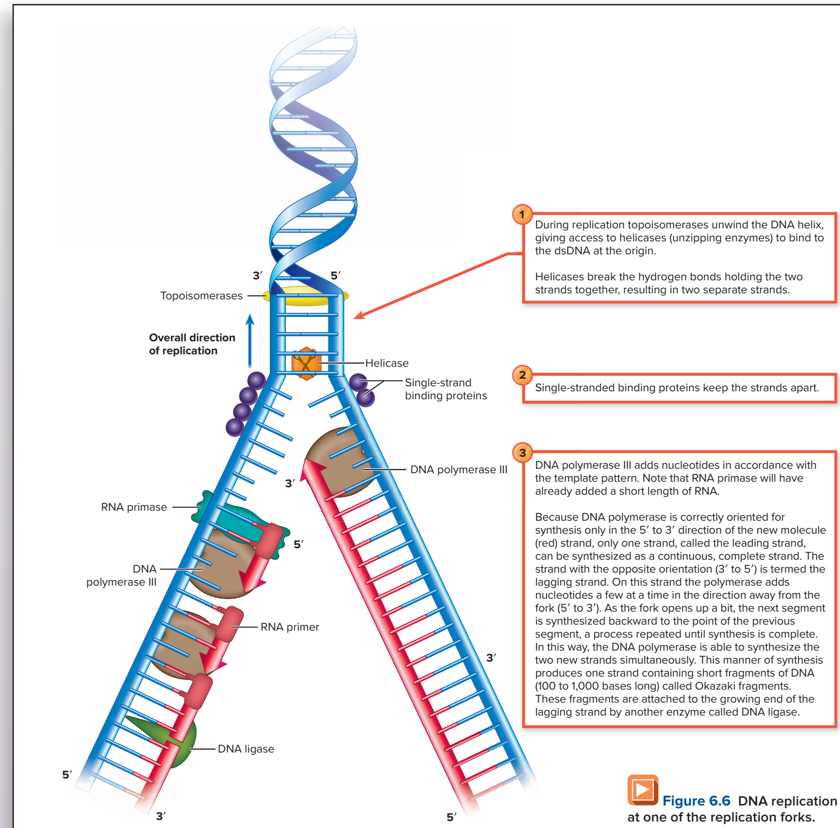
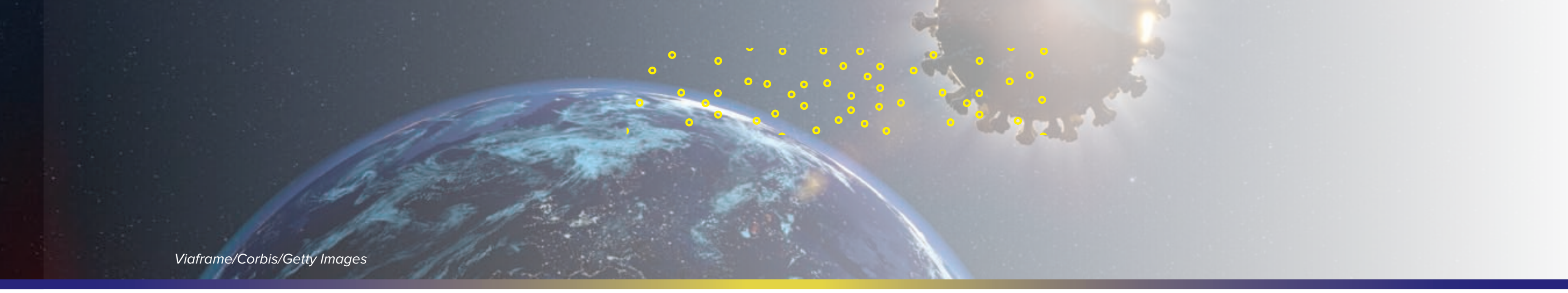


Figure 6.6 DNA replication at one of the replication forks.

Figures

Many difficult microbiological concepts are best portrayed by breaking them down into stages. These figures show each step clearly marked with an orange, numbered circle and the explanation of the step, right next to it.



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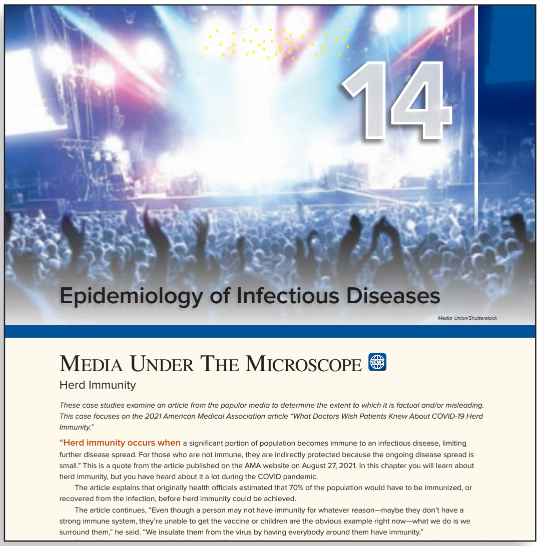
Brand New Comprehensive Epidemiology Chapter

One thing the COVID-19 pandemic showed us is that all of us need a basic understanding of epidemiological principles. Kelly Cowan has taught undergraduate epidemiology for 20+ years, and explains topics such as correlation, causation, screening tests, types of studies, reproductive rates, and the natural history of disease in easy-to-understand terms.



Epidemiology of Infectious Diseases

Media Union/Shutterstock

MEDIA UNDER THE MICROSCOPE

Herd Immunity

These case studies examine an article from the popular media to determine the extent to which it is factual and/or misleading. This case focuses on the 2021 American Medical Association article "What Doctors Wish Patients Knew About COVID-19 Herd Immunity."

"Herd immunity occurs when a significant portion of population becomes immune to an infectious disease, limiting further disease spread. For those who are not immune, they are indirectly protected because the ongoing disease spread is small." This is a quote from the article published on the AMA website on August 27, 2021. In this chapter you will learn about herd immunity, but you have heard about it a lot during the COVID pandemic.

The article explains that originally health officials estimated that 70% of the population would have to be immunized, or recovered from the infection, before herd immunity could be achieved.

The article continues, "Even though a person may not have immunity for whatever reason—maybe they don't have a strong immune system, they're unable to get the vaccine or children are the obvious example right now—what we do is we surround them," he said. "We insulate them from the virus by having everybody around them have immunity."

Systematic Presentation of Disease-Causing Organisms

Microbiology: A Systems Approach takes a unique approach to diseases by organizing microbial agents under the heading of the disease condition they cause. After all of them are covered, the agents are summarized in a comparative table. Every condition gets a table, whether there is one possible cause or a dozen. Through this approach, students study how diseases affect patients—the way future health care professionals will encounter them in their jobs. Other texts separate the viral causes from the bacterial causes from the fungal causes of meningitis in different parts of the chapter, as an example of why this matters.

A Note About the Chapter Organization

In a clinical setting, patients present themselves to health care practitioners with a set of symptoms, and the health care team makes an "anatomical" diagnosis—such as a *generalized vesicular rash*. The anatomical diagnosis allows practitioners to narrow down the list of possible causes to microorganisms that are known to be capable of creating such a condition (the differential diagnosis). Then the proper tests can be performed to arrive at an etiologic diagnosis (determining the exact microbial cause). The order of events is

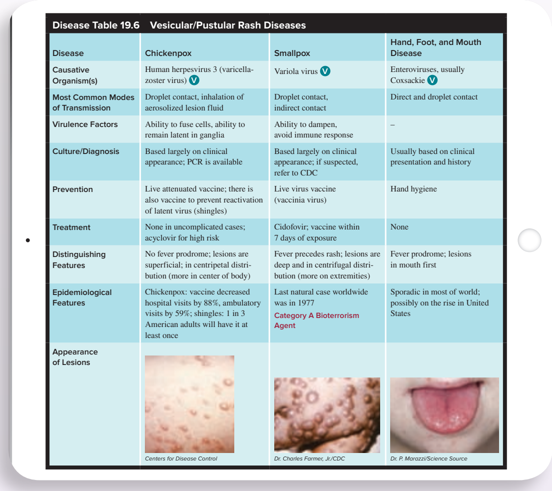
1. anatomical diagnosis,
2. differential diagnosis, and
3. etiologic diagnosis.

In this book, we organize diseases according to anatomical diagnosis (which appears as a boxed heading). Then the agents in the differential diagnosis are each addressed. When we finish addressing each agent that could cause the condition, we sum them up in a Disease Table, whether there is only 1 possible cause or whether there are 9 or 10. Each organism is followed by a B, F, P, V, or H, standing for bacterium, fungus, protozoan, virus, or helminth. If it is a bacterium, its Gram status is also included (G+ or G−).

In the Disease Tables, you will also find a row featuring recommended treatment. Here we will identify the microbes that are on the CDC's "Threat" list for their antibiotic resistance (presented in a table in chapter 12).

Every disease table contains national and/or worldwide epidemiological information for each causative agent.

This approach is logical, systematic, and intuitive, as it encourages clinical and critical thinking in students—the type of thinking they will be using if their eventual careers are in health care. Students learn to examine multiple possibilities for a given condition and grow accustomed to looking for commonalities and differences among the various organisms that cause a given condition.



Disease Table 19.6 Vesicular/Pustular Rash Diseases

Disease	Chickenpox	Smallpox	Hand, Foot, and Mouth Disease
Causative Organism(s)	Human herpesvirus 3 (varicella-zoster virus) V	Variola virus V	Enteroviruses, usually Coxsackie V
Most Common Modes of Transmission	Droplet contact, inhalation of aerosolized lesion fluid	Droplet contact, indirect contact	Direct and droplet contact
Virulence Factors	Ability to fuse cells, ability to remain latent in ganglia	Ability to dampen, avoid immune response	–
Culture/Diagnosis	Based largely on clinical appearance; PCR is available	Based largely on clinical appearance; if suspected, refer to CDC	Usually based on clinical presentation and history
Prevention	Live attenuated vaccine; there is also vaccine to prevent reactivation of latent virus (shingles)	Live virus vaccine (vaccinia virus)	Hand hygiene
Treatment	None in uncomplicated cases; acyclovir for high risk	Cidofovir; vaccine within 7 days of exposure	None
Distinguishing Features	No fever prodrome; lesions are superficial; in centripetal distribution (more in center of body)	Fever precedes rash; lesions are deep and in centrifugal distribution (more on extremities)	Fever prodrome; lesions in mouth first
Epidemiological Features	Chickenpox: vaccine decreased hospital visits by 88%, ambulatory visits by 59%; shingles: 1 in 3 American adults will have it at least once	Last natural case worldwide was in 1977 Category A Bioterrorism Agent	Sporadic in most of world; possibly on the rise in United States
Appearance of Lesions	Centers for Disease Control	Dr. Charles Farmer, Jr./CDC	Dr. P. Marazzi/Science Source

"Diagnosing Infections" Chapter

Chapter 18 brings together in one place the current methods used to diagnose infectious diseases. The chapter starts with collecting samples from the patient and details the biochemical, serological, and molecular methods used to identify causative microbes.

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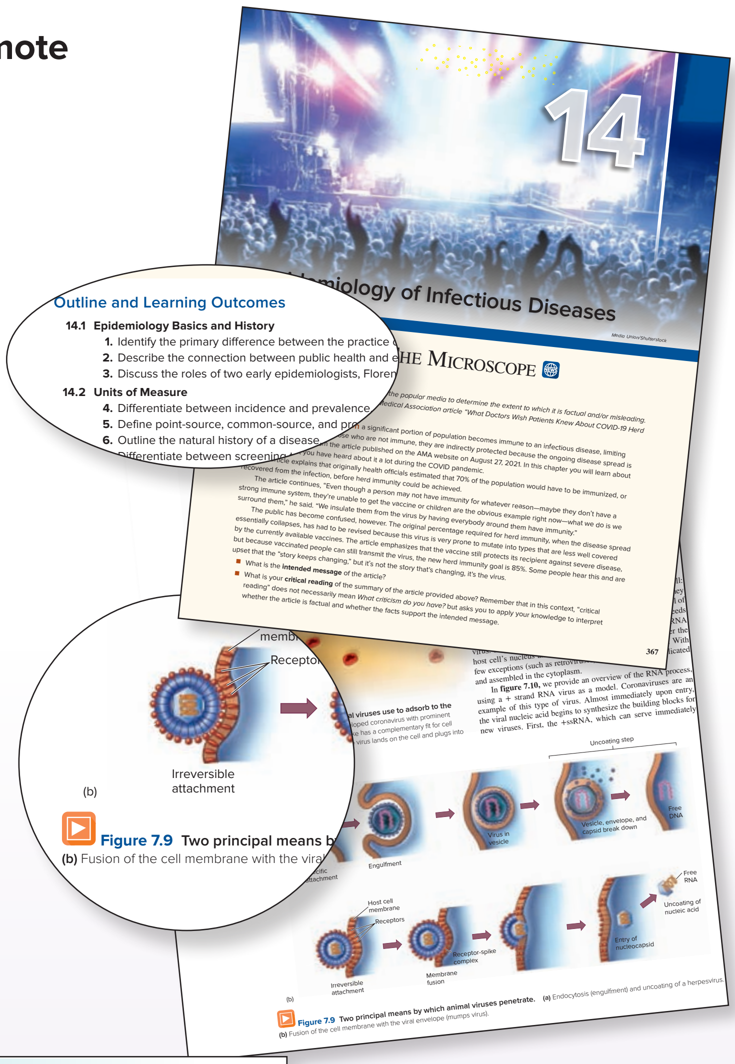
Student-Centered Pedagogy Created to Promote Active Learning

Learning Outcomes and Assess Your Progress Questions

Every chapter in the book opens with an outline—which is a list of Learning Outcomes. Each major section of the text concludes with Assess Your Progress with the learning outcomes covered in that section. The Learning Outcomes are tightly correlated to digital material. Instructors can easily measure student learning in relation to the specific Learning Outcomes used in their course.



Animated Learning Modules

Certain topics need help to come to life off the page. Animations, video, audio, and text all combine to help students understand complex processes. Key topics have an Animated Learning Module assignable through Connect. An icon in the text indicates when these learning modules are available.

Disease Connection

Sometimes it is difficult for students to see the relevance of basic concepts to their chosen professions. So the basic science chapters contain Disease Connections, very short boxes that relate basic science topics to clinical situations.

> **Disease Connection**
>
> *Streptococcus pneumoniae* is a versatile human pathogen. It causes pneumonia, ear infections, meningitis, and other conditions. Its capsule is vital for its disease-causing capacity.

Microbiome Readings

Each chapter includes a Microbiome Insight box. These boxes are a way to emphasize the important and revolutionary ways the microbiome influences almost everything we know about human health.

INSIGHT 11.1 MICROBIOME: Hand Hygiene

How many times have you heard that one of the best ways to prevent infections in hospitals is for health care workers to wash their hands? OK, but now that we know about how important our resident microbiota is, we should ask what frequent hand washing does to that. A recent study followed 34 health care workers in a surgical intensive care unit. Twenty-four of them were registered nurses, six were respiratory therapists, and four were nurse technologists.

During a typical 12-hour shift,

- 53% of them reported washing their hands with soap and water between 6 and 20 times,
- 41% used alcohol rubs more than 20 times, and
- 62% donned more than 40 pairs of gloves.

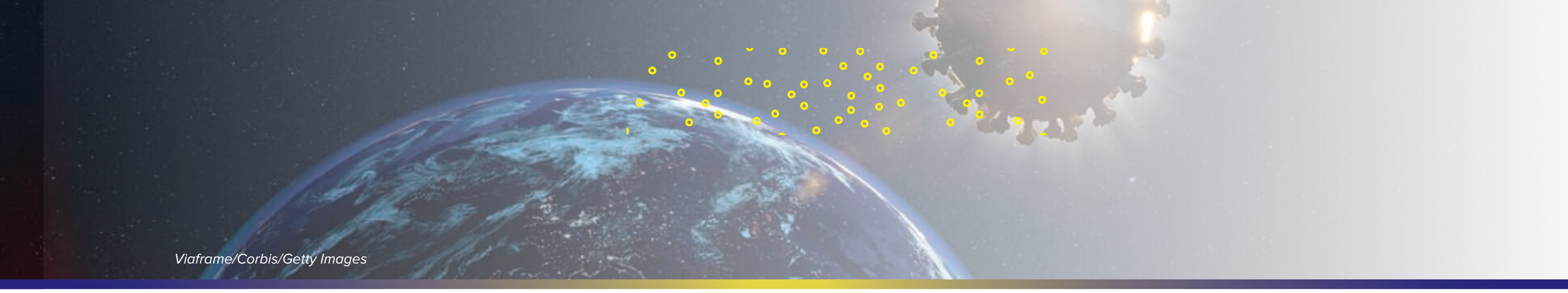
The researchers then tested for common healthcare-associated pathogens and found that approximately 45% of the health care workers' dominant hands were positive for *Staphylococcus aureus*. They detected methicillin-resistant *Staphylococcus aureus* (MRSA) on 3.9% of the dominant hands. About 4% of hands were positive for the fungus *Candida albicans*.

These rates look very similar to the rates found in the general population—those of us who are not washing our hands 20 times a day. This might be an illustration of the difference between *colonization*—when microbes become part of your "normal" microbiota—and *contamination*—when you pick up microbes from your environment and they stay only transiently. Contaminants are usually easily washed off, while colonizers are embedded deeper in your skin oils and the top layers of epithelial cells.

One question raised, but not answered, by this study is whether altering the normal microbiome of the hand by frequent hand hygiene practices might make it (a) easier or (b) more difficult for pathogens to contaminate and/or colonize caregivers' hands.

O. Dimier/PhotoAlto

Source: Rosenthal, et al. "Healthcare Workers' Hand Microbiome May Mediate Carriage of Hospital Pathogens," *Pathogens*. 2014 Mar: 3(1): 1–13.



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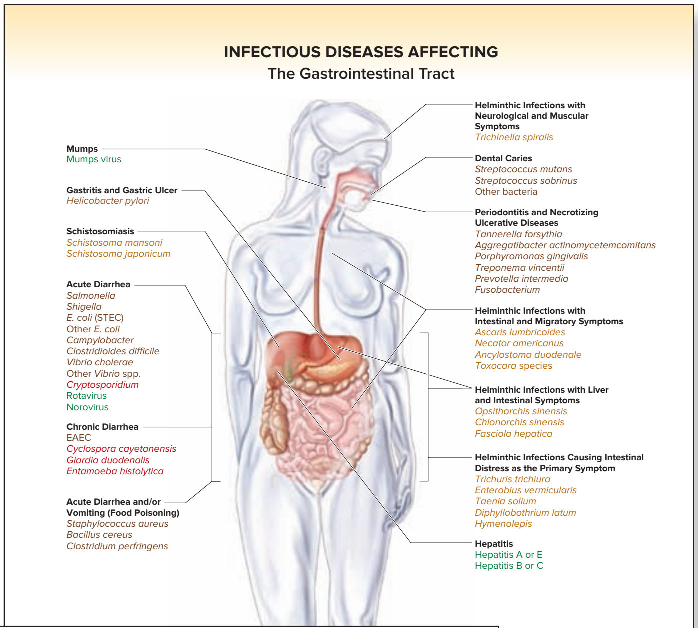
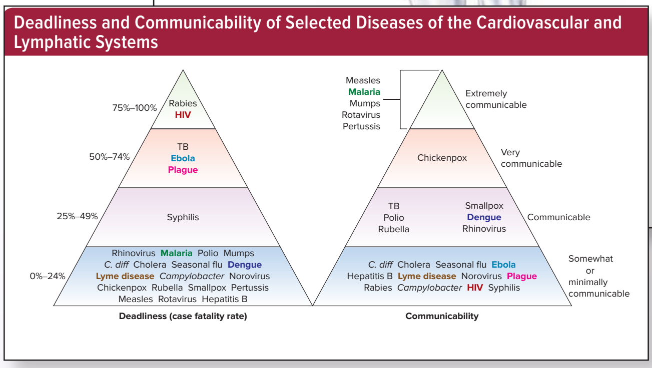
System Summary Figures

"Glass body" figures at the end of each disease chapter highlight the affected organs and list the diseases that were presented in the chapter. In addition, the microbes are color coded by taxonomic type.



Communicability vs. Deadliness Feature

Each microbe can be characterized using two important descriptors: its relative communicability and its relative deadliness. These are important epidemiologically and clinically—and usually receive only sporadic mention in textbooks—so we have created a visual feature that appears in each disease chapter, and in the epidemiology chapter.



Taxonomic List of Organisms

A taxonomic list of organisms is presented at the end of each disease chapter so students can see the taxonomic position of microbes causing diseases in that body system.

▶ Summing Up

Taxonomic Organization Microorganisms Causing Diseases of the Skin and Eyes

Microorganism	Disease	Disease Table
Gram-positive bacteria		
Staphylococcus aureus	MRSA impetigo, cellulitis, scalded skin syndrome, folliculitis, abscesses (furuncles and carbuncles), necrotizing fasciitis, bacterial conjunctivitis	MRSA skin and soft tissue infections, 19.1; Impetigo, 19.2; Cellulitis, 19.3; Scalded skin syndrome, 19.4
Streptococcus pyogenes	Impetigo, cellulitis, erysipelas, necrotizing fasciitis, scarlet fever	Impetigo, 19.2; Cellulitis, 19.3; Maculopapular rash diseases, 19.7
Clostridium perfringens	Gas gangrene	Gas gangrene, 19.5
Bacillus anthracis	Cutaneous anthrax	Large pustular skin lesions, 19.9
Streptococcus pneumoniae	Conjunctivitis	Conjunctivitis, 19.11
Gram-negative bacteria		
Chlamydia trachomatis	Neonatal conjunctivitis, bacterial conjunctivitis	Conjunctivitis, 19.11
Neisseria gonorrhoeae	Neonatal conjunctivitis, bacterial conjunctivitis, trachoma	Conjunctivitis, 19.11; Trachoma, 19.12
Wolbachia (in combination with *Onchocerca*)	River blindness	River blindness, 19.14
Haemophilus influenzae and *Moraxella*	Conjunctivitis	Conjunctivitis, 19.11
DNA viruses		
Human herpesvirus 3 (varicella) virus	Chickenpox	Vesicular or pustular rash diseases, 19.6
Variola virus	Smallpox	Vesicular or pustular rash diseases, 19.6
Parvovirus B19	Fifth disease	Maculopapular rash diseases, 19.7
Human herpesvirus 6	Roseola	Maculopapular rash diseases, 19.7
Human papillomavirus	Warts	Warts and wartlike eruptions, 19.8
Molluscum contagiosum virus	Molluscum contagiosum	Warts and wartlike eruptions, 19.8
Herpes simplex virus	Keratitis	Keratitis, 19.13
Adenovirus	Conjunctivitis	Conjunctivitis, 19.11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Developing Critical Thinkers

The end-of-chapter material is linked to Bloom's Taxonomy. It has been carefully planned to promote active learning and provide review for different learning styles and levels of difficulty.

SmartGrid

This innovative learning tool distributes chapter material among the American Society for Microbiology's six main curricular concepts, plus the competency of *scientific thinking*. Each of the seven areas is probed at three different Bloom's levels. The resulting 21-question grid can be assigned by column (all multiple-choice questions about each core concept, for example) or by row (all questions related to evolution, but at increasing Bloom's level). The highest Bloom's level questions can easily be assigned as a group project or presentation topic.

These are written around the American Society for Microbiology's (ASM) Undergraduate Curriculum guidelines. More recently, ASM has created the "Microbiology in Nursing and Allied Health (MINAH) Undergraduate Curriculum Guidelines." The emphases in these two sets of guidelines are different, but the original guidelines utilized here are weighted to the emphasis in this book's content, which is appropriate for all types of microbiology students.

SmartGrid: From Knowledge to Critical Thinking

This *21 Question Grid* takes the topics from this chapter and arranges them with respect to the American Society for Microbiology's Undergraduate Curriculum guidelines—all six of the important "Concepts" as well as the important "Competency" of scientific literacy. Three questions are supplied, which cover chapter content referring to the Concept or Competency in increasing levels of Bloom's taxonomy for learning.

ASM Concept/ Competency	A. Bloom's Level 1, 2—Remember and Understand (Choose one.)	B. Bloom's Level 3, 4—Apply and Analyze	C. Bloom's Level 5, 6—Evaluate and Create
Evolution	**1.** The identities of microorganisms on our planet **a.** are mostly known. **b.** have nearly all been identified via microscopy. **c.** have nearly all been identified via culturing techniques. **d.** are still mostly unknown.	**2.** Before the availability of molecular techniques, archaea and bacteria were considered to be very closely related. Explain why that is understandable, based on what you learned about microscopy.	**3.** Often bacteria that are freshly isolated from a patient or the environment have thick sugary outer layers (capsules). After they are transferred many times on laboratory medium, they tend to lose their capsule. Speculate about why that might happen.
Cell Structure and Function	**4.** Which of these types of organisms is least likely to be identified to the genus level with light microscopy? **a.** bacteria **b.** protozoa **c.** fungus **d.** helminth	**5.** Obviously, *structures* of microorganisms can be revealed by various types of microscopy. Can you think of any *functions* that might also be revealed? Which ones, and by which microscopic technique?	**6.** Some bacteria can produce a structure called an endospore, which is used as a survival structure. It is surrounded by a very tough and impervious outer layer that keeps it protected in adverse environmental conditions. What kinds of things would you need to know about this structure if you wanted to devise a way to stain it and see it under a microscope?

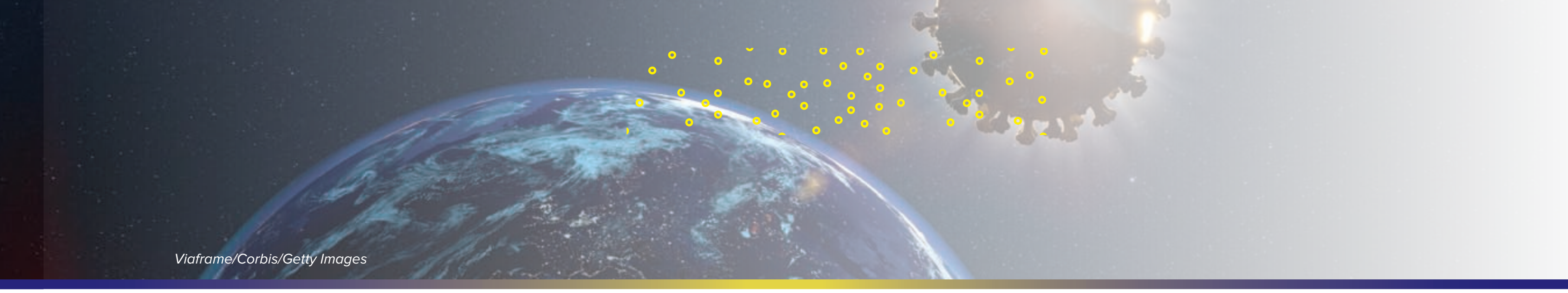
High Impact Study Feature

Students benefit most from varied study and assessment methods. We've created a short set of "Terms" and "Concepts" that help students identify the most important 10 to 15 items in a chapter. If they understand these, they are well on their way to mastery.

High Impact Study

These terms and concepts are most critical for your understanding of this chapter—and may be the most difficult. Have you mastered them? In these disease chapters, the terms and concepts help you identify what is important in a different way than the comprehensive details in the Disease Tables. Your instructor will help you understand what is important for your class.

Concepts	Terms
☐ Defenses of nervous system	☐ Meninges
☐ Normal microbiota of nervous system	☐ Cerebrospinal fluid
☐ Four bacterial causes of meningitis	☐ Blood-brain barrier
☐ Other causes of meningitis	☐ Arbovirus
☐ Foodborne cause of meningitis	☐ Dead-end host
☐ Meningitis vaccines	☐ Prion
☐ Gram-negative diplococci vs. gram-positive diplococci	☐ Progressive multifocal leukoencephalopathy
☐ Difference between CJD and vCJD	☐ Postinfection encephalitis
☐ Global polio eradication	☐ Subacute sclerosing parencephalitis
☐ Three types of botulism	
☐ Differences and similarities between tetanus and botulism	
☐ Organisms in this chapter for which there are vaccines available	
☐ Organisms in this chapter that display significant antibiotic resistance	



Viaframe/Corbis/Getty Images

Group Study Guide

The feature "Study Smarter: Better Together" gives students a format for their self-guided group study. We know that group study can be immensely useful for learning—but only if it is well-structured. This feature, in every chapter, helps students make the best use of their study time with their classmates, either in person or virtually, with no effort on the part of the instructor!

Study Smarter: Better Together

These activities are designed for you to use on your own with a study group—either a face-to-face group or a virtual one, consisting of 3–5 members. Studying together can be very helpful, but there are effective and ineffective ways to do it. For example, getting together without a clear structure is often not a good use of your time. Use your time efficiently by using one or more of the exercises below.

FACE-TO-FACE GROUPS

Use one or more of the activities below.

Peer Instruction: Assign numbers to your group members to use all semester long. Now look at these five concepts from this chapter. Each group member prepares a 5-minute lesson on the topic corresponding to their number. Don't worry if you have fewer than 5 members; just use however many you have! During your group study time, each member presents their lesson, and the group spends another 5–10 minutes discussing that lesson.

1. The spectrum of post-infection consequences (sequelae) from *Streptococcus pyogenes*
2. Defenses of the respiratory system
3. Community-acquired pneumonia vs. healthcare-associated pneumonia
4. Explanation of the "H" and "N" naming system of influenza viruses
5. Explanation of both antigenic drift and antigenic shift in influenza viruses

Concept Maps: Each member of the group should use this list of terms from this chapter to generate their own concept map. This can be hand-drawn or created using software (see Appendix C for guidelines). During group study time, compare each other's concept maps and help each other make sure they are correct. Of course, there are many different "correct" maps. Examining each member's map will help you talk through the varied concepts and how they are related.

Concept Terms:

Bordetella pertussis	pertussis toxin	FHA	cilia
mucus	tracheal cytotoxin	coughing	multiplication
endotoxin	secondary infection		

Table Topics: Each group member should identify a concept or topic from this week's class assignments with which they are having trouble and share it during group study time. The other group members can then help to clarify confusing issues or share how they figured it out. Aim for a maximum of 15 minutes per topic. If the topic remains unclear to the group, bring it up during class or use the instructor's office hours or e-mail to ask for help. Taking the time to struggle with a difficult concept first makes your questions much more specific and more likely to yield helpful answers.

VIRTUAL GROUPS

Not everyone has the time or opportunity to meet with group members outside of class time. You or your instructor can create a virtual group using e-mail or the course software.

Weekly Discussion Board: This forum can be used as a way for groups to discuss topics, via e-mail, or other learning management systems or online platforms, before they are covered in class. As each member of the group answers the current week's question, they should send their responses to every other member of their group. It's best to agree on a deadline based on how your class schedule

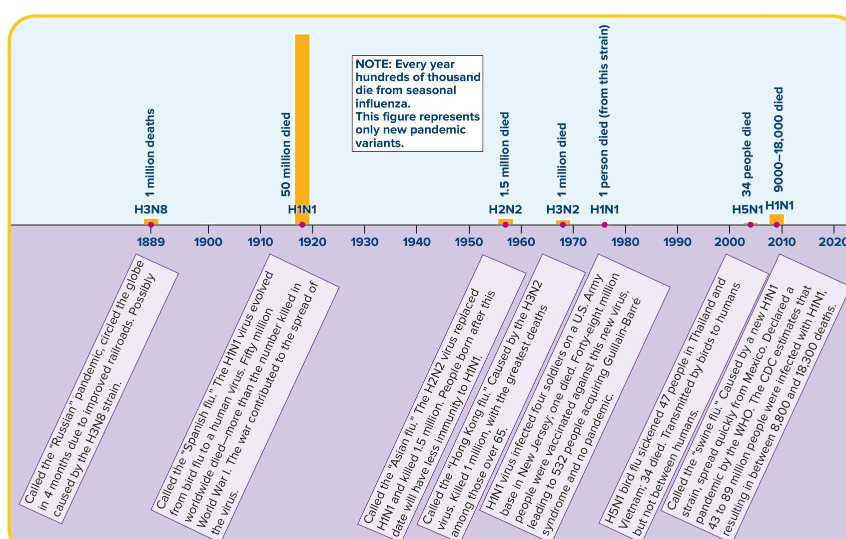
Visual Connections

Visual Connections questions take images and concepts learned in previous chapters or in the current one, and ask students to look at that concept in a different way, that is connected with other content. This helps students evaluate information in new contexts and enhances learning.

Visual Connections

This question uses visual images to connect content within and between chapters.

1. **From this chapter, figure 22.10.** Find the latest data for worldwide deaths due to COVID-19 and draw a bar on this graph to represent that.



Changes to the Seventh Edition

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New to *Microbiology: A Systems Approach*

GLOBAL CHANGES THROUGHOUT THE SEVENTH EDITION

- With every successive edition, I (Kelly) improve readability using my studies of student literacy. This does not involve removing technical terminology. It focuses on shortening sentences and rewriting the context in which the technical terms appear using more conversational terminology, and not “professor” terminology or complex sentence structures.
- The chapter order has been changed for two reasons: (1) The genetics chapter now precedes the virology chapter because a basic understanding of genetics is critical to understanding viral genomes and replication. (2) There is a brand new chapter entitled “Epidemiology of Infectious Diseases,” a subject more important than ever.
- Former Chapter 24, “Microbes and the Environment,” and Chapter 25, “Applied Microbiology and Food and Water Safety,” have been condensed and combined into a new Chapter 25: “Microbes in Our Environment and the Concept of One Health.”
- Chapter Summaries have been redesigned, in an infographic format using less text.
- More than half of the opening case studies, “Media Under the Microscope,” are brand new, covering news reports of such topics as herd immunity, COVID variants, dietary supplement claims, and vaccine misinformation.
- Throughout the book more non-male and diverse scientists are featured, with photos when possible.
- Although Cowan texts have always aimed for equity in our visual representations and language, in this edition we have redoubled our efforts. We worked hard to be inclusive of cultural diversity and gender representations. The contributions of a greater diversity of scientists is also included. This work will never stop, and we welcome comments about how we can do even better.
- In every chapter we have improved the colors and contrasts of labels, colors, and other details to assist readers who have variations in visual acuity and color vision, and to make details more visible in classroom projection.

Major chapter updates or new material

Chapter 1: The Main Themes of Microbiology

- Improved figures for types of microorganisms and burden of diseases
- Addition of CRISPR to “Recent Advances in Microbiology”
- Updated again the science on the origin of cells on the evolutionary timeline
- Added the story of a female scientist and her young daughter discovering and naming a new species

Chapter 2: The Chemistry of Biology

- Improved seven figures for better understanding
- Mentioned the existence of 22 amino acids, with 20 being the most common

Chapter 3: Tools of the Laboratory: Methods for the Culturing and Microscopy of Microorganisms

- New microbiome box about the microbiome of Leonardo da Vinci drawings
- Added super-resolution light microscopy
- Added calcofluor white KOH staining

Chapter 4: Bacteria and Archaea

- Added information about *Achromatium,* a bacterium with numerous non-identical chromosomes; used this example to discuss exceptions in all of biology

Chapter 5: Eukaryotic Cells and Microorganisms

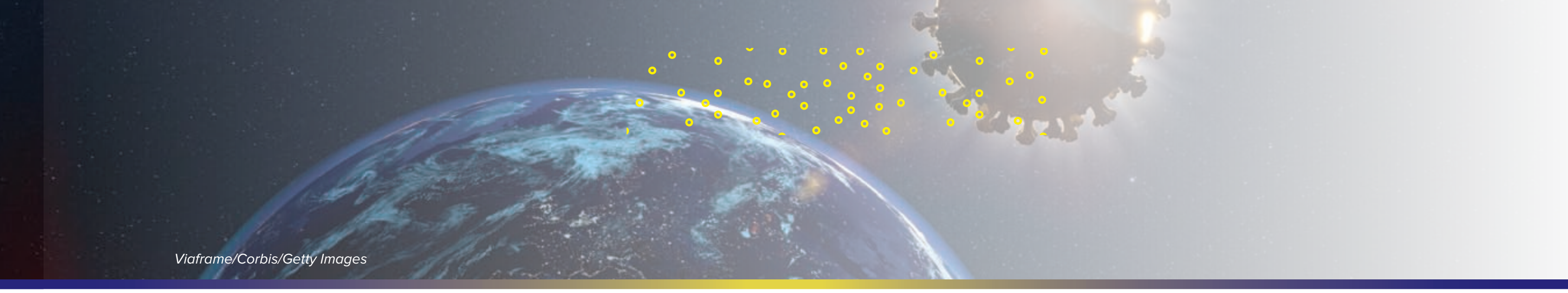
- Included story about fungal infections in India in COVID patients
- Mention of association of *Malassezia* with pancreatic cancer

Chapter 6: Microbial Genetics

- Major overhaul; four new infographic style figures
- New information about a new DNA configuration used for regulation
- New credit given to Esther Lederburg for her work on bacteriophage
- New figure about how the COVID-19 mRNA vaccine is made
- Information on epigenetic regulation of DNA
- Increased emphasis on microRNAs

Chapter 7: Viruses and Prions

- Updated virus taxonomy from the ICTV
- Information about some viruses being found that can replicate independently
- Baltimore Classification system introduced
- COVID-19 information incorporated
- Mention made of viral cancers and oncolytic viruses used as anti-cancer agents
- Several figures enhanced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Chapter 8: Genetic Analysis and Recombinant DNA Technology

- Reorganized for better flow and understanding
- Shifted from the phrase “genetic engineering” to “recombinant DNA technology” due to increasingly negative connotations with the first
- Added discussion of personalized medicine
- Expanded CRISPR section and included photo of the two female Nobel Prize winners
- Added information about SNP analysis being used by companies such as ancestry.com

Chapter 9: Microbial Nutrition and Growth

- New information about antagonism and synergism in the gut microbiome
- Much more emphasis on the role of microbe-microbe interactions
- Added actual photographs in place of drawings (of test tubes, plates)
- Clarified language in many places

Chapter 10: Microbial Metabolism

- New content pointing out how microbes and their hosts and neighboring microbes share their metabolisms and metabolic products
- Updated several figures to be more understandable

Chapter 11: Physical and Chemical Control of Microbes

- Information about disinfecting COVID-contaminated surfaces
- Information about why HEPA filters trap SARS-CoV-2
- Information about essential oils, and also about their unregulated nature

Chapter 12: Antimicrobial Treatment

- Updated accurate history and overview of antibiotic development, and why it has slowed down (beyond the usual profit margin excuse)
- Gram-negative bacteria as the target of important new antibiotic strategies; new figure of gram-negative envelope structure and why it is so difficult to penetrate with antibiotics
- Failed promise of high-throughput synthesis to find new antibiotics
- New approaches: nano materials; antisense RNAs; CRISPR; phages; antibiotics targeting outer membrane proteins
- Many new and heavily revised figures
- New figure on streptomycin/tuberculosis history
- New figure on the influence of antibiotics on the microbiome over the life span

Chapter 13: Microbe–Human Interactions: Health and Disease

- New information about phase 2 of the Human Microbiome Project (HMP)
- Microbiome’s influence on anti-cancer drugs
- Frequent weaving-in of COVID-19; its zoonotic origin, its long-haul symptoms, etc.

Chapter 14: Epidemiology of Infectious Diseases

- Whole new chapter on epidemiology
- Ten brand new figures
- Difference between clinical practice and epidemiology
- History of epidemiology and the CDC
- Units of measure: incidence/prevalence, morbidity/mortality
- Natural history of disease
- Screening
- Causality and Hill’s criteria
- Surveillance and notifiable diseases
- Healthcare-associated infections
- Basic reproduction rate and case-fatality rate
- Vaccinology—how vaccines are approved and continuously monitored and by whom (biology of vaccine remains in Adaptive Immunity chapter)

Chapter 15: Host Defenses I: Overview and Innate Immunity

- Fully converted to terms “adaptive” and “innate” replacing “specific” and “nonspecific”
- Mention of inflammation as part of long-COVID
- Discussion of new view of normal body temperature
- New research about RBCs activating innate immunity

Chapter 16: Host Defenses II: Adaptive Immunity and Immunization

- Cytokine storm defined, and discussed in the context of COVID
- New vaccine overview figure, regrouping the subtypes, because of the introduction of COVID vaccines
- Discussion of the rationale behind booster shots
- Ethical question raised about boosters for fully vaccinated in wealthy countries vs. poor countries having single-digit vaccination rates
- Information about legacy vaccines that are live attenuated being useful in a low vaccine supply situation
- Monoclonal antibody treatment (for COVID) in the category of passive immunity
- New up-and-coming vaccine technologies: including CRISPR and nanoparticles

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- Discussion of a large peer-reviewed study about vaccine hesitancy among health care workers

Chapter 17: Disorders in Immunity

- Shortened and simplified discussion of types II, III, and IV hypersensitivity
- Brief paragraph about possibility that increased autoimmunity can follow COVID-19 infection
- Several figures improved or completely redone
- Brief mention about the effect of wildfires on asthma

Chapter 18: Diagnosing Infections

- Point-of-care tests defined and pointed out throughout chapter
- Bloodstream infections highlighted throughout chapter
- Added complement fixation illustration
- PCR methods grouped under the commonly used clinically heading “NAAT” (nucleic acid amplification techniques)
- PulseNet technology updated to whole genome sequencing (replacing PFGE)
- CRISPR-based diagnosis added

Chapter 19: Infectious Diseases Manifesting on the Skin and Eyes

- For this and all disease chapters, changed title wording to indicate that organization is based on where manifestations are seen
- For this and all disease chapters, changed “Culture and Diagnosis” to “Culture and/or Diagnosis” to indicate that sometimes culture is no longer the go-to or even the gold standard
- Information about new antiviral for poxviruses
- Discussion of erasure of immune memory with measles infection
- Comeback of measles and the causes
- Effect of pandemic on uptake of other childhood vaccines
- *Malassezia* implicated in pancreatic cancer

Chapter 20: Infectious Diseases Manifesting in the Nervous System

- In the Media Under The Microscopic Wrap Up, I mention that I had to be extra careful to check my own biases while critically analyzing the article because it contained a few red flags for me. I wrote that in that case, I had to redouble my efforts to consider the assertions in the article on their own merits, in case they were, in fact, reliable (modeling critical thinking)
- Added neurological symptoms during and after COVID-19
- *Coccidioides* spreading to Washington state and Utah; climate change implicated

Chapter 21: Infectious Diseases Manifesting in the Cardiovascular and Lymphatic Systems

- COVID-19 based in this chapter—with explanation why
- Link between hypertension and gut microbiome
- *C. auris* and sepsis and its pan-resistant forms
- Updates on Post-treatment Lyme Disease Syndrome
- New dengue vaccine
- New malaria vaccine for children

Chapter 22: Infectious Diseases Manifesting in the Respiratory System

- Targeting a human cell that cold viruses need as a treatment for colds
- EV-D68 as a recent cause of severe colds that may lead to acute flaccid myelitis
- Why RSV came in the summer in 2021 instead of fall and winter as usual (COVID)
- Emergence of *C. auris*
- Graph of usual influenza seasonality and death toll, including COVID-19 deaths for comparison

Chapter 23: Infectious Diseases Manifesting in the Gastrointestinal Tract

- Drastic increases in hepatitis A since 2016 and change in its epidemiology
- Vignette and photo of Rita Colwell and her groundbreaking research using saris to filter out copepod-vibrio complexes

Chapter 24: Infectious Diseases Manifesting in the Genitourinary System

- Added a demographic figure commonly used in epidemiology to drive home the role of epidemiology (and discuss *Chlamydia* rates)
- New organisms associated with urethritis (*M. genitalium* and *N. meningitidis*)

Chapter 25: Microbes in Our Environment and the Concept of One Health

- Now contains elements of former chapter 24 and chapter 25
- New climate change section outlining hantavirus, HIV, arbovirus infections, and SARS-CoV-2 and the influence of climate and behavior on them
- One Health emphasis
- Removed all cycles but C and N cycles
- Removed foodborne diseases as it was redundant with text in gastrointestinal chapter

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Acknowledgments

We are most grateful to our students who continually teach us how to communicate this subject. All the professors who reviewed manuscript or sent e-mails with feedback were our close allies as well, especially when they were free with their criticism. Jennifer Lusk contributed invaluable content to the text. Our minders at McGraw Hill are paragons of patience and professionalism: Darlene Schueller is the best editor in the business, which makes it all the more surprising that she continues to work with me on book after book. Other members of our McGraw Hill team upon whom we lean heavily are Lauren Vondra, Tami Hodge, David Hash, Paula Patel, Ron Nelms, Lori Hancock, and Betsy Blumenthal.

—Kelly Cowan

—Heidi Smith

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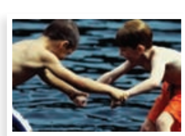
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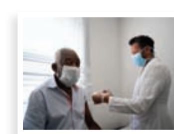
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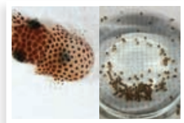
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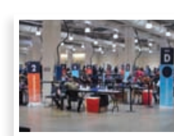
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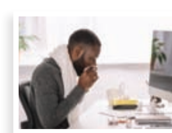

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The Main Themes of Microbiology

McGraw Hill

Media Under The Microscope

Dirty Dish Towels

These case studies examine an article from the popular media to determine the extent to which it is factual and/or misleading. This case focuses on a U.S. News and World Report *article "Study: Harmful Bacteria Is Growing on Kitchen Towels."*

A headline in *U.S. News and World Report* reads "Harmful Bacteria Is Growing on Kitchen Towels." The article summarizes a study conducted at the University of Mauritius and states that after one month of use, 49% of kitchen towels contained bacterial growth.

The researchers are cited in this article as saying that *Escherichia coli* was present in 18 of the 100 towels they studied. The study pointed out that *E. coli* is found in human feces and that this indicates fecal contamination and poor hygiene. The researchers concluded that nonhygienic practices in the kitchen could lead to food poisoning.

- What is the **intended message** of the article?
- What is your **critical reading** of the summary of the article provided above? Remember that in this context, "critical reading" does not necessarily mean *What criticism do you have?* but asks you to apply your knowledge to interpret whether the article is factual and whether the facts support the intended message.
- How would you **interpret** the news item for your nonmicrobiologist friends?
- What is your **overall grade** for the news item—taking into account its accuracy and the accuracy of its intended effect?

Media Under The Microscope Wrap-Up appears at the end of the chapter.

Outline and Learning Outcomes

1.1 The Scope of Microbiology

1. List the seven types of microorganisms studied in the field of microbiology.
2. Identify multiple professions using microbiology.

1.2 The Impact of Microbes on Earth: Small Organisms with a Giant Effect

3. Describe the role and impact of microbes on the earth.
4. Explain the theory of evolution and why it is called a theory.

1.3 Human Use of Microorganisms

5. Explain one old way and one new way that humans manipulate organisms for their own uses.

1.4 Infectious Diseases and the Human Condition

6. Summarize the relative burden of human disease caused by microbes, emphasizing the differences between developed countries and developing countries.

1.5 The General Characteristics of Microorganisms

7. Differentiate among bacteria, archaea, and eukaryotic microorganisms.
8. Identify two types of acellular microorganisms.
9. Compare and contrast the relative sizes of the different microbes.

1.6 The Historical Foundations of Microbiology

10. Make a time line of the development of microbiology from the 1600s to today.
11. List some recent microbiological discoveries of great impact.
12. Explain what is important about the scientific method.

1.7 Naming, Classifying, and Identifying Microorganisms

13. Differentiate among the terms *nomenclature, taxonomy,* and *classification.*
14. Create a mnemonic device for remembering the taxonomic categories.
15. Correctly write the binomial name for a microorganism.
16. Draw a diagram of the three major domains.
17. Explain the difference between traditional and molecular approaches to taxonomy.

1.1 The Scope of Microbiology

Microbiology is a specialized area of biology that deals with living things ordinarily too small to be seen without magnification. Such **microscopic** organisms are collectively referred to as **microorganisms** or **microbes.** In the context of infection and disease, some people call them germs, viruses, or agents; others even call them “bugs”; but none of these terms are clear. In addition, some of these terms tend to emphasize the disagreeable reputation of microorganisms. But, as we will learn throughout the course of this book, only a small minority of microorganisms actually cause harm to other living beings.

Despite that statement, this book does focus on the microorganisms that cause human disease. They can be either cellular or noncellular. The cellular microorganisms we will study are **bacteria, archaea, fungi,** and **protozoa.** Another cellular organism that causes human infections is not technically a microorganism. **Helminths** are multicellular animals whose mature form is visible to the naked eye. Acellular microorganisms causing human disease are the **viruses** and **prions. Table 1.1** gives you a first glimpse at some of these microorganisms. You will see in table 1.1 that the name “bacterium” is paired with something called “archaeon.” We will say more later, but for now just know that archaea are single-celled microorganisms as well. So far, no clear evidence links them to human disease, so they will receive less emphasis in this book. There is a Note in Section 1.2 that says more about them.

The nature of microorganisms makes them both very easy and very difficult to study—easy because they reproduce so rapidly and we can quickly grow large populations in the laboratory and difficult because we usually cannot see them directly. We rely on a variety of indirect means of analyzing them in addition to using microscopes.

Microbiologists study every aspect of microbes—their cell structure and function, their growth and physiology, their genetics, their taxonomy and evolutionary history, and their interactions with the living and nonliving environment. The last aspect includes their uses in industry and agriculture and the way they interact with mammalian hosts, in particular, their properties that may cause disease or lead to benefits.

Studies in microbiology have led to greater understanding of many general biological principles. For example, the study of microorganisms established universal concepts concerning the chemistry of life, systems of inheritance, and the global cycles of nutrients, minerals, and gases. Some descriptions of different branches of study appear in **table 1.2.**

1.1 Learning Outcomes—Assess Your Progress

1. List the seven types of microorganisms studied in the field of microbiology.
2. Identify multiple professions using microbiology.

Table 1.1 Relative Sizes of Microorganisms We Will Study The size of the colored circles, not the size of the drawn organisms, are of the correct scale.

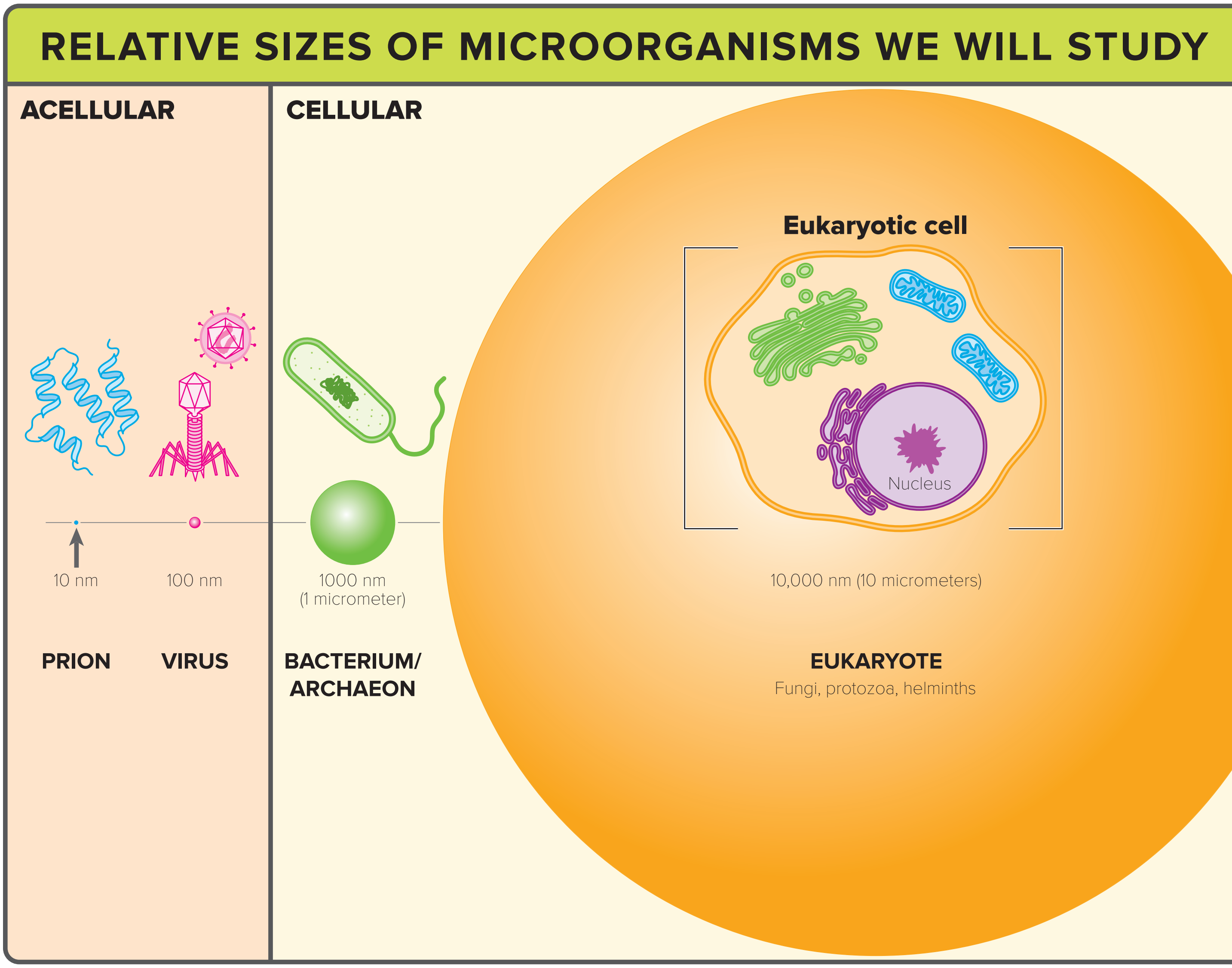
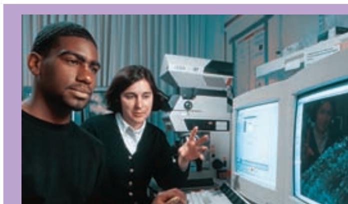
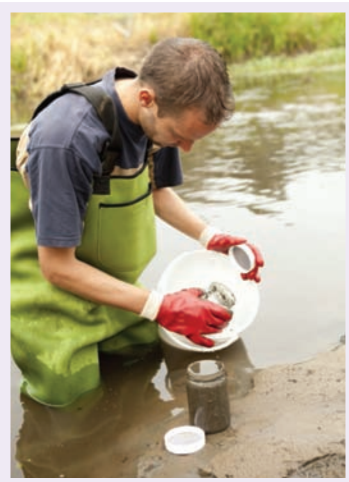


Table 1.2 Microbiology—A Sampler

A. Medical Microbiology This branch of microbiology deals with microbes that cause diseases in humans and animals. Researchers examine factors that make the microbes cause disease and mechanisms for inhibiting them.		**Figure A.** A staff microbiologist at the Centers for Disease Control and Prevention (CDC) examines a culture of influenza virus identical to one that circulated in 1918. The lab is researching why this form of the virus was so deadly and how to develop vaccines and other treatments. Handling such deadly pathogens requires a high level of protection with special personal protection equipment and high-level labs. *James Gathany/CDC*
B. Public Health Microbiology and Epidemiology These branches monitor and control health and the spread of diseases in communities. Institutions involved in this work are the U.S. Public Health Service (USPHS) with its main agency; the Centers for Disease Control and Prevention (CDC) located in Atlanta, Georgia; and the World Health Organization (WHO), the medical limb of the United Nations.		**Figure B.** Two epidemiologists conducting interviews as part of the effort to curb the cholera epidemic in Haiti. Photograph taken in 2013. *Preetha Iyengar, M.D./CDC*

(continued)

Table 1.2 Microbiology—A Sampler (*continued*)

C. Immunology This branch studies the complex web of protective substances and cells produced in response to infection or cancer. It includes such diverse areas as vaccination, blood testing, and allergy. Immunologists also investigate the role of the immune system in autoimmune diseases.		**Figure C.** An immunologist and students prepare samples. *Ariel Skelley/Blend Images LLC*
D. Industrial Microbiology Industrial microbiology safeguards our food and water, and also includes biotechnology, the use of microbial metabolism to arrive at a desired product, ranging from bread making to gene therapy. Microbes can be used to create large quantities of substances such as amino acids, beer, drugs, enzymes, and vitamins.		**Figure D.** Scientists use a multispectral imaging system to inspect chickens. *Stephen R Ausmus/U.S. Department of Agriculture-ARS*
E. Agricultural Microbiology This branch is concerned with the relationships between microbes and farm animals and crops. Plant specialists focus on plant diseases, soil fertility, and nutritional interactions. Animal specialists work with infectious diseases and other associations animals have with microorganisms.		**Figure E.** Plant microbiologists examine images of alfalfa sprouts to see how microbial growth affects plant roots. *Scott Bauer/USDA*
F. Environmental Microbiology These microbiologists study the effect of microbes on the earth's diverse habitats. Whether the microbes are in freshwater or saltwater, topsoil, or the earth's crust, they have profound effects on our planet. Subdisciplines of environmental microbiology are Aquatic microbiology—the study of microbes in the earth's surface water; Soil microbiology—the study of microbes in terrestrial parts of the planet; Geomicrobiology—the study of microbes in the earth's crust; and Astrobiology (also known as exobiology)—the search for/study of microbial and other life in places off of our planet.		**Figure F.** A researcher collects samples and data in Lake Erie. *Photodiem/Shutterstock*

1.2 The Impact of Microbes on Earth: Small Organisms with a Giant Effect

For billions of years, microbes have extensively shaped the development of the earth's habitats and the evolution of other life forms. It is understandable that scientists searching for life on other planets first look for signs of microorganisms.

Scientists are constantly discovering new clues to how life formed on our planet. One view is illustrated in **figure 1.1.** But the actual events are not yet fully understood, so this is just the most current model. It is believed that soon after the earth was formed, the first ancient cells formed. From these cells, two types of single-celled organisms that are still with us today developed, the **bacteria** and the **archaea.** Those were the only types of cells on the planet for more than a billion years, at which time a much more complex cell appeared, called **eukaryotes.** "Eukary-" means *true nucleus* because these were the only cells containing a nucleus. Bacteria and archaea have no true nucleus. For that reason, some scientists have started calling them **akaryotes,** meaning *no nucleus.*

On the scale pictured in figure 1.1, humans seem to have just appeared compared to the existence of all life. Bacteria arose before even the earliest animals by billions of years. This is a good indication that humans are not likely to—nor should we try to—eliminate bacteria from our environment. They've survived and adapted to many catastrophic changes over the course of their geologic history.

Another indication of the huge influence bacteria exert is how **ubiquitous** they are. That word, ubiquitous, means that microbes

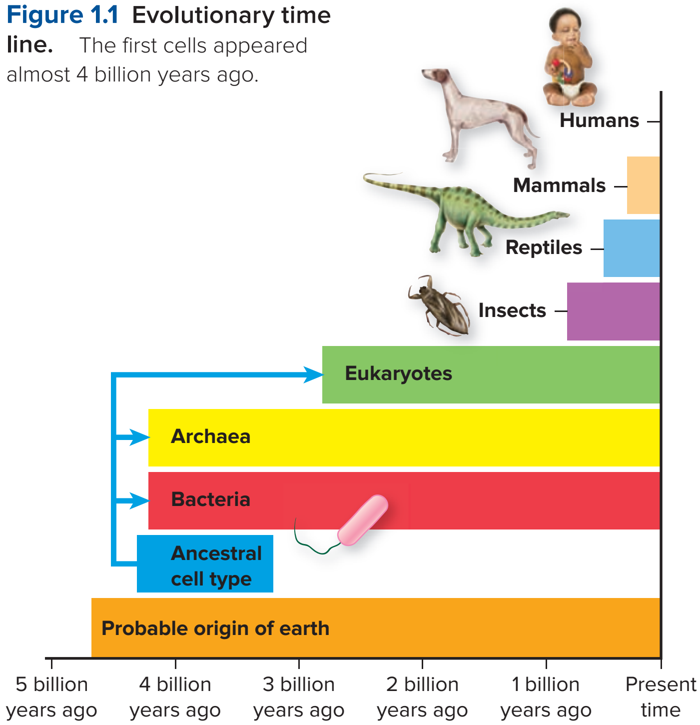


Figure 1.1 Evolutionary time line. The first cells appeared almost 4 billion years ago.

A Note About Bacteria and Archaea

We've just learned that there are three cell types: eukaryotes, bacteria, and archaea. In this book, we are going to focus on bacteria and the eukaryotes because as far as we know these groups are responsible for the majority of human diseases. We will address archaea in various sections of the book where the distinction is useful, but mainly we will refer to bacteria.

can be found nearly everywhere, from deep in the earth's crust to the polar ice caps and from oceans to inside the bodies of plants and animals. Being mostly invisible, the actions of microorganisms are usually not as obvious or familiar as those of larger plants and animals. They make up for their small size by being present in large numbers and living in places where many other organisms cannot survive. Above all, they play central roles that are absolutely essential to life.

When we point out that single-celled organisms have adapted to a wide range of conditions over the billions of years of their presence on this planet, we are talking about **evolution.** Life in its present form would not be possible if the earliest life forms had not changed constantly, adapting to their environment and circumstances. The timeframe from the far left in figure 1.1 to the far right where humans appeared involved billions and billions of tiny changes, starting with the first cell that appeared soon after the planet itself was formed.

You have no doubt heard this concept described as the "theory of evolution." Let's clarify some terms. Evolution is the accumulation of changes that occur in organisms as they adapt to their environments. It is documented every day in all corners of the planet, an observable phenomenon that is testable by science. Referring to it as the **theory of evolution** has led to great confusion among the general public. As we will explain in section 1.6, scientists use the term "theory" in a different way than the general public does. By the time a principle has been labeled a theory in science, it has undergone years and years of testing and not been disproven. This is much different than the common usage, as in "My theory is that he overslept and that's why he was late." The theory of evolution is a label for a well-studied and well-established natural phenomenon.

Microbial Involvement in Shaping Our Planet

Microbes are deeply involved in the flow of energy and food through the earth's ecosystems. (Ecosystems are communities of living organisms and their surrounding environment.) Most people are aware that plants carry out **photosynthesis,** which is the light-fueled conversion of carbon dioxide to organic material, accompanied by the formation of oxygen (called oxygenic photosynthesis). However, bacteria invented photosynthesis long before the first plants appeared, first as a process that did not produce oxygen (*anoxygenic photosynthesis*). This anoxygenic photosynthesis later evolved into oxygenic photosynthesis, which not only produced oxygen but also was much more efficient in extracting energy from sunlight. Hence, bacteria were responsible for changing the atmosphere of the earth from one without oxygen to one with oxygen. The production of oxygen also led to the use of oxygen for aerobic respiration and the formation of ozone, both of which set off an explosion in species diversification. Today, photosynthetic microorganisms (bacteria and algae) account for perhaps 70% of the earth's photosynthesis, contributing the majority of the oxygen to the atmosphere **(figure 1.2*a*).**

Another process that helps keep the earth in balance is the process of biological **decomposition** and nutrient recycling. Decomposition involves the breakdown of dead matter and wastes into simple compounds that can be directed back into the natural cycles of living things **(figure 1.2*b*).** When death occurs, the body immediately begins to decompose. Bacteria play a major role in decomposition of the body. The action of bacteria causes the conversion of soft tissues within the body to liquids and gases. The chemicals released as a result of decomposition, including hydrogen sulfide, are responsible for the pungent smell of death. If it were not for multitudes of bacteria and fungi, many chemical elements would become locked up and unavailable to organisms, and we humans would drown in our own industrial and personal wastes. In the long-term scheme of things, microorganisms are the main forces that drive the structure and content of the soil, water, and atmosphere. For example:

- The very temperature of the earth is regulated by gases, such as carbon dioxide, nitrous oxide, and methane, which create an insulation layer in the atmosphere and help retain heat. Many of these gases are produced by microbes living in the environment and in the digestive tracts of animals.
- Recent studies have found that large numbers of organisms exist within and beneath the earth's crust in sediments, rocks, and even volcanoes.

(a)

(b)

Figure 1.2 Examples of microbial habitats. **(a)** Summer pond with a thick mat of algae—a rich photosynthetic community. **(b)** Microbes play a large role in decomposing dead animal and plant matter.
(a) Jerome Wexler/Science Source; (b) Michel/Christine Denis Huot/Science Source

- Bacteria and fungi live in complex associations with plants and assist the plants in obtaining nutrients and water and may protect them against disease. Microbes form similar interrelationships with animals. For example, a rich assortment of bacteria in the stomach of cattle digests the complex carbohydrates of the animals' diets (and causes the release of methane into the atmosphere).

1.2 Learning Outcomes—Assess Your Progress

3. Describe the role and impact of microbes on the earth.
4. Explain the theory of evolution and why it is called a theory.

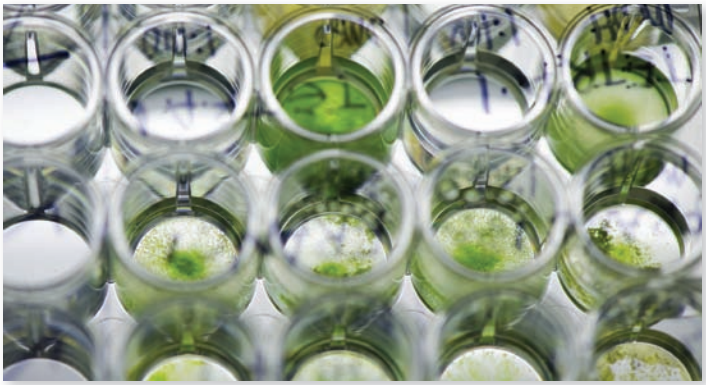
1.3 Human Use of Microorganisms

The diversity and versatility of microorganisms make them excellent candidates for solving human problems. By accident or choice, humans have been using microorganisms for thousands of years to improve life and even to shape civilizations. Baker's and brewer's yeasts, types of single-celled fungi, cause bread to rise and ferment sugar into alcohol to make wine and beers. Other fungi are used to make special cheeses such as blue cheese or Camembert. These and other "home" uses of microbes have been in use for thousands of years. For example, historical records show that households in ancient Egypt kept moldy loaves of bread to apply directly to wounds and lesions. This was long before penicillin was discovered in a mold called *Penicillium*. When humans figure something out through experience, rather than through research or being taught it, it is called an **empirical** finding. Empirical discoveries have shaped the development of humans through our whole history. When humans purposely manipulate microorganisms to make products in an industrial setting, it is called biotechnology. For example, some bacteria have unique capacities to mine precious metals or to create energy **(figure 1.3).**

Recombinant DNA technology is an area of biotechnology that manipulates the genetics of microbes, plants, and animals for the purpose of creating new products and genetically modified organisms (GMOs). This technology makes it possible to transfer genetic material from one organism to another and to deliberately alter DNA. Bacteria and yeasts were some of the first organisms to be genetically engineered.

Even though many citizens are very uncomfortable with GMO processes, it is also true that many people benefit from their medical, industrial, and agricultural uses. Microbes can be engineered to synthesize many critical products such as drugs and hormones. Among the genetically unique organisms that have been designed by bioengineers are bacteria that mass produce antibiotic-like substances, yeasts that produce human insulin, pigs that produce human hemoglobin, and plants that contain natural pesticides or fruits that do not ripen too rapidly.

Another way of tapping into the unlimited potential of microorganisms is the science of **bioremediation** (by′-oh-ree-mee-dee-ay″-shun). This process involves the introduction of microbes into the environment to restore stability or to clean up toxic pollutants. Microbes have a surprising capacity to break down chemicals that would be harmful to other organisms. This includes even human-made chemicals that scientists have developed and for which there are no natural counterparts.



(a)

(b)

(c)

Figure 1.3 Microbes at work. **(a)** Test tubes of yellow and green algae being grown as a possible energy source. **(b)** Microbes fermenting wine in tanks. **(c)** Workers spray nutrients on the shore of Prince William Sound in Alaska after the *Exxon Valdez* oil tanker spill (1989) in an attempt to enrich oil-degrading microbes.

(a) Dennis Schroeder/NREL/US Department of Energy; (b) Bloomberg/Getty Images; (c) Arlis/Alamy Stock Photo

Agencies and companies have developed microbes to handle oil spills and detoxify sites contaminated with heavy metals, pesticides, and other chemical wastes **(figure 1.3*c*).** One form of bioremediation that has been in use for some time is the treatment of water and sewage. Because clean freshwater supplies are dwindling worldwide, it will become even more important to find ways to reclaim polluted water.

1.3 Learning Outcome—Assess Your Progress

5. Explain one old way and one new way that humans manipulate organisms for their own uses.

1.4 Infectious Diseases and the Human Condition

One of the most fascinating aspects of the microorganisms with which we share the earth is that, despite all of the benefits they provide, they also contribute significantly to human misery as **pathogens** (path′-oh-jenz). Please understand: The vast majority of microorganisms that associate with humans cause no harm. In fact, they provide many benefits to their human hosts. It is also important to note that a diverse microbial biota living in and on humans is an important part of human well-being.

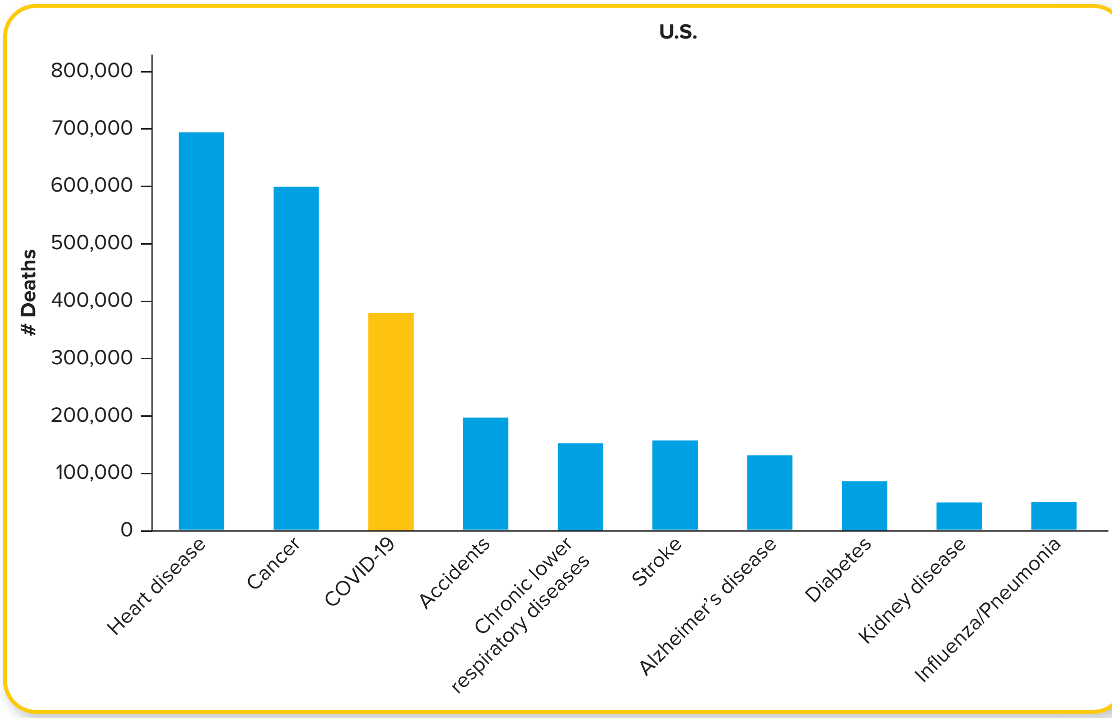
It is estimated that there are more than 2,000 different microbes that can cause various types of diseases. Infectious diseases still devastate human populations worldwide, despite significant strides in understanding and treating them. The World Health Organization (WHO) estimates there are a total of 10 billion new infections across the world every year. **Figure 1.4** depicts the 10 top causes of death per year (by all causes, infectious and noninfectious) in the United States and also worldwide. You will see in the graph where the COVID-19 death toll lies. Keep in mind, COVID-19 caused zero deaths in all years previous to 2019 (indeed, no disease, either). All of the deaths represented by the yellow bars are excess deaths by a cause that had not existed before.

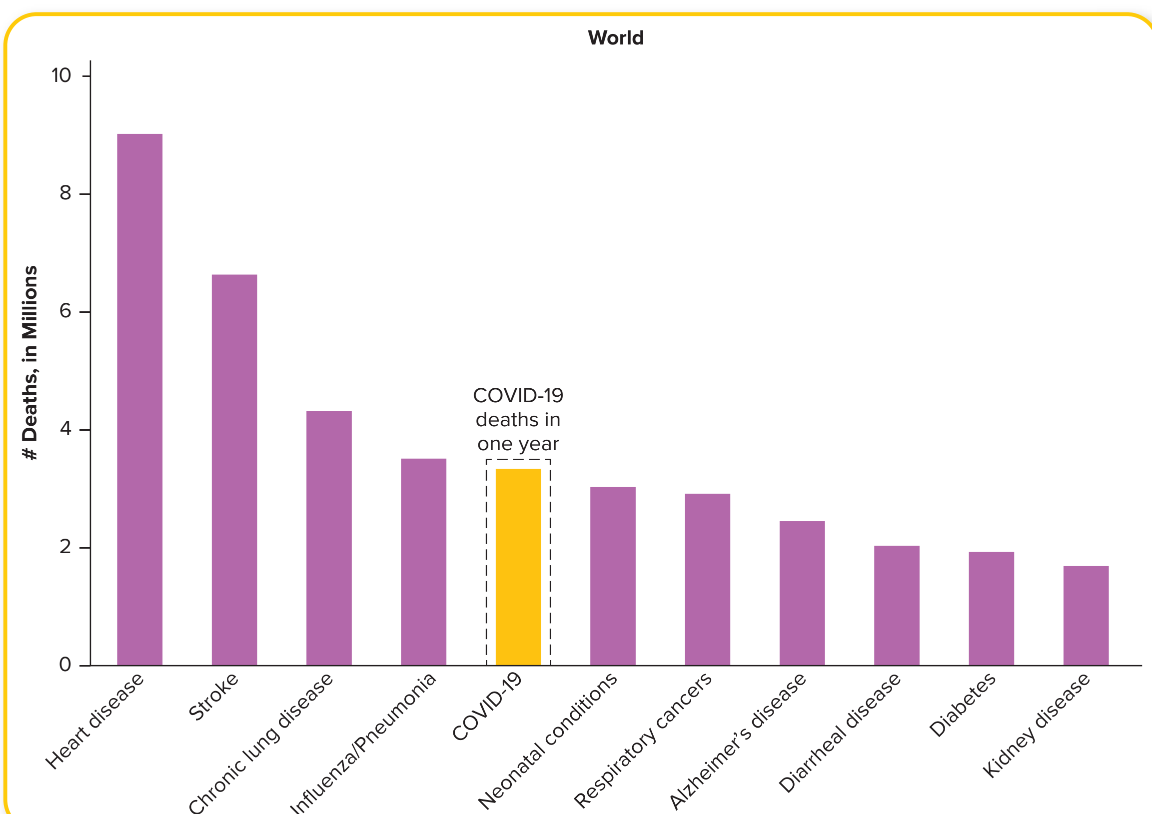
We just used the terms "infectious" and "noninfectious." We'll explore these terms in more detail later. Generally, they refer to diseases caused by microbes (infectious) and diseases not caused by microbes (noninfectious). Note that while all microbial diseases are infectious diseases, they are not all communicable (transmitted from person to person) **(table 1.3).**

In **table 1.4** you see that diseases *not* caused by microbes are much more frequent in both the United States and the world. You will also note that the United States experiences relatively few—*relatively* few—infectious diseases compared to the number of noninfectious diseases. This graph does not account for

Disease Connection

Some of the most serious lower respiratory tract infections are influenza and pneumonia, and now COVID. Influenza and COVID infections put you at risk for developing pneumonia, caused either by the virus itself or by secondary viruses or bacteria. Of course, you can also develop pneumonia without first being infected by SARS-CoV-2 or the influenza virus.





Source: Centers for Disease Control and Prevention, Johns Hopkins University

Figure 1.4 Major causes of death in the U.S. and the world, and where COVID-19 deaths fit in. The top graph, for U.S. deaths, is data for 2020. The bottom graph, for global deaths, is data for 2019 (the latest year for which data are available.) Because COVID did not appear until December 2019, we include the 2020 level of COVID-19 deaths on this graph in yellow so you can see its impact.

Table 1.3 Terminology

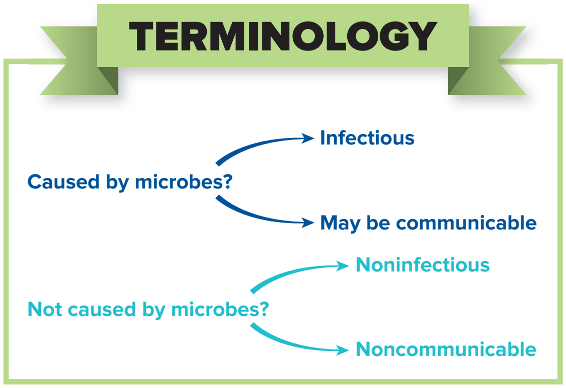
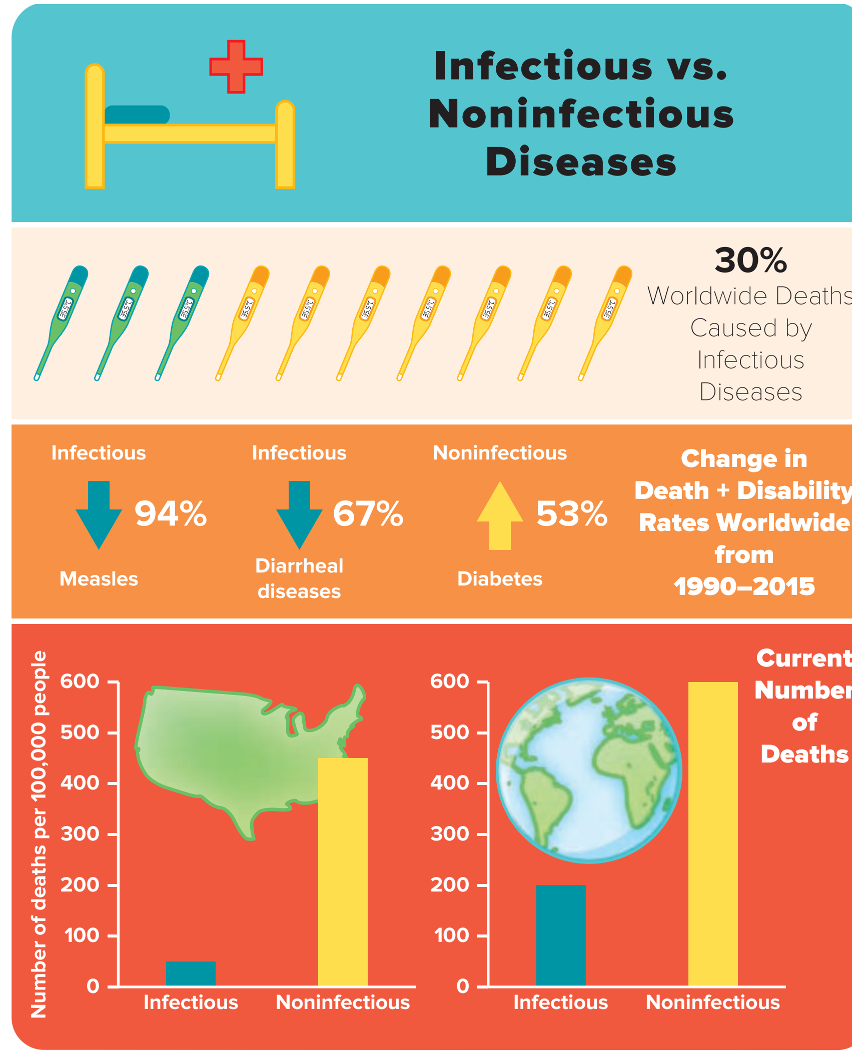


Table 1.4 Infectious vs. Noninfectious Diseases



Source: Data from the World Health Organization and from the Institute for Health Metrics and Evaluation, http://www.healthdata.org/ 2018.

COVID-19 deaths. You saw in figure 1.4 the effect of this one infection on death rates.

Malaria, which kills about 450,000 people every year worldwide, is caused by a microorganism transmitted by mosquitoes. Currently, the most effective way for citizens of developing countries to avoid infection with the causal agent of malaria is to sleep under a bed net because the mosquitoes are most active in the evening. Yet even this inexpensive solution is beyond the reach of many. Mothers in some parts of the world have to make nightly decisions about which of their children will sleep under the single family bed net because a second one, priced at about $10, is too expensive for them.

We are also witnessing an increase in the number of new (emerging) and older (reemerging) diseases. SARS-CoV-2, Ebola, AIDS, hepatitis C, and viral encephalitis are examples of diseases that cause severe mortality and morbidity. To somewhat balance this trend, there have also been some advances in eradication of diseases such as polio and leprosy and diseases caused by certain parasitic worms.

One of the most eye-opening discoveries in recent years is that many diseases that were not previously thought to be caused by microorganisms probably do involve microbial infection. The most famous of these is gastric ulcers, now known to be caused by a bacterium called *Helicobacter*. But there are more. An association has been established between certain cancers and various bacteria and viruses, between diabetes and the coxsackievirus, and between schizophrenia and the coxsackievirus. Diseases as different as multiple sclerosis, obsessive compulsive disorder, coronary artery disease, and even obesity have been linked to chronic infections with microbes. We're now discovering the subtler side of microorganisms. Their roles in quiet but slowly destructive diseases are now well known. These include female infertility, often caused by silent *Chlamydia* infections, and malignancies such as liver cancer (hepatitis viruses) and cervical cancer (human papillomavirus). Researchers are currently researching whether Alzheimer's disease is related to microbes found in the brains of people with the disease.

Another important development in infectious disease trends is the increasing number of patients with weakened defenses that are kept alive for extended periods. They are subject to infections by common microbes that are not pathogenic to healthy people. There is also an increase in microbes that are resistant to the drugs used to treat them.

1.4 Learning Outcome—Assess Your Progress

6. Summarize the relative burden of human disease caused by microbes, emphasizing the differences between developed countries and developing countries.

1.5 The General Characteristics of Microorganisms

Cellular Organization

As discussed in section 1.1, three basic cell lines appeared during evolutionary history. These lines—**Archaea, Eukarya,** and **Bacteria**—differ not only in how complex they are but also in their contents and function.