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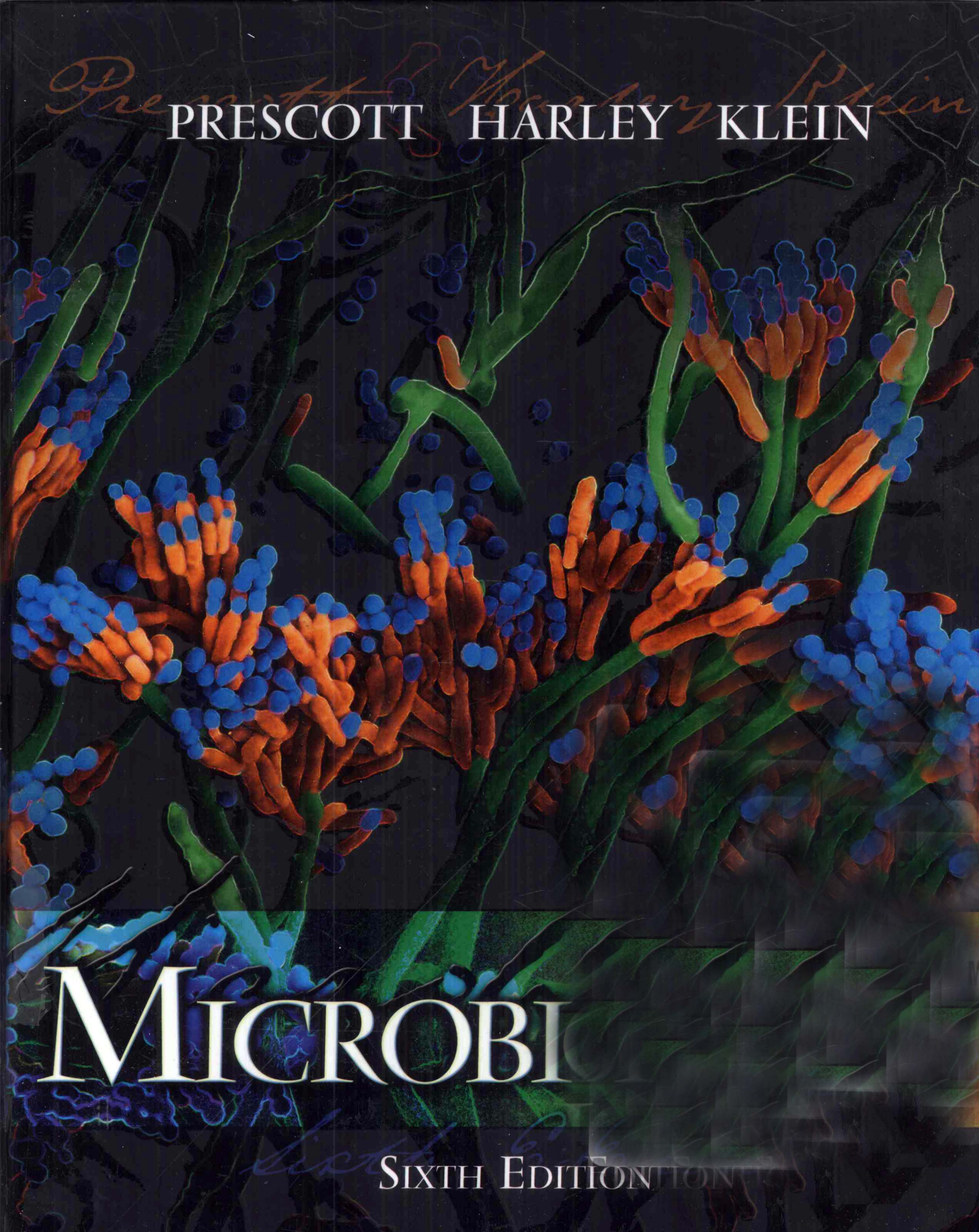

MICROBIOLOGY

SIXTH EDITION

Microbiology

Sixth Edition

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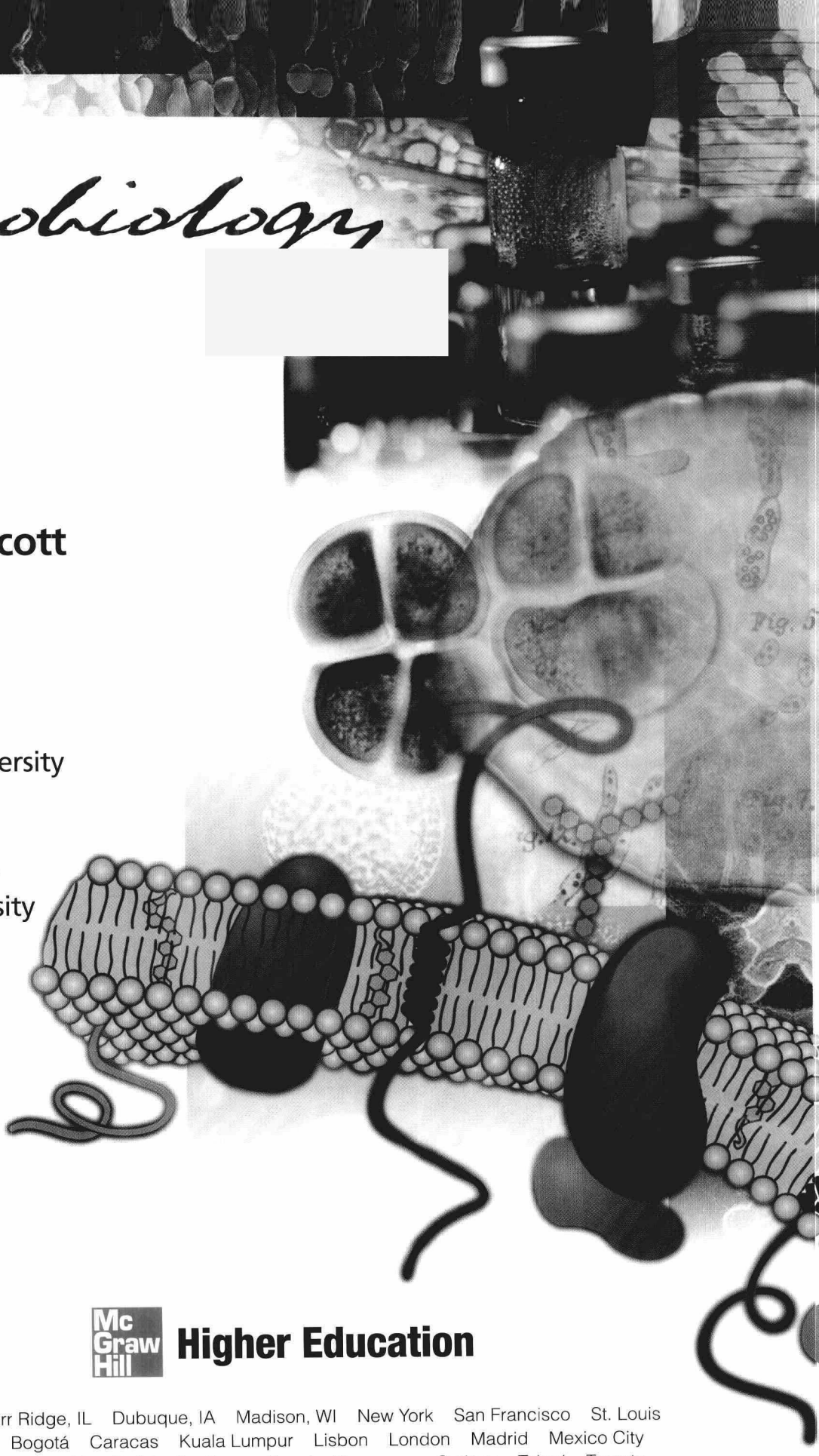

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Preface

Because microbiology is an exceptionally broad discipline encompassing specialties as diverse as biochemistry, cell biology, genetics, taxonomy, pathogenic bacteriology, food and industrial microbiology, and ecology, our goal has been to provide a balanced introduction to the discipline. A microbiologist must be acquainted with many biological disciplines and with all major groups of microorganisms: viruses, bacteria, fungi, algae, and protozoa. Students new to the subject need an introduction to the whole before concentrating on specialized areas that might be of more interest to them. *Microbiology,* sixth edition, provides a balanced introduction to all major areas of microbiology for a variety of students. Because of this balance, the book is suitable for courses with orientations ranging from basic microbiology to medical and applied microbiology. Students preparing for careers in medicine, dentistry, nursing, and allied health professions will find the text just as useful as those aiming for careers in research, teaching, and industry. While two quarters/semesters each of biology and chemistry are assumed, we provide a strong overview of the relevant chemistry in appendix I.

OUR STRENGTHS

Main Themes

Seven themes permeate the text. They recur regularly and help integrate the specific information in an orderly manner. The seven themes are:

1. Development of microbiology as a science
2. Nature and importance of the techniques used to isolate, culture, observe, and identify microorganisms
3. Control of microorganisms and reduction of their detrimental effects
4. Importance of molecular biology and biochemistry for microbiology
5. Medical significance of microbiology
6. Ways in which microorganisms interact with their environments and the practical consequences of these interactions
7. Influences that microorganisms and microbiological applications have on everyday life

These themes help unify the text and enhance continuity. The student should get a feeling for what microbiologists do and for how their activities affect society.

Strong Biochemical Presentations

Despite the great variety in microbial structure and function, microorganisms share a biochemical unity that is basic to all life processes. Furthermore, specialized functions of individual microbial cells can only be described in biochemical terms. Thus it is not possible to understand microbiology in any fundamental sense without a consideration of biochemical mechanisms and the metabolic pathways common to all life. We provide biochemical background in two ways:

- First, you will find many illustrations that clarify the molecular processes being discussed in every chapter (for example, figures 9.19, 10.28, 11.17, and 31.19). The biochemical links are highlighted and described throughout.
- Second, two illustrated appendices (I and II) present graphic presentations of the Chemistry of Biological Molecules and Common Metabolic Pathways. This makes them easy to locate for reference purposes, and accessible for study and review.

Organizational Flexibility

Our flexible organization allows every instructor to sequence chapters and topics to suit their own syllabus. Each chapter is as self-contained as possible to promote this flexibility. For example, chapter 17, "The Viruses: Bacteriophages," contains all information critical to understanding the structure and function of bacteriophages. Students do not need to hunt through several chapters to assemble the information. They can return to chapter 17 to refer to specific details easily, making review a natural part of their study activities.

Readability

Because a student can not learn from a text they can not read, careful attention has been paid to the presentation of information in *Microbiology,* sixth edition. Comprehension is facilitated by a relatively simple, direct writing style. Information is broken up with numerous section headings and organized in an outline format within each chapter. The American Society for Microbiology's *ASM Style Manual* conventions for nomenclature and abbreviations were followed as consistently as possible. To help students with the many new terms they will encounter in the study of microbiology, new terminology is boldfaced when first used and clearly defined. Every term in the extensive glossary includes a page reference.

Study-Friendly Features

All students need help organizing their study time to maximize success. We have reorganized several key features to help them with this critical task. For example, the usefulness of the chapter summaries has been improved by organizing the summary statements under the appropriate chapter section number and title. A student can now go directly in the summary to a specific chapter section, rather than having to search for the desired statements. References in appendix V also are organized by numbered section headings within each chapter to facilitate the location of supplemental readings for specific topics.

In addition, no other text on the market today presents the reference resources that are part of *Microbiology,* sixth edition. These rich resources make it possible for students to expand their study, extend their reading, and use their text as a reference for many semesters to come. They include:

- A Review of the Chemistry of Biological Molecules (appendix I) is a visual reference on the chemistry of organic molecules. Definitions and line art provide a review or an introduction depending on the student's needs.
- Common Metabolic Pathways (appendix II) provides illustrations of nine critical biochemical pathways in one location, making review and reference more convenient for the student than if they were embedded in the text.
- Classification of Procaryotes (appendix III) summarizes the latest classification as reflected in the second edition of *Bergey's Manual of Systematic Bacteriology.*
- Classification of Viruses (appendix IV) provides a visual directory to a selected group of common viruses. The physical characteristics, family, and genera for each are provided.
- The Recommended Reading material (appendix V) is organized by chapter and provides direction to additional information for interested students.

NEW TO THIS EDITION!

Our New Look . . . Design

The interior of *Microbiology,* sixth edition, has been completely redesigned. Students today are very sensitive to visual presentations and our new design presents information within the framework of a bright, clean, modern-looking environment. We believe this appealing new look will help students move into the content and focus on the important topics. New icons call attention to the numbered main heads, and colorful headings help the students recognize shifts in focus. All of the boxed essays have been organized around five main themes and identified by category (Historical Highlights, Techniques & Applications, Disease, Microbial Diversity & Ecology, and Microbial Tidbits).

And . . . Illustrations

Tied in to this bright new look is our continuing improvement of our art program. New illustrations have been added to most chapters, and many older figures have been revised to improve their usefulness. Particular attention has been paid to consistency in the use of color. We have also tried to employ colors in such a way that the figures are easier to understand.

Not Just a New Look . . . New Content

Due to the fast pace of discoveries in the life sciences, substantial changes and updates have been made to keep the adopters of the sixth edition at the cutting edge of information. A summary of important new material by parts includes:

Parts One–Six (chapters 1–18) introduce the foundations of microbiology: the development of the field, the structure of microorganisms, microbial growth and control, metabolism, molecular biology and genetics, DNA technology and genomics, and the nature of viruses.

New and Significantly Updated Topics

Chapter 3—Protein secretion in procaryotes; fimbriae and bacterial movement
Chapter 6—Thermophile survival in high-temperature environments and the effect of salt on microbial growth
Chapter 11—Antiparallel nature of DNA
Chapter 12—Atomic structures of RNA polymerase and ribosomes; regulation by sRNA
Chapter 15—Thoroughly updated information on completed genomes
Chapter 18—Construction of the poliovirus from its genome sequence; mechanism of prion action; virus entry into host cells

Part Seven, The Diversity of the Microbial World (chapters 19–27) contains a survey of the procaryotes that closely follows the general organization of the second edition of *Bergey's Manual of Systematic Bacteriology.* Although principal attention is devoted to bacteria, the fungi, algae, and protozoa receive more than usual coverage.

New and Significantly Updated Topics

Chapter 19—Use of signature sequences in phylogenetic analysis; updated discussion of the classification system in the second edition of *Bergey's Manual of Systematic Bacteriology*
Chapter 20—Methane-consuming archaea and protein secretion in the archaea

Part Eight, Ecology and Symbiosis (chapters 28–30) focuses on the relationships of microorganisms to other organisms and the environment (microbial ecology). Aquatic and terrestrial microbiology are introduced here.

New and Significantly Updated Topics

Chapter 28—Methods of microbial ecology; discussion of lichens as controlled parasitic relationships; genomic reduction resulting from endosymbiosis; coevolution of gut microorganisms; inclusion of latest information on the hyperthermophile, *Geogemma barossii*
Chapter 29—Addition of *Cryptosporidium* to U.S. drinking water standards; removal of nitrogen and phosphorus by on-site water treatment processes; Canadian geese as a reservoir for *Giardia* and *Cryptosporidium*
Chapter 30—Occurrence of polyprosthecate bacteria such as *Verrucomicrobium;* the role of the oxidative burst in plant-microbe interactions; mycorrhizal interactions with achlorophyllous plants

Parts Nine and Ten, Nonspecific (Innate) Resistance and the Immune Response; Microbial Diseases and Their Control (chapters 31–33 in Part Nine and 34–40 in Part Ten) are concerned with pathogenicity, resistance, and disease. The disease survey is organized taxonomically on the chapter level; within each chapter diseases are covered according to mode of transmission. This provides flexibility and allows the student to easily locate information on a disease of interest.

New and Significantly Updated Topics

Chapter 31—Cathelicidin antimicrobial peptides; pattern-recognition receptors on macrophages, and Toll-like receptors in nonphagocytic host defense

Chapter 33—Vaccine table includes the latest recommendations approved for use in the United States including five new vaccines

Chapter 34—Use of actin-based motility by bacterial pathogens to spread within the host

Chapter 35—The Etest for antibiotic sensitivity; expansion of information on drug inactivation by chemical modification; discussion of antibiotic resistance genes on genetic elements other than plasmids

Chapter 37—New essays on the first recorded incidence of biological warfare and the SARS epidemic

Chapter 38—New or expanded discussion of smallpox, West Nile virus, and hepatitis G virus

Chapter 39—Weaponization of anthrax and expanded information on anthrax

Part Eleven, Food and Industrial Microbiology (chapters 41 and 42) concludes the text with an introduction to these fields.

New and Significantly Updated Topics

Chapter 41—Norwalk-like viruses in food and water; malo-lactic fermentation in wine production; use of probiotic *Lactobacillus* in feed to reduce the occurrence of *E. coli* in beef cattle

Chapter 42—Discussion of newest approaches for recovery from nature of previously "unculturable" microorganisms

SUPPLEMENTARY AND MEDIA MATERIALS

For the Student

- A **Student Study Guide** by Linda Sherwood of Montana State University is a valuable resource that provides learning objectives, study outlines, learning activities, and self-testing material to help students master course content.
- The ***Microbiology,* sixth edition, Online Learning Center** (www.mhhe.com/prescott6) provides self-quizzes, terminology exercises, study tips, web resources, etc., to aid students in mastering and integrating content.
- The sixth edition of ***Laboratory Exercises in Microbiology*** by John P. Harley has been prepared to accompany the text. Like the text, the laboratory manual provides a balanced introduction to laboratory techniques and principles that are important in each area of microbiology. The class-tested exercises are modular and short so that an instructor can easily choose only those exercises that fit his or her course. The sixth edition contains recipes for all reagents and media. New exercises in biotechnology have been added to this edition. A new appendix provides practice in solving dilution problems.

Dynamic Media

- ***Microbes in Motion,*** third edition, is an interactive, easy-to-use general microbiology CD-ROM that helps students actively explore and understand microbial structure and function through audio, video, animations, illustrations, slide shows, and text. Eighteen books cover topics from microbial genetics to vaccines.
- ***HyperClinic,*** second edition, CD-ROM allows students to evaluate realistic case studies that include patient histories and descriptions of signs and symptoms. Students can either analyze the results of physician-ordered clinical tests to reach a diagnosis, or evaluate a case study scenario and decide which clinical samples should be taken and which diagnostic tests should be run. More than 200 pathogens are profiled, 105 case studies presented, and 46 diagnostic tests covered.

For the Instructor

- The ***Digital Content Manager*** **CD-ROM** is the image resource for course presentations. The DCM contains virtually all of the line art, photos, and tables from *Microbiology,* sixth edition, as well as animations, videos, active-art, and a PowerPoint Lecture set for each chapter. See page xx for further details!
- **Instructor Testing and Resource CD-ROM** is offered free on request to adopters of the text. This cross-platform CD provides a database of over 2,500 objective questions for preparing exams and a grade-recording program.
- A set of 250 full-color acetate **transparencies** is available to supplement classroom lectures. These have been enhanced for projection and are available to adopters of the sixth edition.
- The **Online Learning Center** (www.mhhe.com/prescott6) provides multiple resources for course enhancement. Moreover, all the McGraw-Hill media resources are easily loaded into course management systems such as WebCT or Blackboard.

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Lansing M. Prescott
John P. Harley
Donald A. Klein

Visual Preview

Rich tapestries reveal the grand scale of life.

Visual Program

The key to every biological problem must finally be sought in the cell.—E.B. Wilson

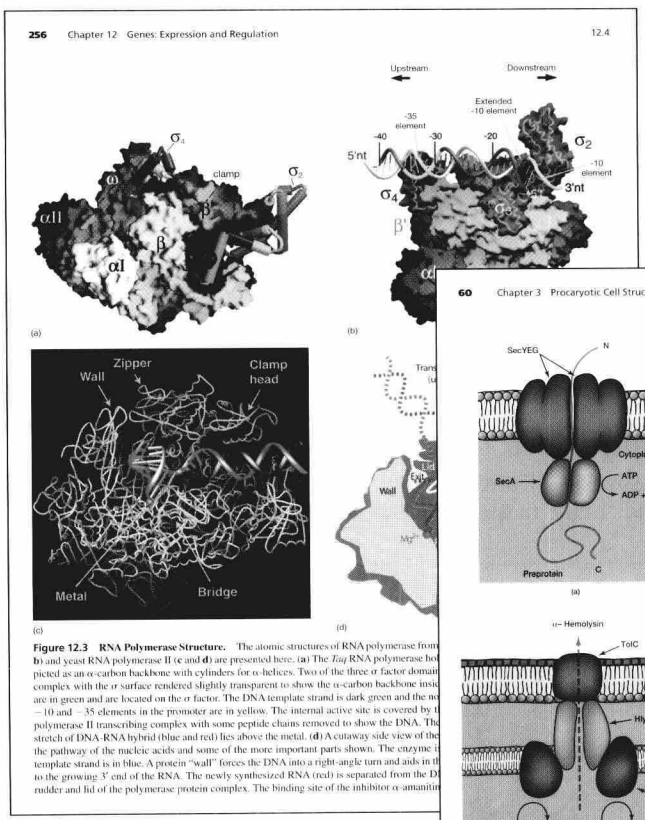
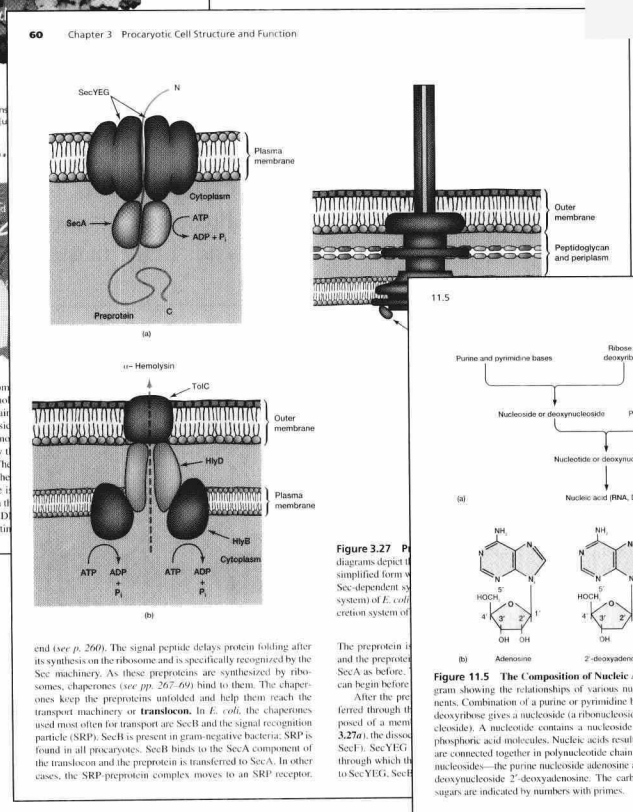


Figure 12.3 RNA Polymerase Structure. The atomic structures of RNA polymerase from **b**) and yeast RNA polymerase II (**c** and **d**) are presented here. (**a**) The *Taq* RNA polymerase hol picted as an α-carbon backbone with cylinders for α-helices. Two of the three σ factor domain complex with the σ surface rendered slightly transparent to show the α-carbon backbone insid are in green and are located on the σ factor. The DNA template strand is dark green and the nc −10 and −35 elements in the promoter are in yellow. The internal active site is covered by t polymerase II transcribing complex with some peptide chains removed to show the DNA. Th stretch of DNA-RNA hybrid (blue and red) lies above the metal. (**d**) A cutaway side view of the the pathway of the nucleic acids and some of the more important parts shown. The enzyme i template strand is in blue. A protein "wall" forces the DNA into a right-angle turn and aids in t to the growing 3′ end of the RNA. The newly synthesized RNA (red) is separated from the D rudder and lid of the polymerase protein complex. The binding site of the inhibitor α-amanitin



end (*see p. 260*). The signal peptide delays protein folding after its synthesis on the ribosome and is specifically recognized by the Sec machinery. As these preproteins are synthesized by ribosomes, chaperones (*see pp. 267–69*) bind to them. The chaperones keep the preproteins unfolded and help them reach the transport machinery or **translocon.** In *E. coli*, the chaperones used most often for transport are SecB and the signal recognition particle (SRP). SecB is present in gram-negative bacteria; SRP is found in all procaryotes. SecB binds to the SecA component of the translocon and the preprotein is transferred to SecA. In other cases, the SRP-preprotein complex moves to an SRP receptor.

Figure 3.27 P
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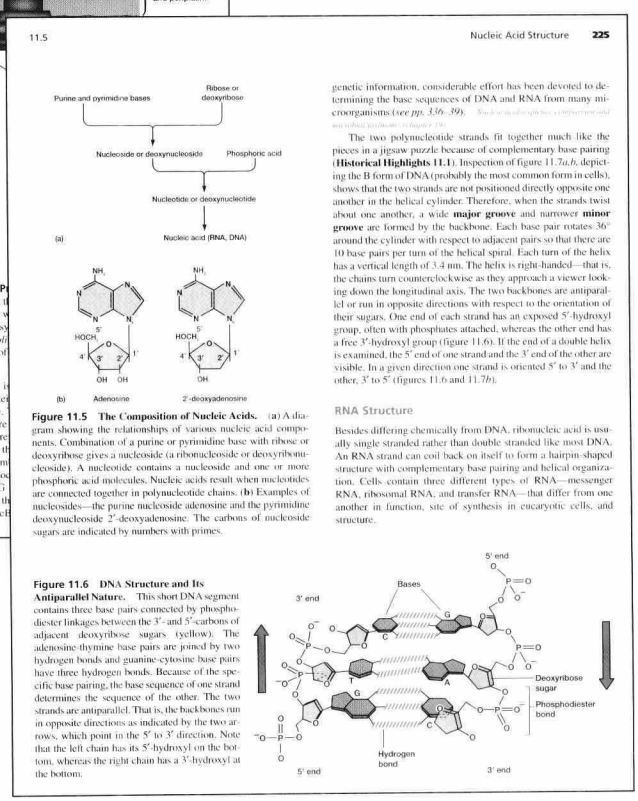


Figure 11.5 The Composition of Nucleic Acids. (**a**) A diagram showing the relationships of various nucleic acid components. Combination of a purine or pyrimidine base with ribose or deoxyribose gives a nucleoside (a ribonucleoside or deoxyribonucleoside). A nucleotide contains a nucleoside and one or more phosphoric acid molecules. Nucleic acids result when nucleotides are connected together in polynucleotide chains. (**b**) Examples of nucleosides—the purine nucleoside adenosine and the pyrimidine deoxynucleoside 2′-deoxyadenosine. The carbons of nucleoside sugars are indicated by numbers with primes.

genetic information, considerable effort has been devoted to determining the base sequences of DNA and RNA from many microorganisms (*see pp. 336–39*).

The two polynucleotide strands fit together much like the pieces in a jigsaw puzzle because of complementary base pairing (**Historical Highlights 11.1**). Inspection of figure 11.7*a,b*, depicting the B form of DNA (probably the most common form in cells), shows that the two strands are not positioned directly opposite one another in the helical cylinder. Therefore, when the strands twist about one another, a wide **major groove** and narrower **minor groove** are formed by the backbone. Each base pair rotates 36° around the cylinder with respect to adjacent pairs so that there are 10 base pairs per turn of the helical spiral. Each turn of the helix has a vertical length of 3.4 nm. The helix is right-handed—that is, the chains turn counterclockwise as they approach a viewer looking down the longitudinal axis. The two backbones are antiparallel or run in opposite directions with respect to the orientation of their sugars. One end of each strand has an exposed 5′-hydroxyl group, often with phosphates attached, whereas the other end has a free 3′-hydroxyl group (figure 11.6). If the end of a double helix is examined, the 5′ end of one strand and the 3′ end of the other are visible. In a given direction one strand is oriented 5′ to 3′ and the other, 3′ to 5′ (figures 11.6 and 11.7*b*).

RNA Structure

Besides differing chemically from DNA, ribonucleic acid is usually single stranded rather than double stranded like most DNA. An RNA strand can coil back on itself to form a hairpin-shaped structure with complementary base pairing and helical organization. Cells contain three different types of RNA—messenger RNA, ribosomal RNA, and transfer RNA—that differ from one another in function, site of synthesis in eucaryotic cells, and structure.

Figure 11.6 DNA Structure and Its Antiparallel Nature. This short DNA segment contains three base pairs connected by phosphodiester linkages between the 3′- and 5′-carbons of adjacent deoxyribose sugars (yellow). The adenosine-thymine base pairs are joined by two hydrogen bonds and guanine-cytosine base pairs have three hydrogen bonds. Because of the specific base pairing, the base sequence of one strand determines the sequence of the other. The two strands are antiparallel. That is, the backbones run in opposite directions as indicated by the two arrows, which point in the 5′ to 3′ direction. Note that the left chain has its 5′-hydroxyl on the bottom, whereas the right chain has a 3′-hydroxyl at the bottom.

50 New Art Figures

- Bring the wonders of microbiology to life
- Feature dynamic colors to aid in understanding complex concepts

The illustrations are effective and accurate. The artwork truly helps the student master essential concepts.

Professor Bernard Frye, University of Texas

100 Revised Art Figures

- Present the unseen world in a consistent palette of color
- Inject new life into the study of microbiology

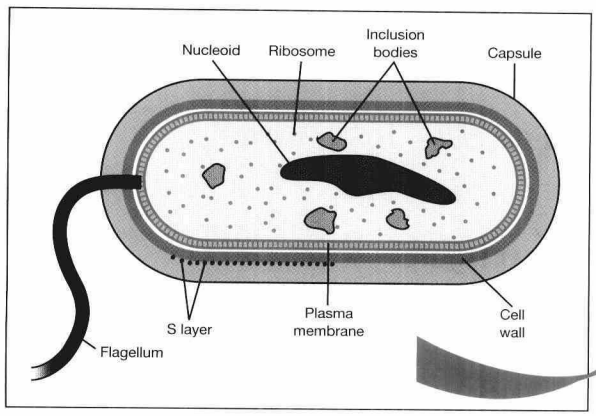


Figure 3.4

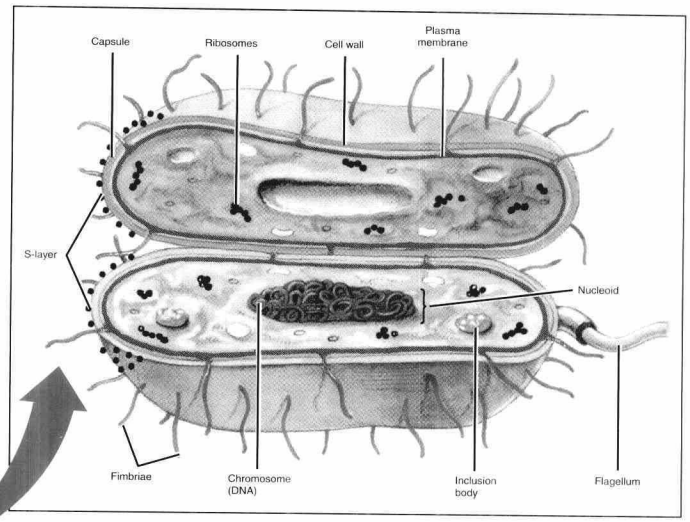


Figure 3.4

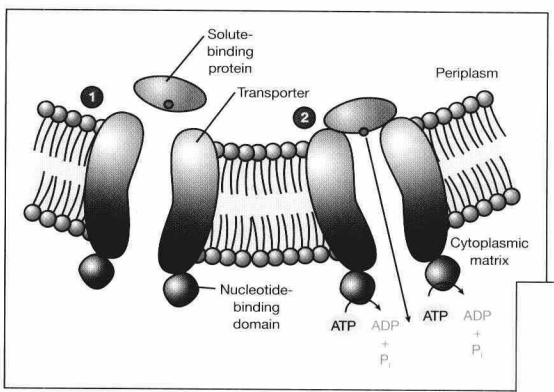


Figure 5.3

Art at Its Best

- Presents consistent color
- Aids in the mastery of complex concepts

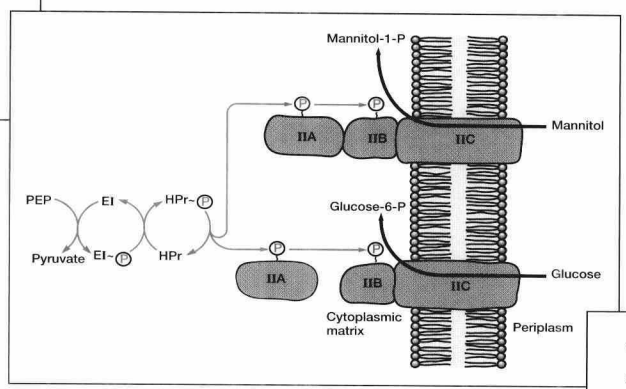


Figure 5.5

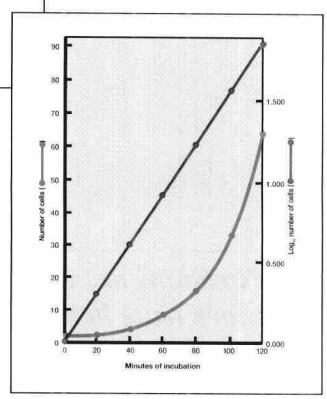


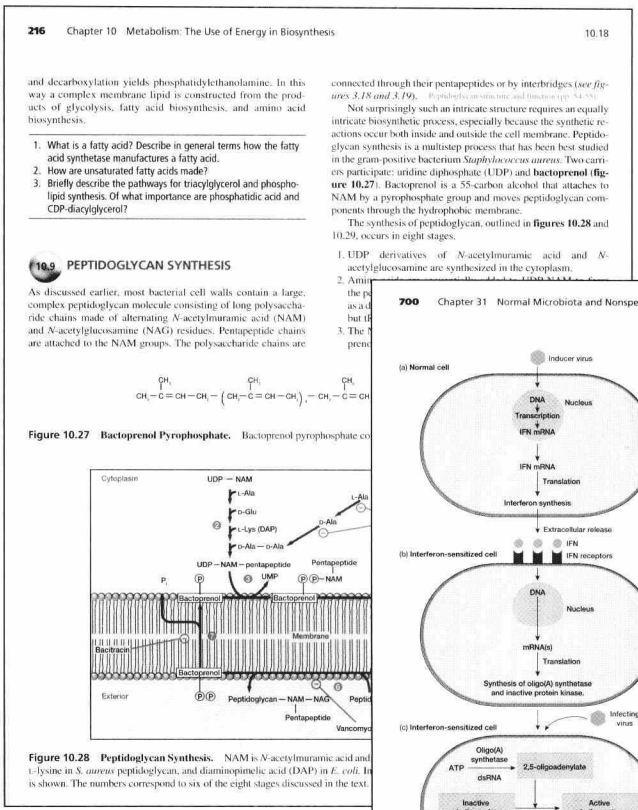
Figure 6.3

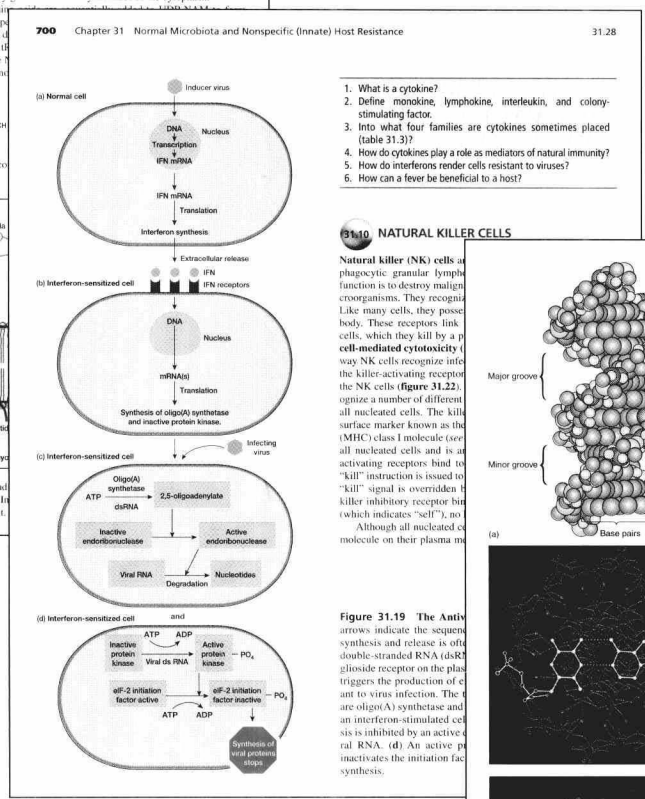
I was very impressed with the illustrations. Figure 6.3 detailed very nicely the difference between expression of cell number arithmetically vs. logarithmically.

Professor Richard Ellis, Bucknell University

Conceptual Illustrations

- Strengthen the biochemical perspective
- Emphasize the pathways and interactions involved in all organism functions
- Focus on the biochemical unity that is basic to all life processes





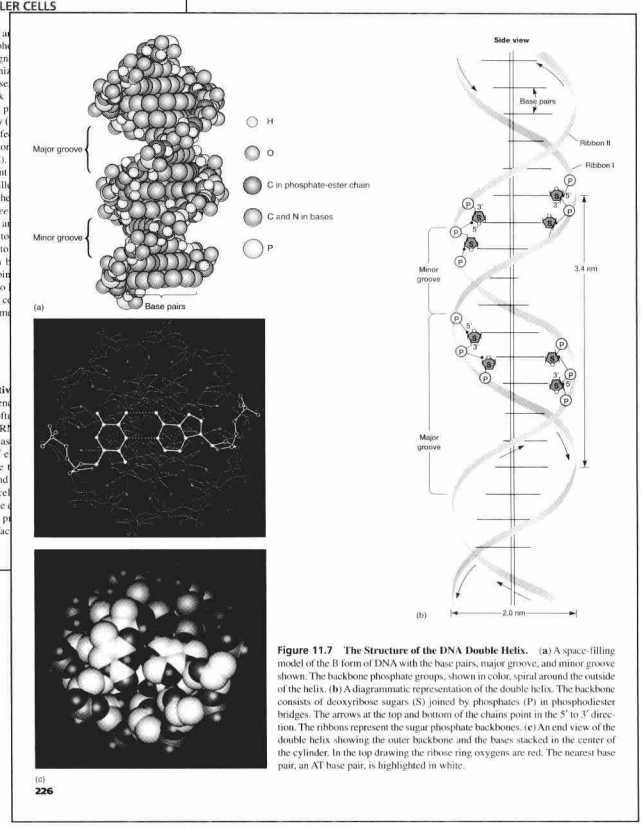


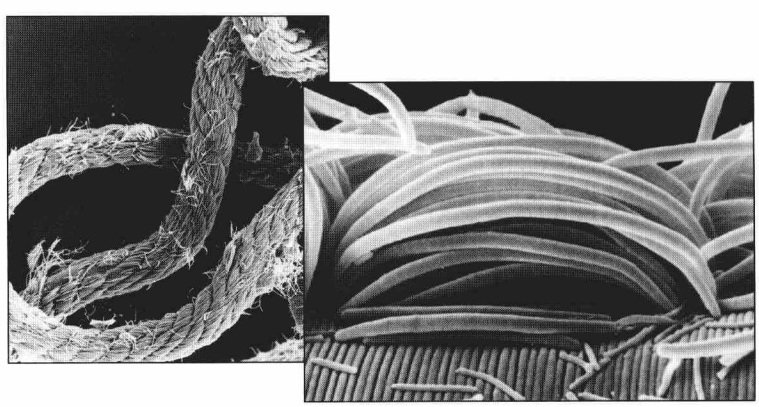
Figure 11.7 **The Structure of the DNA Double Helix.** (a) A space-filling model of the B form of DNA with the base pairs, major groove, and minor groove shown. The backbone phosphate groups, shown in color, spiral around the outside of the helix. (b) A diagrammatic representation of the double helix. The backbone consists of deoxyribose sugars (S) joined by phosphates (P) in phosphodiester bridges. The arrows at the top and bottom of the chains point in the 5′ to 3′ direction. The ribbons represent the sugar phosphate backbones. (c) An end view of the double helix showing the outer backbone and the bases stacked in the center of the cylinder. In the top drawing the ribose ring oxygens are red. The nearest base pair, an AT base pair, is highlighted in white.

There is good use of specific examples to illustrate the application of general concepts.

Professor Phil Achey, University of Florida

Rich Photo Program

- Introduces students to a diverse microbial world



Learning System

Content is poised on the cutting edge of life science discoveries.

chapter 12

Genes:
Expression and Regulation

Concepts

- In transcription the RNA polymerase copies the appropriate sequence on the DNA template strand to produce a complementary RNA copy of the gene. Transcription differs in a number of ways between procaryotes and eucaryotes, even though the basic mechanism of RNA polymerase action is essentially the same.
- Translation is the process by which the nucleotide sequence of mRNA is converted into the amino acid sequence of a polypeptide through the action of ribosomes, tRNAs, aminoacyl-tRNA synthetases, ATP and GTP energy, and a variety of protein factors. As in the case of DNA replication, this complex process is designed to minimize errors.
- The long-term regulation of metabolism in bacteria is achieved through the control of transcription by such mechanisms as sigma factors, repressor proteins during induction and repression, and by the attenuation of many biosynthetic operons.
- Procaryotes must be able to respond rapidly to changing environmental conditions and often control many operons simultaneously using global regulatory systems.
- DNA replication and cell division are coordinated in such a way that the distribution of new DNA copies to each daughter cell is ensured.

The particular field which excites my interest is the division between the living and the non-living, as typified by, say, proteins, viruses, bacteria and the structure of chromosomes. The eventual goal, which is somewhat remote, is the description of these activities in terms of their structure, i.e., the spatial distribution of their constituent atoms, in so far as this may prove possible. This might be called the chemical physics of biology.

—Francis Crick

Lactose operon activity is under the control of a repressor protein. The *lac* repressor (violet) and catabolite activator protein (blue) are bound to the *lac* operon. The repressor blocks transcription when bound to the operators (red).

Chapter Concepts

- Briefly summarize important concepts

Cross-Referenced Notes

- Refer students to major topics that may require review in order to understand and integrate concepts

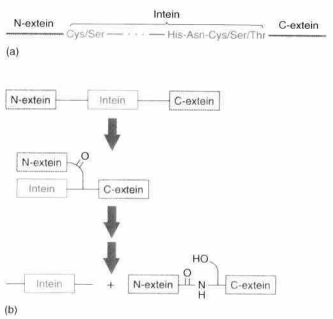


Figure 12.21 Protein Splicing. (a) A generalized illustration of intein structure. The amino acids that are commonly present at each end of the inteins are shown. Note that many are thiol- or hydroxyl-containing amino acids. (b) An overview of the proposed pattern or sequence of splicing. The precise mechanism is not yet known but presumably involves the hydroxyls or thiols located at each end of the intein.

polypeptide folds into its final shape. Self-splicing proteins begin as larger precursor proteins composed of one or more internal intervening sequences called **inteins** flanked by external sequences or **exteins,** the N-exteins and C-exteins (**figure 12.21***a*). Inteins, which are between about 130 and 600 amino acids in length, are removed in an autocatalytic process involving a branched intermediate (figure 12.21*b*). Thus far, more than 130 inteins in 34 types of self-splicing proteins have been discovered. Over 120 inteins have been found in bacteria and archaea. Some examples are an ATPase in the yeast *Saccharomyces cerevisiae,* the recA protein of *Mycobacterium tuberculosis,* and DNA polymerase in *Pyrococcus.* The presence of self-splicing proteins in all three domains may mean that these proteins are quite widespread and prevalent.

1. In which direction are polypeptides synthesized? What is a polyribosome and why is it useful?
2. Briefly describe the structure of transfer RNA and relate this to its function. How are amino acids activated for protein synthesis, and why is the specificity of the aminoacyl-tRNA synthetase reaction so important?
3. What are translational and exit domains? Contrast procaryotic and eucaryotic ribosomes in terms of structure. What roles does ribosomal RNA have?
4. Describe the nature and function of the following: fMet-tRNA, initiator codon, IF-3, IF-2, IF-1, elongation cycle, peptidyl and aminoacyl sites, EF-Tu, EF-Ts, transpeptidation reaction, peptidyl transferase, translocation, EF-G or translocase, nonsense codon, and release factors.
5. What are molecular chaperones and heat-shock proteins? Describe their functions.

12.3 REGULATION OF mRNA SYNTHESIS

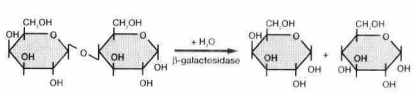
The control of metabolism by regulation of enzyme activity is a fine-tuning mechanism: it acts rapidly to adjust metabolic activity from moment to moment. Microorganisms also are able to control the expression of their genome, although over longer intervals. For example, the *E. coli* chromosome can code for about 2,000 to 4,000 peptide chains, yet many fewer proteins are present in *E. coli* growing with glucose as its energy source. Regulation of gene expression serves to conserve energy and raw material, to maintain balance between the amounts of various cell proteins, and to adapt to long-term environmental change. Thus control of gene expression complements the regulation of enzyme activity. Regulation of enzyme activity (pp. 161–65)

Induction and Repression

The regulation of β-galactosidase synthesis has been intensively studied and serves as a primary example of how gene expression is controlled. This enzyme catalyzes the hydrolysis of the sugar lactose to glucose and galactose (**figure 12.22**). When *E. coli* grows with lactose as its carbon source, each cell contains about 3,000 β-galactosidase molecules, but has less than three molecules in the absence of lactose. The enzyme β-galactosidase is an **inducible enzyme**—that is, its level rises in the presence of a small molecule called an **inducer** (in this case the lactose derivative allolactose).

The genes for enzymes involved in the biosynthesis of amino acids and other substances often respond differently from genes coding for catabolic enzymes. An amino acid present in the surroundings may inhibit the formation of the enzymes responsible for its biosynthesis. This makes good sense because the microor-

Figure 12.22 The β-Galactosidase Reaction.



Review Questions Within Narrative

- Assist students in mastering section concepts before moving on to other topics

Numbered Headings

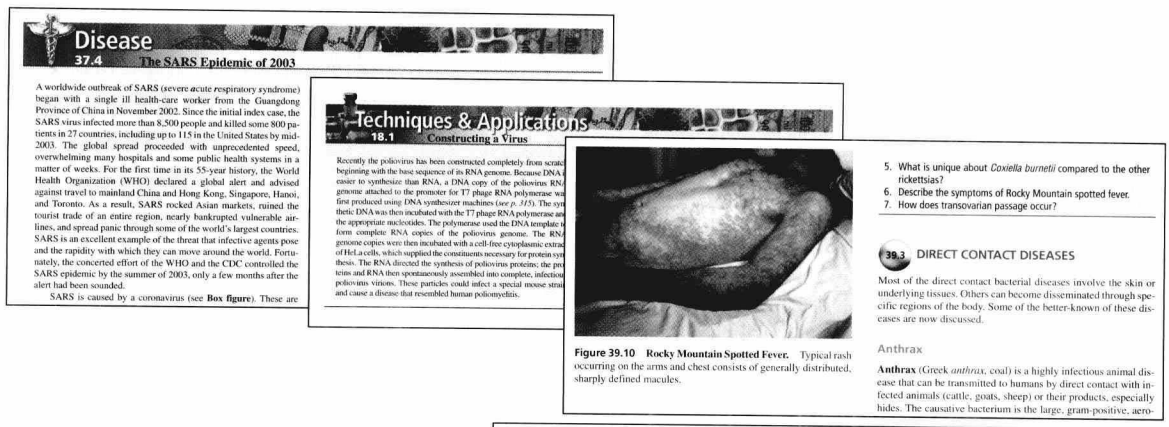
- Identify each major topic and are used for easy reference throughout the text

I believe the writing style is an easier read than my current text, particularly in the Genetics chapter.

Professor Donald Glassman, Des Moines Area Community College

Timely Topics

- Link the text topics to today's headlines



Disease

37.4 The SARS Epidemic of 2003

A worldwide outbreak of SARS (severe acute respiratory syndrome) began with a single ill health-care worker from the Guangdong Province of China in November 2002. Since the initial index case, the SARS virus infected more than 8,500 people and killed some 800 patients in 27 countries, including up to 115 in the United States by mid-2003. The global spread proceeded with unprecedented speed, overwhelming many hospitals and some public health systems in a matter of weeks. For the first time in its 55-year history, the World Health Organization (WHO) declared a global alert and advised against travel to mainland China and Hong Kong, Singapore, Hanoi, and Toronto. As a result, SARS rocked Asian markets, ruined the tourist trade of an entire region, nearly bankrupted vulnerable airlines, and spread panic through some of the world's largest countries. SARS is an excellent example of the threat that infective agents pose and the rapidity with which they can move around the world. Fortunately, the concerted effort of the WHO and the CDC controlled the SARS epidemic by the summer of 2003, only a few months after the alert had been sounded.

SARS is caused by a coronavirus (see **Box figure**). These are

Techniques & Applications

18.1 Constructing a Virus

Recently the poliovirus has been constructed completely from scratc
beginning with the base sequence of its RNA genome. Because DNA
easier to synthesize than RNA, a DNA copy of the poliovirus RN
genome attached to the promoter for T7 phage RNA polymerase wa
first produced using DNA synthesizer machines (*see p. 353*). The syn
thetic DNA was then incubated with the T7 phage RNA polymerase an
the appropriate nucleotides. The polymerase used the DNA template t
form complete RNA copies of the poliovirus genome. The RNA
genome copies were then incubated with a cell-free cytoplasmic extrac
of HeLa cells, which supplied the constituents necessary for protein syn
thesis. The RNA directed the synthesis of poliovirus proteins; the pro
teins and RNA then spontaneously assembled into complete, infectiou
poliovirus virions. These particles could infect a special mouse strai
and cause a disease that resembled human poliomyelitis.

5. What is unique about *Coxiella burnetii* compared to the other rickettsias?
6. Describe the symptoms of Rocky Mountain spotted fever.
7. How does transovarian passage occur?

39.3 DIRECT CONTACT DISEASES

Most of the direct contact bacterial diseases involve the skin or underlying tissues. Others can become disseminated through specific regions of the body. Some of the better-known of these diseases are now discussed.

Anthrax

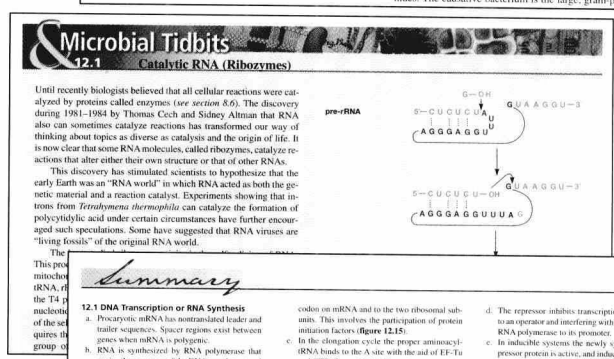
Anthrax (Greek *anthrax*, coal) is a highly infectious animal disease that can be transmitted to humans by direct contact with infected animals (cattle, goats, sheep) or their products, especially hides. The causative bacterium is the large, gram-positive, aero-

Figure 39.10 Rocky Mountain Spotted Fever. Typical rash occurring on the arms and chest consists of generally distributed, sharply defined macules.

Special Interest Essays

Historical Highlights, Techniques & Applications, Microbial Diversity and Ecology, Disease, and Microbial Tidbits

- Provide additional perspective on the many facets of microbiology



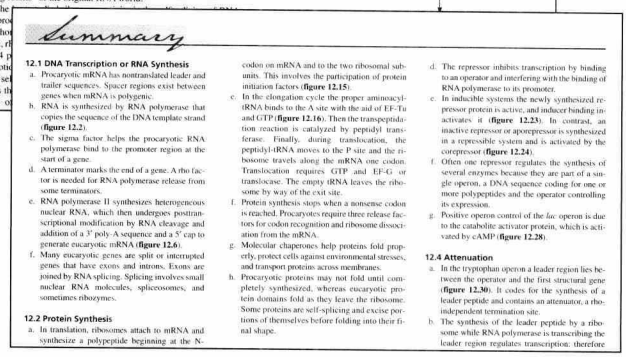
Microbial Tidbits

12.1 Catalytic RNA (Ribozymes)

Until recently biologists believed that all cellular reactions were catalyzed by proteins called enzymes (*see section 8.6*). The discovery during 1981–1984 by Thomas Cech and Sidney Altman that RNA also can sometimes catalyze reactions has transformed our way of thinking about topics as diverse as catalysis and the origin of life. It is now clear that some RNA molecules, called ribozymes, catalyze reactions that alter either their own structure or that of other RNAs.

This discovery has stimulated scientists to hypothesize that the early Earth was an "RNA world" in which RNA acted as both the genetic material and a reaction catalyst. Experiments showing that introns from *Tetrahymena thermophila* can catalyze the formation of polycytidylic acid under certain circumstances have further encouraged such speculations. Some have suggested that RNA viruses are "living fossils" of the original RNA world.

pre-rRNA



Summary

12.1 DNA Transcription or RNA Synthesis

a. Procaryotic mRNA has nontranslated leader and trailer sequences. Spacer regions exist between genes when mRNA is polygenic.
b. RNA is synthesized by RNA polymerase that copies the sequence of the DNA template strand (**figure 12.2**).
c. The sigma factor helps the procaryotic RNA polymerase bind to the promoter region at the start of a gene.
d. A terminator marks the end of a gene. A rho factor is needed for RNA polymerase release from some terminators.
e. RNA polymerase II synthesizes heterogeneous nuclear RNA, which then undergoes posttranscriptional modification by RNA cleavage and addition of a 3′ poly-A sequence and a 5′ cap to generate eucaryotic mRNA (**figure 12.6**).
f. Many eucaryotic genes are split or interrupted genes that have exons and introns. Exons are joined by RNA splicing. Splicing involves small nuclear RNA molecules, spliceosomes, and sometimes ribozymes.

12.2 Protein Synthesis

a. In translation, ribosomes attach to mRNA and synthesize a polypeptide beginning at the N-codon on mRNA and to the two ribosomal subunits. This involves the participation of protein initiation factors (**figure 12.15**).
e. In the elongation cycle the proper aminoacyl-tRNA binds to the A site with the aid of EF-Tu and GTP (**figure 12.16**). Then the transpeptidation reaction is catalyzed by peptidyl transferase. Finally, during translocation, the peptidyl-tRNA moves to the P site and the ribosome travels along the mRNA one codon. Translocation requires GTP and EF-G or translocase. The empty tRNA leaves the ribosome by way of the exit site.
f. Protein synthesis stops when a nonsense codon is reached. Procaryotes require three release factors for codon recognition and ribosome dissociation from the mRNA.
g. Molecular chaperones help proteins fold properly, protect cells against environmental stresses, and transport proteins across membranes.
h. Procaryotic proteins may not fold until completely synthesized, whereas eucaryotic protein domains fold as they leave the ribosome. Some proteins are self-splicing and excise portions of themselves before folding into their final shape.
d. The repressor inhibits transcription by binding to an operator and interfering with the binding of RNA polymerase to its promoter.
e. In inducible systems the newly synthesized repressor protein is active, and inducer binding inactivates it (**figure 12.23**). In contrast, an inactive repressor or aporepressor is synthesized in a repressible system and is activated by the corepressor (**figure 12.24**).
f. Often one repressor regulates the synthesis of several enzymes because they are part of a single operon, a DNA sequence coding for one or more polypeptides and the operator controlling its expression.
g. Positive operon control of the *lac* operon is due to the catabolite activator protein, which is activated by cAMP (**figure 12.28**).

12.4 Attenuation

a. In the tryptophan operon a leader region lies between the operator and the first structural gene (**figure 12.30**). It codes for the synthesis of a leader peptide and contains an attenuator, a rho-independent termination site.
b. The synthesis of the leader peptide by a ribosome while RNA polymerase is transcribing the leader region regulates transcription; therefore

Chapter Summaries

- Organized by numbered headings.
- Provide a snapshot of important chapter concepts

c. The transcription of genes can be regulated by altering the promoters to which RNA polymerase binds by changing the available sigma factors. A good example is the control of sporulation.

12.6 Small RNAs and Regulation

a. Small RNA molecules can regulate gene expression, RNA processing, translation, and other cell processes. For example, antisense RNAs help control porin protein levels.

12.7 Two-Component Phosphorelay Systems

a. Two-component phosphorelay systems are signal transduction systems that use phosphoryl group transfers in regulation. They have a sensor kinase and a response regulator.
b. Sporulation and chemotaxis regulatory systems are two-component phosphorelay systems.

12.8 Control of the Cell Cycle

a. The complete sequence of events extending from the formation of a new cell through the next division is called the cell cycle.
b. The end of DNA replication is tightly linked to cell division, so division in *E. coli* usually takes place about 20 minutes after replication is finished (**figure 12.35**). Special division and regulatory proteins are involved.
c. In very rapidly dividing bacterial cells, a new round of DNA replication begins before the cells divide.

Key Terms

amino acid activation 260
aminoacyl or acceptor site (A site) 265
aminoacyl-tRNA synthetases 260
anticodon triplet 260
antisense RNA 278
aporepressor 271
attenuation 276
attenuator 274
catabolite activator protein (CAP) 273
catabolite repression 276
cell cycle 280
constitutive mutant 271
core enzyme 254
corepressor 271
3′, 5′-cyclic adenosine monophosphate (cAMP) 273
cyclic AMP-receptor protein (CRP) 273
diauxic growth 276
domains 269
elongation cycle 265
elongation factors 265
exit site (E site) 265
exon 257
exteins 270
global regulatory systems 276
heat-shock proteins 268
heterogeneous nuclear RNA (hnRNA) 257
inducer 270
inducible enzyme 270
initiation factors 263
initiator codon 262
inteins 270
intron 257
leader region 274
leader sequence 254
methyl-accepting chemotaxis protein (MCP) 279
molecular chaperones 267
negative control 271
nonsense codons 265
operator 271
operon 271
peptidyl or donor site (P site) 265
peptidyl transferase 265
polyribosome 260
positive operon control 273
posttranscriptional modification 257
Pribnow box 255
promoter 254
protein splicing 269
regulon 276
release factors 265
repressible enzyme 271
repressor proteins 271
rho factor 257
ribosomal RNA (rRNA) 254
ribozyme 259
RNA polymerase 254
RNA splicing 257
sigma factor 254
small nuclear RNA (snRNA) 259
small RNAs (sRNAs) 278
spliceosome 259
split or interrupted genes 257
structural gene 271
terminator 255
transfer RNA (tRNA) 254
translocation 265
transpeptidation reaction 265
two-component phosphorelay system 279

Key Terms

- Highlight chapter terminology and list term location in the chapter

Questions for Thought and Review

- Spur students to apply and integrate chapter content

Questions for Thought and Review

1. Describe how RNA polymerase transcribes procaryotic DNA. How does the polymerase know where to begin and end transcription?
2. How do eucaryotic RNA polymerases and promoters differ from those in procaryotes? In what ways does eucaryotic mRNA differ from procaryotic mRNA with respect to synthesis and structure? How does eucaryotic synthesis of rRNA and tRNA resemble that of mRNA? How does it differ?
3. Draw diagrams summarizing the sequence of events in the three stages of protein synthesis (initiation, elongation, and termination) and accounting for the energy requirements of translation.
4. Describe in some detail the organization of the regulatory systems responsible for induction and repression, and the mechanism of their operation.
5. How is *E. coli* able to use glucose exclusively when presented with a mixture of glucose and lactose?
6. Of what practical importance is attenuation in coordinating the synthesis of amino acids and proteins? Describe how attenuation activity would vary when protein synthesis suddenly rapidly accelerated, then later suddenly decelerated.
7. How does the timing of DNA replication seem to differ between slow-growing and fast-growing cells? Be able to account for the fact that bacterial cells may contain more than a single copy of DNA.

Critical Thinking Questions

- Stimulate analytical problem solving skills

Critical Thinking Questions

1. Attenuation affects anabolic pathways, whereas repression can affect either anabolic or catabolic pathways. Provide an explanation for this.
2. Many people say that RNA was the first of the information molecules (RNA, DNA, protein) to arise during evolution. Given the information in this chapter, what evidence is there to support this hypothesis?
3. Compare and contrast RNA and DNA synthesis.

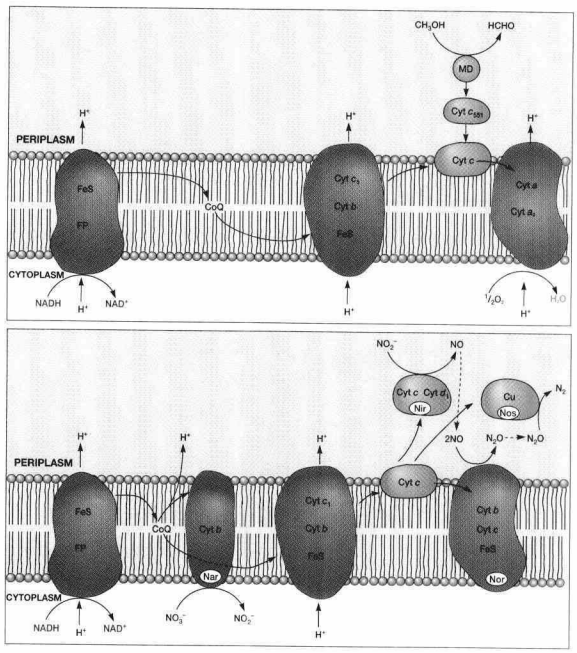
For recommended readings on these and related topics, see Appendix V.

A Powerful Lecture Resource

This multimedia collection of visual resources allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually-based tests and quizzes, dynamic course website content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped within the following easy-to-use folders.

Art and Photo Library

Full-color digital files of all the tables and illustrations and most of the photos in *Microbiology,* sixth edition, can be readily incorporated into lecture presentations, exams, or custom-made classroom materials.

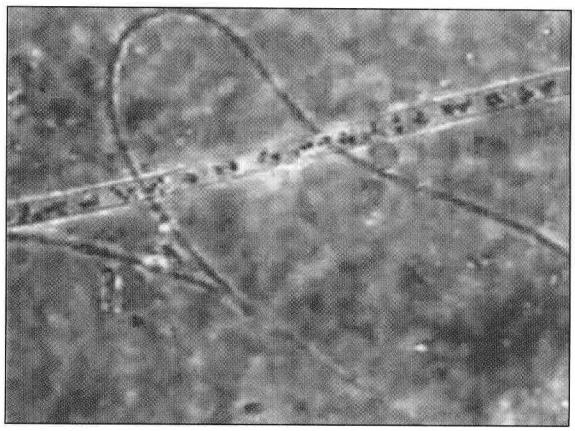


Information in DNA generates diversity

- Four bases – G (guanine), A (adenine), T (thymine), and C (cytosine) are the nucleotide building blocks of DNA
- DNA is a double stranded helix composed of A-T and G-C complementary bases

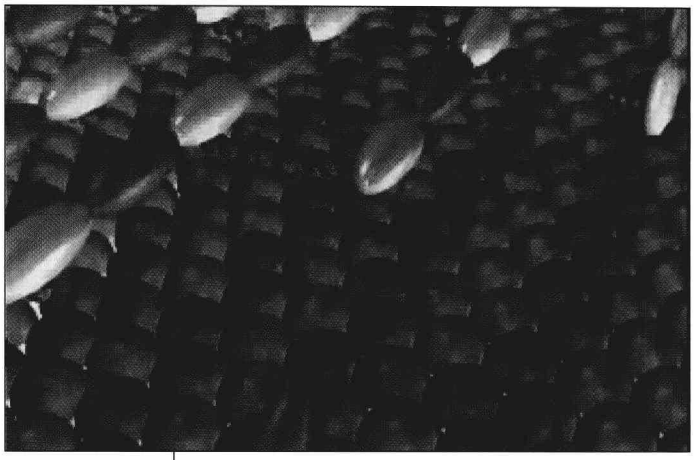
PowerPoint Lecture Outlines

Ready-made presentations that combine art and lecture notes cover each of the 42 chapters of the text. These lectures can be used as they are or can be tailored to reflect your preferred lecture topics and sequences.

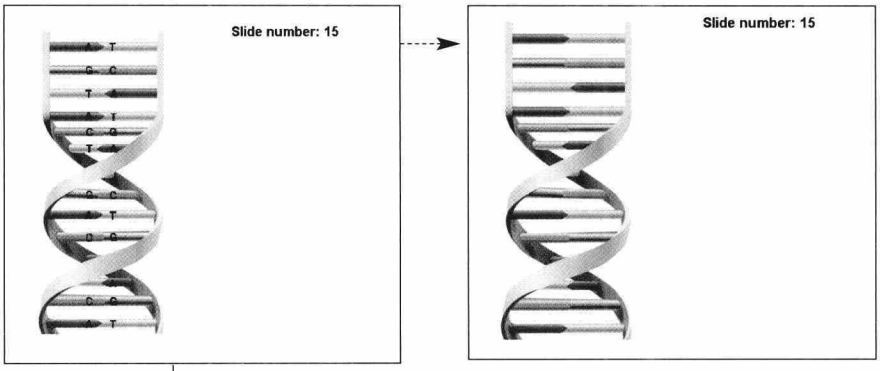


Animations and Videos

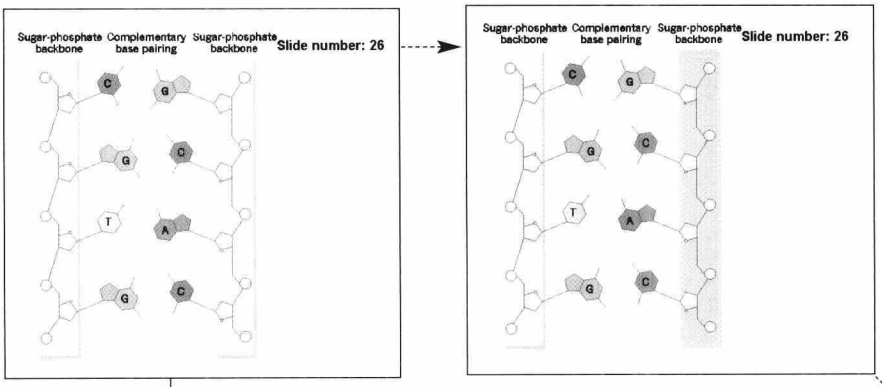
Instructive, full-color animations and videos are available to harness the visual impact of processes in motion. Import these animations into classroom presentations or online course materials.



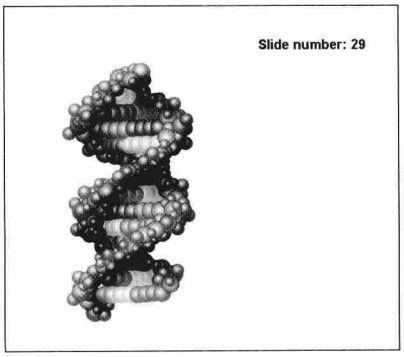
Active Art Active Art allows you to customize key figures from the text to complement your lecture! Figures have been broken into smaller digestable parts so each piece can be used in any desired order or format. Using Microsoft PowerPoint's ungroupable art feature, instructors can also move, resize, or change the color of any or all objects in a piece of art.



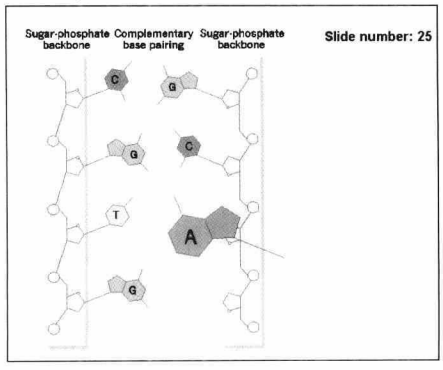
Remove Labels Labels and leader lines can be easily repositioned, edited, or removed. Your customized images can then be used for course assignments or additional quizzing for your students.



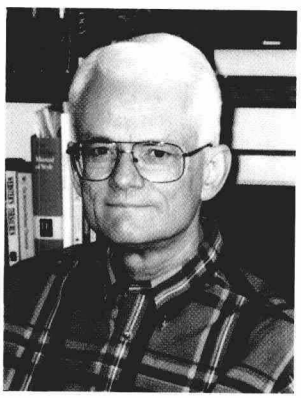
Change Colors Colors can be removed and/or changed from any Active Art slide or object. Black and white images can be created for use in lecture supplements or exams.



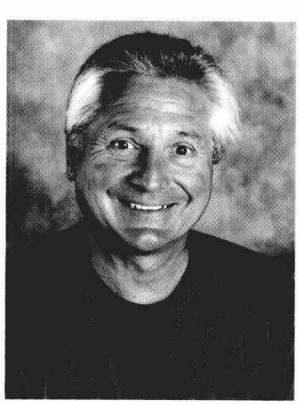
Resize Objects The entire image or parts of the image can be made larger or smaller depending on what you choose to emphasize.



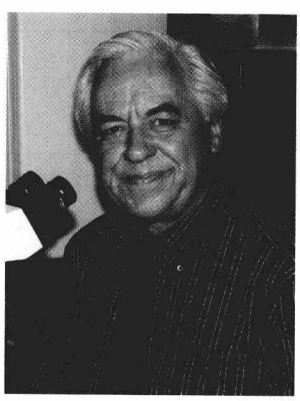
About the Authors



Lansing Prescott served as Professor of Biology and chair of the department at Augustana College in Sioux Falls, South Dakota, until May 1999. Dr. Prescott received his B.A. and M.A. in biology from Rice University and his Ph.D. in biochemistry from Brandeis University. He was a visiting lecturer at the University of Georgia in 1980. Dr. Prescott's research interests are the properties of bacterial aspartate transcarbamylases (particularly those from *Bacillus stearothermophilus* and *B. psychrophilus*) and the effect of toxicants on diatom morphology and physiology. As is the case in small, liberal arts colleges, one of Dr. Prescott's primary responsibilities was teaching undergraduates. He has taught courses in introductory microbiology for nursing and allied health students, general microbiology for majors, cell biology, biological chemistry, immunology, human physiology, and parasitology. In 1989, he received a faculty achievement award for excellence in teaching. Presently living just outside Austin, Texas, Dr. Prescott enjoys listening to music, playing golf and chess, and reading both fiction and nonfiction when he is not engaged in academic pursuits. Dr. Prescott's commitment to writing is long-standing. Besides his involvement in *Microbiology* and *Laboratory Exercises in Microbiology,* now in their sixth editions, he was a contributing author for a general biology textbook, L. G. Johnson's (1983) *Biology.* Dubuque, IA: Wm. C. Brown, and has been a Choice book reviewer for many years. Dr. Prescott can be reached at lansing_prescott@augie.edu.



John Harley is a professor at Eastern Kentucky University. He received his B.A. degree in biology and chemistry from Youngstown State University in 1964, an M.A. degree in parasitology and microbiology from Kent State University in 1966, and his Ph.D. in cardiovascular physiology from Kent State University in 1969. Dr. Harley did postdoctoral work at Baylor College of Medicine, Argonne National Lab, and Vanderbilt University. In 1972 he accepted a faculty position at Eastern Kentucky University, where he rose through the ranks to full professor and in 1990 was named a Foundation Professor by the EKU Alumni Association and Board of Reagents. He also holds full graduate status at the University of Kentucky where he teaches a pathophysiology course in the graduate program. Dr. Harley's research interests are in parasitology (abnormal and normal host relationships, biochemistry, life cycle studies, and pharmacology) and the effects of parasites on normal host physiology. He has published over 80 research papers and publications and was advisor to 16 graduate students. Together with Stephen Miller, he wrote the sixth edition of *Zoology,* published by McGraw-Hill. Dr. Harley teaches general zoology, general biology, human anatomy, microbiology, general physiology, human physiology, and pathophysiology. In addition to his academic pursuits, Dr. Harley raises and breeds Cavalier King Charles Spaniels, enjoys working on automobiles, traveling, gardening, reading science journals and fiction. Dr. Harley can be reached at john.harley@eku.edu.



Donald Klein is a Professor of Microbiology at Colorado State University, Fort Collins, Colorado. Dr. Klein received his B.S. and M.S. degrees in agriculture and agricultural microbiology from the University of Vermont. After predoctoral studies at the University of Tübingen, Germany, he received his Ph.D. in microbiology from the Pennsylvania State University. His research interests are in the area of environmental microbiology, with major emphases on plant-microbe relationships in the rhizosphere, plant community succession, and the fungal-bacterial structure of natural systems. In addition to work in these areas, Dr. Klein has had a long-standing interest in teaching, especially at the undergraduate level. He has taught courses in soil, aquatic and industrial microbiology, as well as courses in the areas of general microbiology, microbial diversity and microbial ecology. In addition to his contributions to the environmental, food, and industrial microbiology sections of *Microbiology,* Dr. Klein has edited books on microbial aspects of weather modification and soil reclamation. He is a member of the American Academy of Microbiology, and has served on the editorial boards of several scientific journals. In addition to his academic interests, Dr. Klein enjoys reading classic German literature, Jaguar XK150 restoration, sculpting mythical animals in stone, and sailing a beetlecat sailboat on Buzzards Bay, Massachusetts, in the summertime. Dr. Klein can be reached at dakspk@cape.com.

Brief Contents