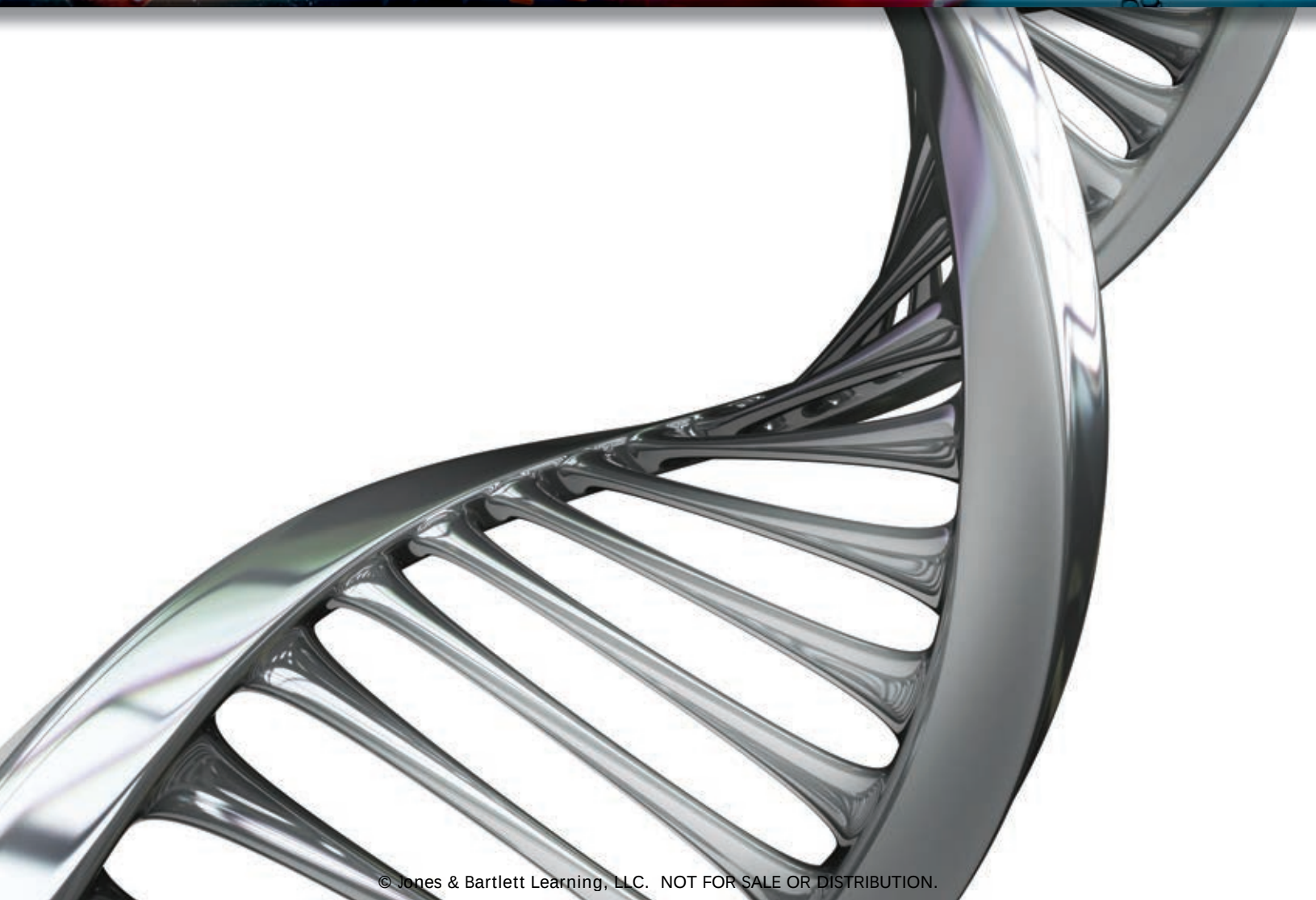
Molecular BIOTECHNOLOGY



Molecular BIOTECHNOLOGY

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Brief Contents

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Preface

Connecting the Dots

In this first edition of *Molecular Biotechnology*, history and science are interwoven into a narrative yet technical account of humanity taking control of its destiny. This may seem like an overzealous or romantic description for a science textbook. Nonetheless my primary goal in writing these pages was to bring color into an otherwise black-and-white subject. Biotechnology exists at the intersection of scientific research and the business of profit. It can be taught strictly as an arsenal of laboratory techniques and smattering of government regulations. Many existing publications follow this precept. Yet in the educational environment of today, relevance and meaning hold the attention of learners to a much higher degree than facts alone. To that end, *Molecular Biotechnology* places a strong emphasis on cultural and personal aspects, such as bioethical issues and the diverse career paths in this expanding field. It seeks to connect the dots in exploring the past, describing the present, and considering the future of biotechnology.

As early as the introduction of agriculture, humanity has sought to control its fate by controlling nature. Biotechnology is an extension of this. After millennia of plant breeding and animal husbandry, this past century has experienced an unprecedented acceleration of scientific knowledge, edging out even the Age of Enlightenment. Discovery of the genetic material, DNA, its structure and transmission have led to the Modern Synthesis of scientific understanding. With the Modern Synthesis, the molecular details of evolution and genetics were elucidated. While Charles Darwin conceived the steps of natural selection leading to adaptation, he could not begin to explain exactly how organisms changed over time or how traits were passed through generations. Biotechnology has answered these questions. The Chromosomal Theory of Inheritance and the Genetic Code laid the foundation in this regard. From there, we have gone from describing molecular events to orchestrating them. Instead of selecting traits to develop plant varieties and breed animals, we can select genes. Furthermore, the advances taking place concurrently in computer science and information technology have allowed biotechnologists to store and process enormous amounts of genetic data. Without that ability, we would not be where we are today. What a serendipitous series of events!

We live in a time when the average person is likely to be more influenced and affected by science than ever before. In particular, most of us have daily contact with biotechnology in one form or another. At minimum, the food we eat and the medicine we take are unmistakenly the results of biotechnology. Along with this, the concept of scientific literacy is creeping into our collective mindset. Ironically, it is also a time when well-established and almost universally recognized theories are subject to harsh criticism by the scientifically illiterate. As an educator, combatting this paradox is of utmost importance. Among the maligned theories, evolution and climate change are at the forefront. Reading headlines and hearing voice clips in mainstream media would suggest these heavily supported paradigms of science are merely unfounded suggestions cherry-picked from a whole realm of possibilities. Perhaps this is not new at all, considering the words of Darwin in *The Descent of Man*:

> Ignorance more frequently begets confidence than does knowledge: it is those who know little, not those who know much, who so positively assert that this or that problem will never be solved by science.

To become scientifically literate, one must join the ranks of those who know much. By knowing much, one becomes an informed citizen, a discerning consumer, and an enfranchised member of society. That is the inspiration for *Molecular Biotechnology.*

It would be an act of hubris to suggest this or that problem will always be solved by science. But the possibilities before us are truly mind-boggling. We are at the precipice of personalized medicine based on genetic make-up. We are seeking to protect and expand the world's food supply through genetic engineering and cloning. We are improving products and processes by making them faster, cheaper, and of better quality. We

are cleaning up pollution and preserving endangered species. We are exonerating wrongly accused felons through DNA fingerprinting. We are determining how genes and other molecules interact to create the diversity of life on this planet. We are even unraveling the mysteries of our own past by delving deeper into the evolution of *Homo sapiens*.

In using this textbook, be mindful of its spirit and intent: connecting the dots. Historical narrative, bioethical discussion, and career preparation are the main focus. Technical information is offered as contextual detail. The laboratory methods utilized in biotechnology must be learned by any learner entering this profession, but this is not a lab manual. Foundational knowledge in the areas of chemistry, genetics, and molecular biology is undeniably beneficial. For those lacking that knowledge or those in need of a refresher, the appendices provide summaries of the most basic and most necessary information. The technical aspects of biotechnology are also heavily presented in graphics and images with the intention of simplifying concepts. This subject can be complex, challenging, and even overwhelming. This textbook was purposefully designed to be none of these things. Instead, the aim was to create a textbook covering a relatively advanced subject in a familial tone and with an approachable presentation. I hope you will agree.

The Student Experience

Learning Objectives: The learning objectives identify the knowledge and competencies that a student needs to master through reading and comprehension of the chapter material. To use the objectives effectively, they should be reviewed before and after reading the chapters. This review will help students focus on the major knowledge points in each chapter and facilitate answering the questions and completing the activities at the end of each chapter.

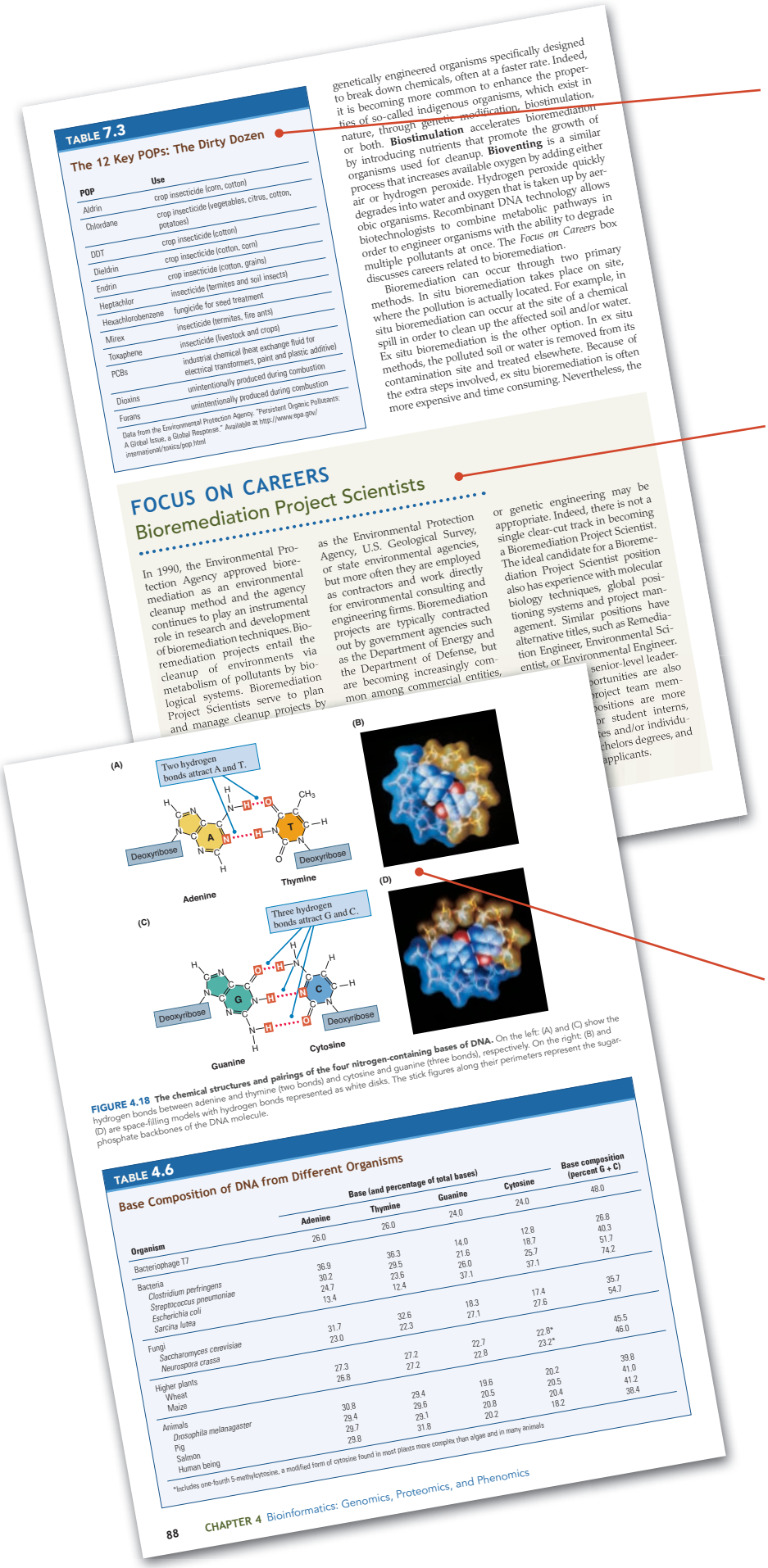


TABLE 7.3

The 12 Key POPs: The Dirty Dozen

POP	Use
Aldrin	crop insecticide (corn, cotton)
Chlordane	crop insecticide (vegetables, citrus, cotton, potatoes)
DDT	crop insecticide (cotton)
Dieldrin	crop insecticide (cotton, corn)
Endrin	crop insecticide (cotton, grains)
Heptachlor	insecticide (termites and soil insects)
Hexachlorobenzene	fungicide for seed treatment
Mirex	insecticide (termites, fire ants)
Toxaphene	insecticide (livestock and crops)
PCBs	industrial chemical (heat exchange fluid for electrical transformers, paint and plastic additive)
Dioxins	unintentionally produced during combustion
Furans	unintentionally produced during combustion

Data from the Environmental Protection Agency. "Persistent Organic Pollutants: A Global Issue, a Global Response." Available at http://www.epa.gov/international/toxics/pop.html

genetically engineered organisms specifically designed to break down chemicals, often at a faster rate. Indeed, it is becoming more common to enhance the properties of so-called indigenous organisms, which exist in nature, through genetic modification, biostimulation, or both. **Biostimulation** accelerates bioremediation by introducing nutrients that promote the growth of organisms used for cleanup. **Bioventing** is a similar process that increases available oxygen by adding either air or hydrogen peroxide. Hydrogen peroxide quickly degrades into water and oxygen that is taken up by aerobic organisms. Recombinant DNA technology allows biotechnologists to combine metabolic pathways in order to engineer organisms with the ability to degrade multiple pollutants at once. The *Focus on Careers* box discusses careers related to bioremediation.

Bioremediation can occur through two primary methods. In situ bioremediation takes place on site, where the pollution is actually located. For example, in situ bioremediation can occur at the site of a chemical spill in order to clean up the affected soil and/or water. Ex situ bioremediation is the other option. In ex situ methods, the polluted soil or water is removed from its contamination site and treated elsewhere. Because of the extra steps involved, ex situ bioremediation is often more expensive and time consuming. Nevertheless, the

FOCUS ON CAREERS

Bioremediation Project Scientists

In 1990, the Environmental Protection Agency approved bioremediation as an environmental cleanup method and the agency continues to play an instrumental role in research and development of bioremediation techniques. Bioremediation projects entail the cleanup of environments via metabolism of pollutants by biological systems. Bioremediation Project Scientists serve to plan and manage cleanup projects by

as the Environmental Protection Agency, U.S. Geological Survey, or state environmental agencies, but more often they are employed as contractors and work directly for environmental consulting and engineering firms. Bioremediation projects are typically contracted out by government agencies such as the Department of Energy and the Department of Defense, but are becoming increasingly common among commercial entities,

or genetic engineering may be appropriate. Indeed, there is not a single clear-cut track in becoming a Bioremediation Project Scientist. The ideal candidate for a Bioremediation Project Scientist position also has experience with molecular biology techniques, global positioning systems and project management. Similar positions have alternative titles, such as Remediation Engineer, Environmental Scientist, or Environmental Engineer. ... senior-level leadership opportunities are also ... project team members ... positions are more ... or student interns, ... es and/or individu... chelors degrees, and ... applicants.

(A)

Two hydrogen bonds attract A and T.

Deoxyribose

Adenine

Thymine

Deoxyribose

(B)

(C)

Three hydrogen bonds attract G and C.

Deoxyribose

Guanine

Cytosine

Deoxyribose

(D)

FIGURE 4.18 **The chemical structures and pairings of the four nitrogen-containing bases of DNA.** On the left: (A) and (C) show the hydrogen bonds between adenine and thymine (two bonds) and cytosine and guanine (three bonds), respectively. On the right: (B) and (D) are space-filling models with hydrogen bonds represented as white disks. The stick figures along their perimeters represent the sugar-phosphate backbones of the DNA molecule.

TABLE 4.6

Base Composition of DNA from Different Organisms

Organism	Base (and percentage of total bases)				Base composition (percent G + C)
	Adenine	Thymine	Guanine	Cytosine	
Bacteriophage T7	26.0	26.0	24.0	24.0	48.0
Bacteria					
Clostridium perfringens	36.9	36.3	14.0	12.8	26.8
Streptococcus pneumoniae	30.2	29.5	21.6	18.7	40.3
Escherichia coli	24.7	23.6	26.0	25.7	51.7
Sarcina lutea	13.4	12.4	37.1	37.1	74.2
Fungi					
Saccharomyces cerevisiae	31.7	32.6	18.3	17.4	35.7
Neurospora crassa	23.0	22.3	27.1	27.6	54.7
Higher plants					
Wheat	27.3	27.2	22.7	22.8*	45.5
Maize	26.8	27.2	22.8	23.2*	46.0
Animals					
Drosophila melanagaster	30.8	29.4	19.6	20.2	39.8
Pig	29.4	29.6	20.5	20.5	41.0
Salmon	29.7	29.1	20.8	20.4	41.2
Human being	29.8	31.8	20.2	18.2	38.4

*Includes one-fourth 5-methylcytosine, a modified form of cytosine found in most plants more complex than algae and in many animals.

88 CHAPTER 4 Bioinformatics: Genomics, Proteomics, and Phenomics

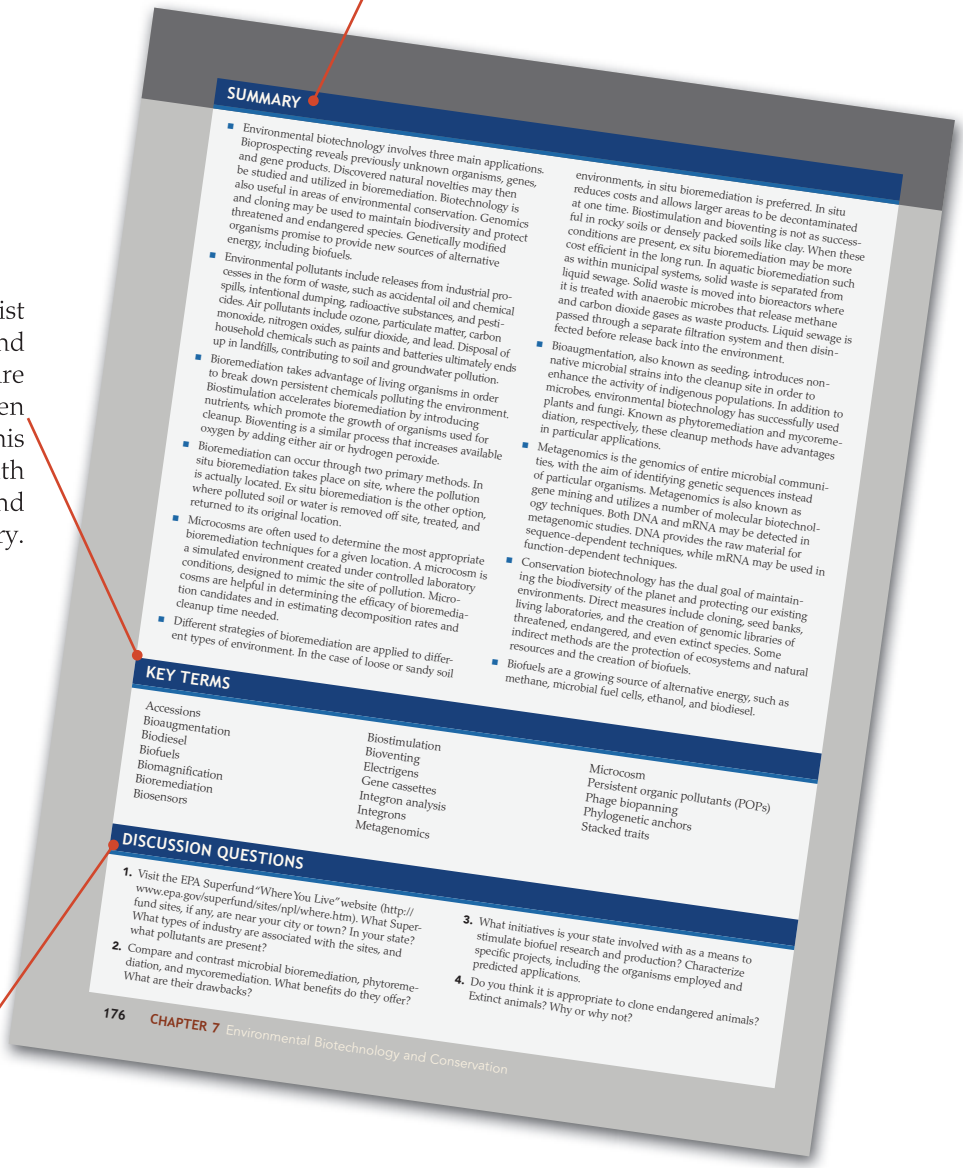
Instructional Tables: Useful tables organize important information from trusted sources into easy-to-read lists. These tables provide current data to help summarize key material.

***Focus on Careers* Boxes:** These informative boxes introduce students to exciting and cutting-edge career opportunities in the area of molecular biotechnology. The information contained within these boxes can help students formulate their educational needs to achieve their career aspirations.

Full-color Illustrations: Figures illustrate key molecular processes and gene sequences, making difficult concepts easier to understand.

End-of-Chapter Summary: Chapter Summaries appear at the end of each chapter and contain a comprehensive summary of the main points in the chapter. These provide students with a great reference tool and study guide to help them determine if they comprehended the key competencies and core knowledge in each chapter.

Key Terms: A comprehensive list of key terms is listed at the end of each chapter. These terms are also bolded in the chapter when the term is first introduced. This list can be used to help with comprehension and to expand students' professional vocabulary.



SUMMARY

- Environmental biotechnology involves three main applications. Bioprospecting reveals previously unknown organisms, genes, and gene products. Discovered natural novelties may then be studied and utilized in bioremediation. Biotechnology is also useful in areas of environmental conservation. Genomics and cloning may be used to maintain biodiversity and protect threatened and endangered species. Genetically modified organisms promise to provide new sources of alternative energy, including biofuels.
- Environmental pollutants include releases from industrial processes in the form of waste, such as accidental oil and chemical spills, intentional dumping, radioactive substances, and pesticides. Air pollutants include ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead. Disposal of household chemicals such as paints and batteries ultimately ends up in landfills, contributing to soil and groundwater pollution.
- Bioremediation takes advantage of living organisms in order to break down persistent chemicals polluting the environment. Biostimulation accelerates bioremediation by introducing nutrients, which promote the growth of organisms used for cleanup. Bioventing is a similar process that increases available oxygen by adding either air or hydrogen peroxide.
- Bioremediation can occur through two primary methods. In situ bioremediation takes place on site, where the pollution is actually located. Ex situ bioremediation is the other option, where polluted soil or water is removed off site, treated, and returned to its original location.
- Microcosms are often used to determine the most appropriate bioremediation techniques for a given location. A microcosm is a simulated environment created under controlled laboratory conditions, designed to mimic the site of pollution. Microcosms are helpful in determining the efficacy of bioremediation candidates and in estimating decomposition rates and cleanup time needed.
- Different strategies of bioremediation are applied to different types of environment. In the case of loose or sandy soil environments, in situ bioremediation is preferred. In situ reduces costs and allows larger areas to be decontaminated at one time. Biostimulation and bioventing is not as successful in rocky soils or densely packed soils like clay. When these conditions are present, ex situ bioremediation may be more cost efficient in the long run. In aquatic bioremediation such as within municipal systems, solid waste is separated from liquid sewage. Solid waste is moved into bioreactors where it is treated with anaerobic microbes that release methane and carbon dioxide gases as waste products. Liquid sewage is passed through a separate filtration system and then disinfected before release back into the environment.
- Bioaugmentation, also known as seeding, introduces non-native microbial strains into the cleanup site in order to enhance the activity of indigenous populations. In addition to microbes, environmental biotechnology has successfully used plants and fungi. Known as phytoremediation and mycoremediation, respectively, these cleanup methods have advantages in particular applications.
- Metagenomics is the genomics of entire microbial communities, with the aim of identifying genetic sequences instead of particular organisms. Metagenomics is also known as gene mining and utilizes a number of molecular biotechnology techniques. Both DNA and mRNA may be detected in metagenomic studies. DNA provides the raw material for sequence-dependent techniques, while mRNA may be used in function-dependent techniques.
- Conservation biotechnology has the dual goal of maintaining the biodiversity of the planet and protecting our existing environments. Direct measures include cloning, seed banks, living laboratories, and the creation of genomic libraries of threatened, endangered, and even extinct species. Some indirect methods are the protection of ecosystems and natural resources and the creation of biofuels.
- Biofuels are a growing source of alternative energy, such as methane, microbial fuel cells, ethanol, and biodiesel.

KEY TERMS

Accessions
Bioaugmentation
Biodiesel
Biofuels
Biomagnification
Bioremediation
Biosensors
Biostimulation
Bioventing
Electrigens
Gene cassettes
Integron analysis
Integrons
Metagenomics
Microcosm
Persistent organic pollutants (POPs)
Phage biopanning
Phylogenetic anchors
Stacked traits

DISCUSSION QUESTIONS

1. Visit the EPA Superfund "Where You Live" website (http://www.epa.gov/superfund/sites/npl/where.htm). What Superfund sites, if any, are near your city or town? In your state? What types of industry are associated with the sites, and what pollutants are present?
2. Compare and contrast microbial bioremediation, phytoremediation, and mycoremediation. What benefits do they offer? What are their drawbacks?
3. What initiatives is your state involved with as a means to stimulate biofuel research and production? Characterize specific projects, including the organisms employed and predicted applications.
4. Do you think it is appropriate to clone endangered animals? Extinct animals? Why or why not?

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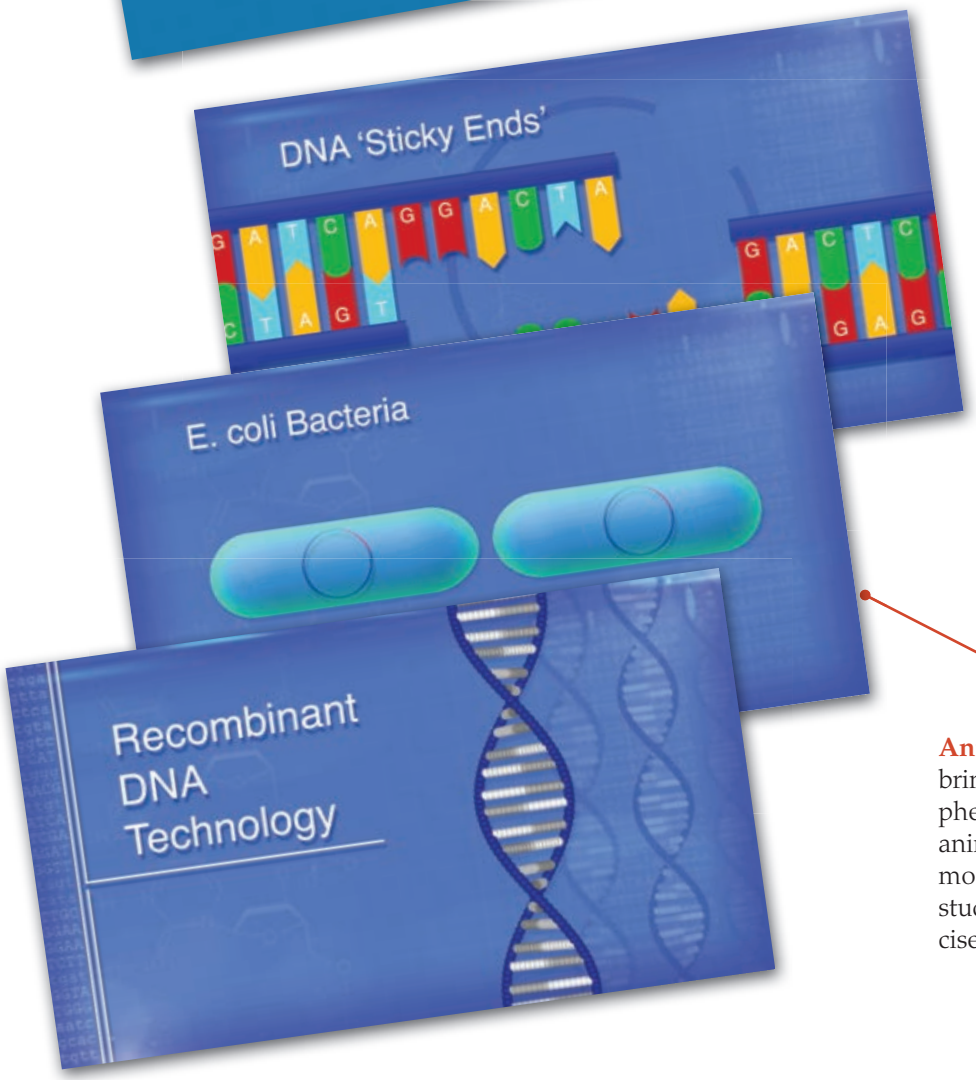
Discussion Questions: The purpose of the discussion questions at the end of each chapter is to provide the students with feedback regarding their mastery of the chapter's content. These critical thinking style questions help students apply their knowledge in an individual assignment or as part of a group project.

Companion Website: Online resources, including practice quizzes, weblinks, and an interactive glossary with flashcards, are available to help students study.

Lab Exercises: The Student Lab Exercises contain a lab activity for each chapter. These labs can be used as an applied study tool, assigned as a classroom activity, or as an individual homework assignment. The Student Lab Exercises are an excellent way for students to apply knowledge and gain practical lab skills.

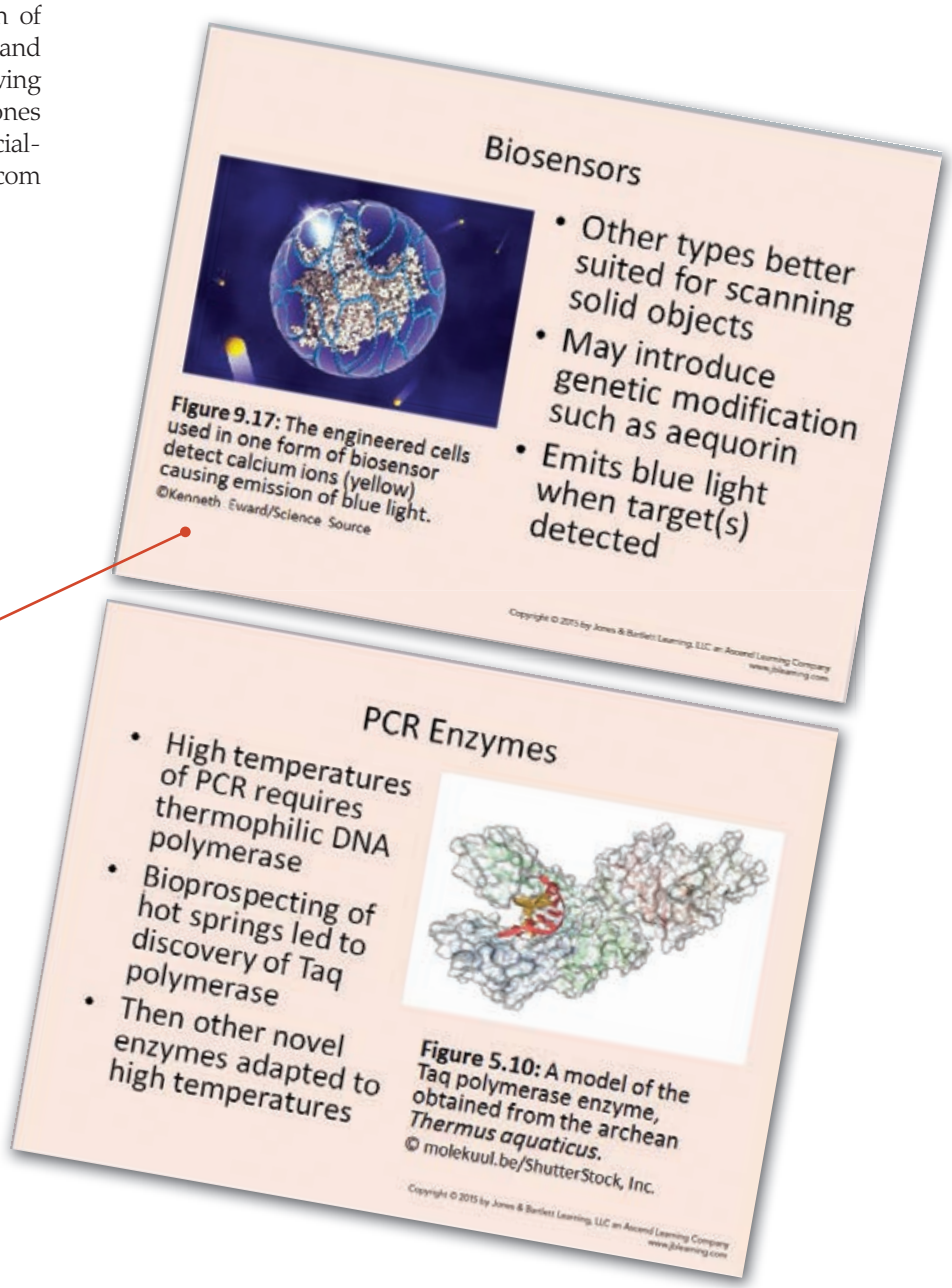


Animations: Engaging animations bring fascinating molecular biology phenomena to life! Each interactive animation guides students through molecular processes and gauges student's understanding with exercises and assessment questions.

Teaching Tools

Jones & Bartlett Learning offers an array of resources to save instructors valuable time in preparation and instruction of this course. Additional information and review copies of any of the following items are available through your Jones & Bartlett Learning Account Specialist or by going to go.jblearning.com /MolecularBiotechnology.

Lecture Outlines in PowerPoint format: This presentation package provides lecture notes and images from the text for each chapter of *Molecular Biotechnology*. Instructors with the Microsoft PowerPoint software can customize the outlines, art, and order of presentation to suit their course needs.



Sample Syllabus: This text file is provided to offer instructors a sample course outline. Instructors can customize the syllabus to tailor their course needs and schedule.

Test Bank: This text file provides instructors with hundreds of exam questions and their answers for each chapter of *Molecular Biotechnology*.

About the Author

Carolyn A. Dehlinger is a professor of Biological Sciences at Keiser University in Jacksonville, Florida. She received her Master of Applied Science in Technology Management from the University of Denver and her Master of Science in Biology from Mississippi State University. She completed her undergraduate degree at the University of Florida. She teaches students in the Biomedical Science and Biotechnology degree programs in addition to students enrolled in non-majors biology courses. At Keiser, Carolyn played an integral role in the development of the Biomedical Science degree curriculum and has served on multiple National Science Foundation grant projects aimed at delivering biotechnology education to both students and educators. Carolyn serves as a subject matter expert with the American Council on Education in Washington, DC. In this role, she evaluates curriculum and determines their eligibility for accreditation. She is a proud member of the Honorable Order of Kentucky Colonels, an honor bestowed by the governor of Kentucky for community service. Carolyn is a practitioner and registered teacher of yoga and enjoys spending her free time with her husband Charles, their two golden retrievers, Alice and Ivan, and their calico cat, Chloe.

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—Carolyn A. Dehlinger

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