

Preface

This text is intended for students in any field of science or engineering who want a one-semester introduction to biochemistry but who do not intend to be biochemistry majors. Our main goal in writing this book is to make biochemistry as clear and applied as possible and to familiarize science students with the major aspects of biochemistry. For students of biology, chemistry, physics, geology, nutrition, sports physiology, and agriculture, biochemistry impacts greatly on the content of their fields, especially in the areas of medicine and biotechnology. For engineers, studying biochemistry is especially important for those who hope to enter a career in biomedical engineering or some form of biotechnology.

Students who will use this text are at an intermediate level in their studies. A beginning biology course, general chemistry, and at least one semester of organic chemistry are assumed as preparation.

What's New

All textbooks evolve to meet the interests and needs of students and instructors and to include the most current information. Several changes mark this edition.

Biochemistry Hot Topics These articles are now conveniently located within the relevant chapters. They highlight new breakthroughs and topics in the area of biochemistry such as CRISPR, Alzheimer's disease, epigenetics, brown fat, and more!



Updated Coverage Each chapter in the text has been updated with the current developments and scientific findings in the biochemistry field.

New Design and Updated Art
Illustrations throughout the text have been redrawn for improved consistency. In conjunction with the book's updated art program, a more contemporary design and color palette have been utilized.



Further Reading An annotated bibliography is now provided in the Further Reading section at the end of each chapter, making these resources more easily accessible to the student.

HOT TOPIC CRISPR

Genetic engineering is the process by which scientists use biotechnology to manipulate the DNA of an organism by introducing/eliminating genes or inserting/deleting mutations to achieve desired traits. One example of genetic engineering introduced earlier in this chapter is the *Simploc* infested potato. In this case, scientists identified and cloned genes from the wild potato into the genome of the inbred potato to eliminate the production of enzymes that cause browning and bruising. The three most common methods that scientists use to edit a genome are (i) clustered, regularly interspaced, short palindromic repeats (CRISPR) in combination with the Cas9 RNA-guided nuclease (CRISPR/Cas9);

plasmids. CRISPR was first described in 1987 and fundamental research was performed on the genome editing approach up until a major breakthrough in 2012, when it was demonstrated that CRISPR/Cas9 RNA-guided DNA endonuclease could be applied to mediate site-specific genome engineering in eukaryotic cells, including human cells. Since 2012, well over 1,000 studies have been published in the scientific literature and the fundamental research on *in vitro* model systems has shifted to *in vivo* mammalian testing. To understand how genome editing with the CRISPR/Cas9 method works, let's first begin with the four key components of the system CRISPR, Cas9, sgRNA, and PAM (Table B3.2).

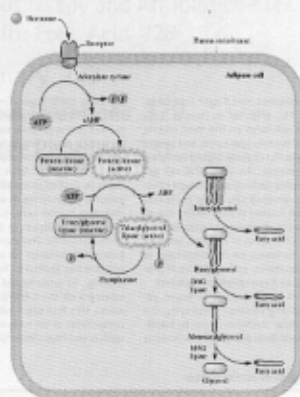
Table 15.2 Components of the CRISPR/Cas9 genome editing system

Accessory	Spooled out	Significance	Image
CRISPR	Clustered Regularity Inter-spaced Palindromic Repeats	Lost on DNA that were an gene insertion or deletion positions	
Cas9	CRISPR associated protein 9	Nuclease for cutting DNA (Can 1...10 cuts)	
sgRNA	Single guide ribonucleic acid	A construct/clone of CRISPR RNA (crRNA) and trans-activating crRNA (tracrRNA), contains sequence information for insertion/deletion	
PAM	Protospacer adjacent motif	sgRNA binds to a target gene locus next to PAM; sequence NGG (any, guanine, guanine) in E. proger or 5'-NAG (any, adenine, guanine) in humans	E. proger NGG Human 3'-NAG

CRISPR - <https://en.wikipedia.org/wiki/CRISPR> (adapted from Jean Harnett, P. and R. Barrington Science 325, 167 (2008); Cui et al. Science 347, 6537 (2014) and www.danaher.com/US/Products/Edman/CRISPR; <https://www.thermofisher.com>)

Table of Changes by Chapter

- Chapter 1** Added summary of major types of biomolecules
- Chapter 3** Expanded Biochemical Connection on oxytocin and its social effects, added four new Review Exercises
- Chapter 4** Updated Biochemical Connection on prion diseases, added Hot Topic about aging
- Chapter 6** Updated Biochemical Connection on enzyme markers for diseases
- Chapter 7** Added new Hot Topic on Alzheimer's disease, added four new Review Exercises
- Chapter 8** Added expanded Hot Topic on happiness and depression, added two new Review Exercises
- Chapter 9** Added Hot Topic on breast cancer, added material on long noncoding RNA, added new section on medical applications of RNA, deleted Biochemical Connection on synthetic genome
- Chapter 10** Added brief mention of replication termination
- Chapter 11** Added new Hot Topic on epigenetics, deleted Biochemical Connections box about CREB, deleted Biochemical Connections about epigenetics and cancer
- Chapter 13** Added new Hot Topic on clustered, regularly interspaced, short palindromic repeat technology in combination with the Cas9 RNA-guided nuclease (CRISPR/Cas9) method of genetic engineering, example of CRISPR/Cas9 to engineer Innate potato
- Chapter 14** Updated content on vaccine development for Ebola and advances in stem cell research
- Chapter 16** New research findings that correlate the use of artificial sweeteners to gut microbiome, suggesting the reason diet products may not result in weight loss
- Chapter 17** Updated content associated with biofuels
- Chapter 19** New information on the use of the compound 1080 (sodium fluoroacetate) for control of mammal populations in New Zealand
- Chapter 20** Added a new Hot Topic on brown fat to include recent research developments demonstrating the benefits of brown adipose tissue to maintenance of healthy metabolism
- Chapter 24** Added updated Hot Topic on G-protein-coupled receptors to include recent research on the biased agonism or functional selectivity model associated with opioid receptors



Proven Features

Visual Impact Ideal for visual learners, this book's state-of-the-art approach helps students visualize key processes and understand important topics.

Biochemical Connections The Biochemical Connections highlight special topics of particular interest to students. Topics frequently have clinical implications, such as cancer, AIDS, and nutrition. These essays help students make the connection between biochemistry and the real-world. They are flowed in with the narrative and are placed exactly where they need to be read in each chapter. And although they have a different presentation than the rest of the narrative, they are meant to be read with the narrative and should not be skipped. They are like crescendos in classical music—the change in tempo from the usual narrative to the unique visual presentation and voice of the Biochemical Connections prevents the student's level of interest from dipping—students are always engaged. See a full listing of Biochemical Connections boxes in the Table of Contents.

12B BIOCHEMICAL CONNECTIONS

Neurology

Protein Synthesis Makes Memories

2.1 APPLY YOUR KNOWLEDGE

pH Calculations

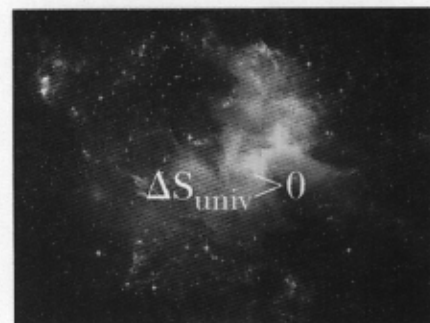
Apply Your Knowledge The Apply Your Knowledge boxes are interspersed within chapters and are designed to provide students with problem-solving experience. The topics chosen are areas of study where students usually have the most difficulty. Solutions and problem-solving strategies are included, giving examples of the problem-solving approach for specific material.

Marginal Glossary No flipping back and forth to read full definitions of key terms. Terms are defined in the margins.

titration an experiment in which a measured amount of base is added to an acid

Early Inclusion of Thermodynamics Select material on thermodynamics appears early in the text. Chapter 1 includes sections on energy and change, spontaneity in biochemical reactions, and life and thermodynamics. Also, Chapter 4 contains an extended section on protein-folding dynamics. We feel it is critical that students understand the driving force of biological processes and see that so much of biology (protein folding, protein-protein interactions, small molecule binding, etc.) is driven by the favorable disordering of water molecules.

Summaries and Questions Each chapter closes with a concise summary, a broad selection of questions, and an annotated bibliography that suggests sources for further reading. The Review Exercises fall into four categories: **RECALL**, **REFLECT AND APPLY**, **BIOCHEMICAL CONNECTIONS**, and **MATHEMATICAL**. The **RECALL** questions are designed for students to quickly assess their mastery of the material, and the **REFLECT AND APPLY** questions are for students to work through more thought-provoking questions. **BIOCHEMICAL CONNECTIONS** questions test students on the **BIOCHEMICAL CONNECTIONS** essays in that chapter. The **MATHEMATICAL** questions are quantitative in nature and focus on calculations.



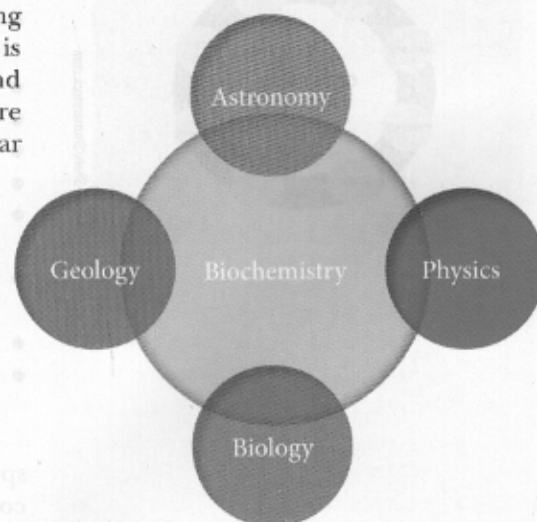
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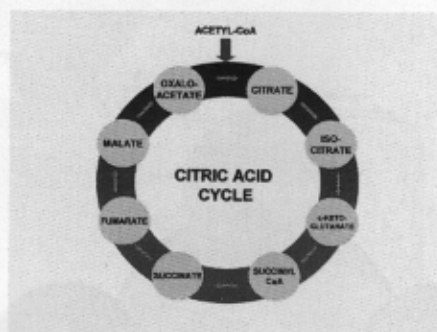
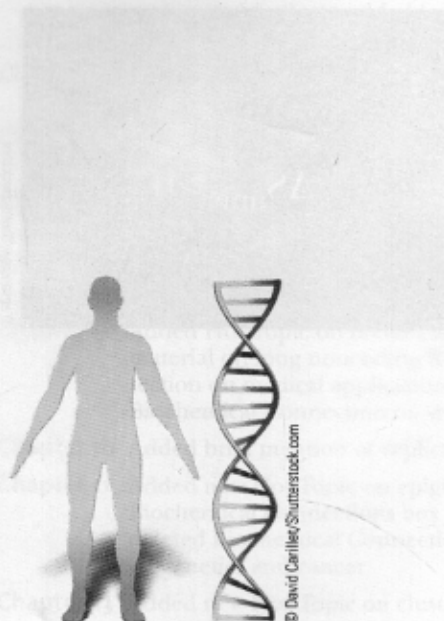
Organization

Because biochemistry is a multidisciplinary science, the first task in presenting it to students of widely varying backgrounds is to put it in context. The text is organized into four categories. The first provides the necessary background and connects biochemistry to other sciences. The next focuses on the structure and dynamics of important cellular components. This is followed by molecular biology and then intermediary metabolism.

Chapters 1 & 2: Background and Connections

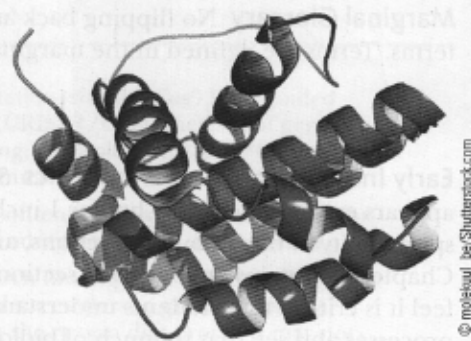
- Relationship between biochemistry and other sciences, particularly concerning the origins of life
- Organic functional groups in the context of biochemistry
- Link between biochemistry and biology, especially the distinction between prokaryotes and eukaryotes and the role of organelles in eukaryotes
- Biochemical view of buffers, solvent properties of water, and other familiar general chemistry topics





Chapters 3-8: Structure and Dynamics of Cellular Components

- Amino acids, peptides, the structure and action of proteins, including enzyme catalysis
- Thermodynamics, hydrophobic interactions
- Techniques for isolating and studying proteins
- Enzyme kinetics and mechanisms
- Structure of membranes and their lipid components



Chapters 9-14: Molecular Biology

- Replication of DNA
- Transcription and gene regulation
- Biosynthesis of nucleic acids
- Translation of the genetic message and protein synthesis
- Biotechnology techniques
- Viruses, cancer, and immunology

Chapters 15-24: Intermediary Metabolism

- Thermodynamic concepts applied specifically to biochemical topics such as coupled reactions
- Connection between metabolism and electron transfer (oxidation-reduction) reactions
- Coenzymes
- Overview of the metabolic pathways: glycolysis
- Glycogen metabolism, gluconeogenesis, and the pentose phosphate pathway
- Citric acid cycle, electron transport chain, and oxidative phosphorylation
- Catabolic and anabolic aspects of lipid metabolism
- Photosynthesis and carbohydrate metabolism
- Plant origin of antimalarials
- Metabolism of nitrogen-containing compounds such as amino acids, porphyrins, and nucleobases
- Integrated look at metabolism, including a treatment of hormones and second messengers
- Nutrition
- Immune system

Some topics such as enzymes and the biosynthesis of nucleic acids are split into two chapters to give students ample time to fully understand the concepts involved. Some are discussed several times, such as the control of carbohydrate metabolism. Subsequent discussions make use of and build on information students have already learned. It is particularly useful to return to a topic after students have had time to assimilate and reflect on it.

This text gives an overview of important topics of interest to biochemists and shows how the remarkable recent progress of biochemistry impinges on other sciences. The length is intended to provide instructors with a choice of favorite topics without being overwhelming for the limited amount of time available in one semester.

Alternative Teaching Options

The order in which individual chapters are covered can be changed to suit the needs of specific groups of students. Although we prefer an early discussion of thermodynamics, the portions of Chapters 1 and 4 that deal with thermodynamics can be covered at the beginning of Chapter 15. All of the molecular biology chapters (Chapters 9 through 14) can precede metabolism or can follow it, depending on the instructor's choice. The order in which the material on molecular biology is treated can be varied according to the preference of the instructor.

Alternate Editions

Loose-Leaf Edition for Biochemistry 9e

ISBN: 978-1-305-96195-1

A loose-leaf (unbound, three-hole-punched) version of *Biochemistry 9e*, which can be inserted in a binder, is also available.

Acknowledgments

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Reviewers Acknowledgments

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Supporting Materials

Please visit <http://www.cengage.com/chemistry/campbell/biochemistry9e> for information about student and instructor resources for this text.

A Final Note from Shawn Farrell

I cannot adequately convey how impossible this project would have been without my wonderful family, who put up with a husband and father who became a hermit in the back office. I would also like to thank David Hall, book representative, for starting me down this path, and the late John Vondeling for giving me an opportunity to expand into other types of books and projects.

I met Mary Campbell in the mid-1990s when I was asked to collaborate on the fourth edition of this textbook with her. She was a fascinating individual and a visionary in this field. She believed that biochemistry should be accessible not only to the hard-core chemistry and biochemistry majors, but also to the wide range of majors that embrace biochemistry. Such was her inspiration for this one-semester text. She was very generous with her time and helped me immensely during the process of writing our first edition together. She also had a rapier wit and was a hoot to hang out with at science conventions. Her sudden passing in May 2014 was a shock to us all, and she will be sorely missed.

A Final Note from Owen McDougal

I wish to thank my wife Lynette for her patience and support, may the road rise to meet you..., my children McKenzie and Riley for reminding me where my priorities belong, and my parents Bob and Bobbie for unconditional support and inspiration to be all I can be.