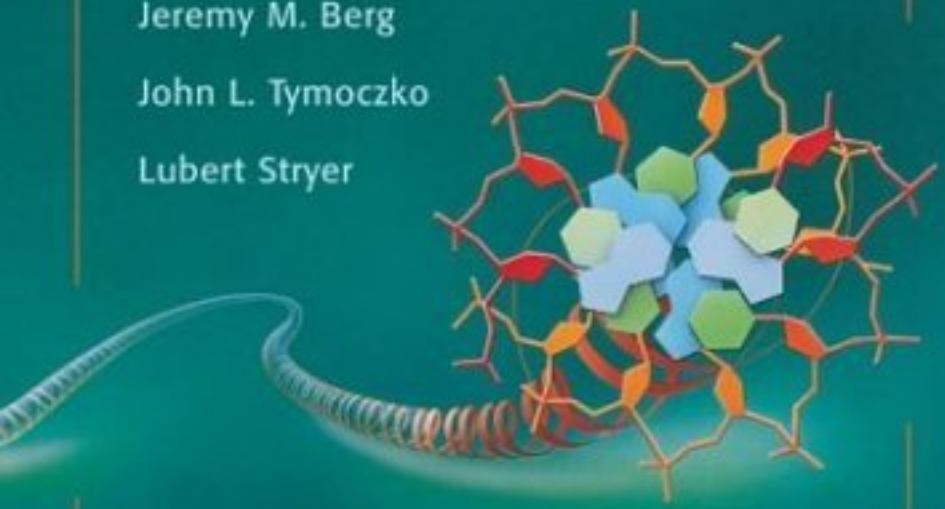
BIOCHEMISTRY

FIFTH EDITION

Jeremy M. Berg

John L. Tymoczko

Lubert Stryer



Dedication

TO OUR TEACHERS AND OUR STUDENTS

About the authors

JEREMY M. BERG has been Professor and Director (Department Chairperson) of Biophysics and Biophysical Chemistry at Johns Hopkins University School of Medicine since 1990. He received his B.S. and M.S. degrees in Chemistry from Stanford (where he learned X-ray crystallography with Keith Hodgson and Lubert Stryer) and his Ph.D. in Chemistry from Harvard with Richard Holm. He then completed a postdoctoral fellowship with Carl Pabo. Professor Berg is recipient of the American Chemical Society Award in Pure Chemistry (1994), the Eli Lilly Award for Fundamental Research in Biological Chemistry (1995), the Maryland Outstanding Young Scientist of the Year (1995), and the Harrison Howe Award (1997). While at Johns Hopkins, he has received the W. Barry Wood Teaching Award (selected by medical students), the Graduate Student Teaching Award, and the Professor's Teaching Award for the Preclinical Sciences. He is co-author, with Stephen Lippard, of the text *Principles of Bioinorganic Chemistry*.

JOHN L. TYMOCZKO is the Towsley Professor of Biology at Carleton College, where he has taught since 1976. He currently teaches Biochemistry, Biochemistry Laboratory, Oncogenes and the Molecular Biology of Cancer, and Exercise Biochemistry and co-teaches an introductory course, Bioenergetics and Genetics. Professor Tymoczko received his B.A. from the University of Chicago in 1970 and his Ph.D. in Biochemistry from the University of Chicago with Shutsung Liao at the Ben May Institute for Cancer Research. He followed that with a post-doctoral position with Hewson Swift of the Department of Biology at the University of Chicago. Professor Tymoczko's research has focused on steroid receptors, ribonucleoprotein particles, and proteolytic processing enzymes.

LUBERT STRYER is currently Winzer Professor in the School of Medicine and Professor of Neurobiology at Stanford University, where he has been on the faculty since 1976. He received his M.D. from Harvard Medical School. Professor Stryer has received many awards for his research, including the Eli Lilly Award for Fundamental Research in Biological Chemistry (1970) and the Distinguished Inventors Award of the Intellectual Property Owners' Association. He was elected to the National Academy of Sciences in 1984. Professor Stryer was formerly the President and Scientific Director of the Affymax Research Institute. He is a founder and a member of the Scientific Advisory Board of Senomyx, a company that is using biochemical knowledge to develop new and improved flavor and fragrance molecules for use in consumer products. The publication of the first edition of his text *Biochemistry* in 1975 transformed the teaching of biochemistry.

Preface

For more than 25 years, and through four editions, Stryer's *Biochemistry* has laid out this beautiful subject in an exceptionally appealing and lucid manner. The engaging writing style and attractive design have made the text a pleasure for our students to read and study throughout our years of teaching. Thus, we were delighted to be given the opportunity to participate in the revision of this book. The task has been exciting and somewhat daunting, doubly so because of the dramatic changes that are transforming the field of biochemistry as we move into the twenty-first century. Biochemistry is rapidly progressing from a science performed almost entirely at the laboratory bench to one that may be explored through computers. The recently developed ability to determine entire genomic sequences has provided the data needed to accomplish massive comparisons of derived protein sequences, the results of which may be used to formulate and test hypotheses about biochemical function. The power of these new methods is explained by the impact of evolution: many molecules and biochemical pathways have been generated by duplicating and modifying existing ones. Our challenge in writing the fifth edition of *Biochemistry* has been to introduce this philosophical shift in biochemistry while maintaining the clear and inviting style that has distinguished the preceding four editions.Figure 9.44

A New Molecular Evolutionary Perspective

How should these evolution-based insights affect the teaching of biochemistry? Often macromolecules with a common evolutionary origin play diverse biological roles yet have many structural and mechanistic features in common. An example is a protein family containing macromolecules that are crucial to moving muscle, to transmitting the information that adrenaline is present in the bloodstream, and to driving the formation of chains of amino acids. The key features of such a protein family, presented to the student once in detail, become a model that the student can apply each time that a new member of the family is encountered. The student is then able to focus on how these features, observed in a new context, have been adapted to support other biochemical processes. Throughout the text, a stylized tree icon is  positioned at the start of discussions focused primarily on protein homologies and evolutionary origins.

Two New Chapters.

To enable students to grasp the power of these insights, two completely new chapters have been added. The first, "Biochemical Evolution" (Chapter 2), is a brief tour from the origin of life to the development of multicellular organisms. On one level, this chapter provides an introduction to biochemical molecules and pathways and their cellular context. On another level, it attempts to deepen student understanding by examining how these molecules and pathways arose in response to key biological challenges. In addition, the evolutionary perspective of Chapter 2 makes some apparently peculiar aspects of biochemistry more reasonable to students. For example, the presence of ribonucleotide fragments in biochemical cofactors can be accounted for by the likely occurrence of an early world based largely on RNA. The second new chapter, "Exploring Evolution" (Chapter 7), develops the conceptual basis for the comparison of protein and nucleic acid sequences. This chapter parallels "Exploring Proteins" (Chapter 4) and "Exploring Genes" (Chapter 6), which have thoughtfully examined experimental techniques in earlier editions. Its goal is to enable students to use the vast information available in sequence and structural databases in a critical and effective manner.

Organization of the Text.

The evolutionary approach influences the organization of the text, which is divided into four major parts. As it did in the preceding edition, Part I introduces the language of biochemistry and the structures of the most important classes of biological molecules. The remaining three parts correspond to three major evolutionary challenges—namely, the interconversion of different forms of energy, molecular reproduction, and the adaptation of cells and organisms to changing environments. This arrangement parallels the evolutionary path outlined in Chapter 2 and naturally flows from the simple to the more complex.

PART I, the molecular design of life, introduces the most important classes of biological macromolecules, including proteins, nucleic acids, carbohydrates, and lipids, and presents the basic concepts of catalysis and enzyme action. Here are two examples of how an evolutionary perspective has shaped the material in these chapters:

- **Chapter 9 ,** on catalytic strategies, examines four classes of enzymes that have evolved to meet specific challenges: promoting a fundamentally slow chemical reaction, maximizing the absolute rate of a reaction, catalyzing a reaction at one site but not at many alternative sites, and preventing a deleterious side reaction. In each case, the text considers the role of evolution in fine-tuning the key property.
- **Chapter 13 ,** on membrane channels and pumps, includes the first detailed three-dimensional structures of an ion channel and an ion pump. Because most other important channels and pumps are evolutionarily related to these proteins, these two structures provide powerful frameworks for examining the molecular basis of the action of these classes of molecules, so important for the functioning of the nervous and other systems.

PART II, transducing and storing energy, examines pathways for the interconversion of different forms of energy. Chapter 15, on signal transduction, looks at how DNA fragments encoding relatively simple protein modules, rather than entire proteins, have been mixed and matched in the course of evolution to generate the wiring that defines signal-transduction pathways. The bulk of Part II discusses pathways for the generation of

ATP and other energy-storing molecules. These pathways have been organized into groups that share common enzymes. The component reactions can be examined once and their use in different biological contexts illustrated while these reactions are fresh in the students' minds.

- Chapter 16 covers both glycolysis and gluconeogenesis. These pathways are, in some ways, the reverse of each other, and a core of enzymes common to both pathways catalyze many of the steps in the center of the pathways. Covering the pathways together makes it easy to illustrate how free energy enters to drive the overall process either in the direction of glucose degradation or in the direction of glucose synthesis.
- Chapter 17, on the citric acid cycle, ties together through evolutionary insights the pyruvate dehydrogenase complex, which feeds molecules into the citric acid cycle, and the α-ketoglutarate dehydrogenase complex, which catalyzes one of the key steps in the cycle itself.Figure 15.34
- Oxidative phosphorylation, in **Chapter 18** , is immediately followed in **Chapter 19** by the light reactions of photosynthesis to emphasize the many common chemical features of these pathways.
- The discussion of the light reactions of photosynthesis in **Chapter 19** leads naturally into a discussion of the dark reactions—that is, the components of the Calvin cycle—in **Chapter 20** . This pathway is naturally linked to the pentose phosphate pathway, also covered in **Chapter 20** , because in both pathways common enzymes interconvert three-, four-, five-, six-, and seven-carbon sugars.

PART III, synthesizing the molecules of life, focuses on the synthesis of biological macromolecules and their components.

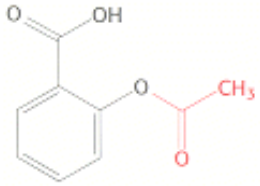
- Chapter 24, on the biosynthesis of amino acids, is linked to the preceding chapter on amino acid degradation by a family of enzymes that transfer amino groups to and from the carbon frameworks of amino acids.
- Chapter 25 covers the biosynthesis of nucleotides, including the role of amino acids as biosynthetic precursors. A key evolutionary insight emphasized here is that many of the enzymes in these pathways are members of the same family and catalyze analogous chemical reactions. The focus on enzymes and reactions common to these biosynthetic pathways allows students to understand the logic of the pathways, rather than having to memorize a set of seemingly unrelated reactions.
- Chapters 27, 28, and 29 cover DNA replication, recombination, and repair; RNA synthesis and splicing; and protein synthesis. Evolutionary connections between prokaryotic systems and eukaryotic systems reveal how the basic biochemical processes have been adapted to function in more-complex biological systems. The recently elucidated structure of the ribosome gives students a glimpse into a possible early RNA world, in which nucleic acids, rather than proteins, played almost all the major roles in catalyzing important pathways.

PART IV, responding to environmental changes, looks at how cells sense and adapt to changes in their environments. Part IV examines, in turn, sensory systems, the immune system, and molecular motors and the cytoskeleton. These chapters illustrate how signaling and response processes, introduced earlier in the text, are integrated in multicellular organisms to generate powerful biochemical systems for detecting and responding to environmental changes. Again, the adaptation of proteins to new roles is key to these discussions.

Integrated Chemical Concepts

We have attempted to integrate chemical concepts throughout the text. They include the mechanistic basis for the action of selected enzymes, the thermodynamic basis for the folding and assembly of proteins and other macromolecules, and the structures and chemical reactivity of the common cofactors. These fundamental topics underlie our understanding of all biological processes. Our goal is not to provide an encyclopedic examination of enzyme reaction mechanisms. Instead, we have selected for examination at a more detailed chemical level specific topics that will enable students to understand how the chemical features help meet the biological needs.

Chemical insight often depends on a clear understanding of the structures of biochemical molecules. We have taken considerable care in preparing stereochemically accurate depictions of these molecules where appropriate. These structures should make it easier for the student to develop an intuitive feel for the shapes of molecules and comprehension of how these shapes affect reactivity.



Aspirin (acetylsalicyclic acid)

Newly Updated to Include Recent Discoveries

Given the breathtaking pace of modern biochemistry, it is not surprising that there have been major developments since the publication of the fourth edition. Foremost among them is the sequencing of the human genome and the genomes of many simpler organisms. The text's evolutionary framework allows us to naturally incorporate information from these historic efforts. The determination of the three-dimensional structures of proteins and macromolecular assemblies also has been occurring at an astounding pace.

- As noted earlier, the discussion of excitable membranes in **Chapter 13** incorporates the detailed structures of an ion channel (the prokaryotic potassium channel) and an ion pump (the sacroplasmic reticulum calcium ATPase). Figure 9.21
- Great excitement has been generated in the signal transduction field by the first determination of the structure of a seven-transmembrane-helix receptor—the visual system protein rhodopsin—discussed in **Chapters 15** and **32**
- The ability to describe the processes of oxidative phosphorylation in **Chapter 18** has been greatly aided by the determination of the structures for two large membrane protein complexes: cytochrome *c* oxidase and cytochrome bc_1.
- Recent discoveries regarding the three-dimensional structure of ATP synthase are covered in **Chapter 18** , including the remarkable fact that parts of the enzyme rotate in the course of catalysis.
- The determination of the structure of the ribosome transforms the discussion of protein synthesis in **Chapter 29** .
- The elucidation of the structure of the nucleosome core particle—a large protein–DNA complex— facilitates the description in **Chapter 31** of key processes in eukaryotic gene regulation.

Finally, each of the three chapters in Part IV is based on recent structural conquests.

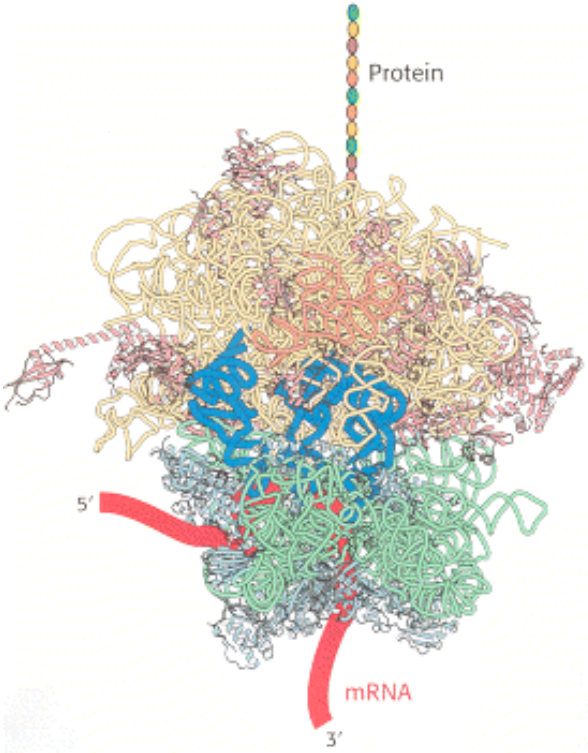
- The ability to grasp key concepts in sensory systems (**Chapter 32**) is aided by the structures of rhodopsin and the aforementioned ion channel.
- **Chapter 33** , on the immune system, now includes the more recently determined structure of the T-cell receptor and its complexes.
- The determination of the structures of the molecular motor proteins myosin and kinesin first revealed the evolutionary connections on which **Chapter 34** , on molecular motors, is based.

New and Improved Illustrations

The relation of structure and function has always been a dominant theme of *Biochemistry*. This relation becomes even clearer to students using the fifth edition through the extensive use of molecular models. These models are superior to those in the fourth edition in several ways.

- All have been designed and rendered by one of us (JMB), with the use of MOLSCRIPT, to emphasize the most important structural features. The philosophy of the authors is that the reader should be able to write the caption from looking at the picture.
- We have chosen ribbon diagrams as the most effective, clearest method of conveying molecular structure. All molecular diagrams are rendered in a consistent style. Thus students are able to compare structures easily and to develop familiarity and facility in interpreting the models. Labels highlight key features of the molecular models.
- Many new molecular models have been added, serving as sources of structural insight into additional molecules and in some cases affording multiple views of the same molecule.

In addition to the molecular models, the fifth edition includes more diagrams providing an overview of pathways and processes and setting processes in their biological context.



New Pedagogical Features

The fifth edition of *Biochemistry* supplies additional tools to assist students in learning the subject matter.

Icons.

Icons are used to highlight three categories of material, making these topics easier to locate for the interested student or teacher.

A *caduceus* signals the beginning of a clinical application.

A *stylized tree* marks sections or paragraphs that primarily or exclusively explore evolutionary aspects of biochemistry.

A *mouse and finger* point to references to animations on the text's Web site (www.whfreeman.com/biochem5) for those students who wish to reinforce their understanding of concepts by using the electronic media.

More Problems.

The number of problems has increased by 50%. Four new categories of problem have been created to develop specific skills.

Mechanism problems ask students to suggest or elaborate a chemical mechanism.
Data interpretation problems ask questions about a set of data provided in tabulated or graphic form. These exercises give students a sense of how scientific conclusions are reached.

Chapter integration problems require students to use information from multiple chapters to reach a solution. These problems reinforce awareness of the interconnectedness of the different aspects of biochemistry.
Media problems encourage and assist students in taking advantage of the animations and tutorials provided on our Web site. Media problems are found both in the book and on our Web site.Figure 15.23

New Chapter Outline and Key Terms.

An outline at the beginning of each chapter gives major headings and serves as a framework for students to use in organizing the information in the chapter. The major headings appear again in the chapter's summary, again helping to organize information for easier review. A set of key terms also helps students focus on and review the important concepts.Figure 17.4

Tools and Techniques

The fifth edition of *Biochemistry* offers three chapters that present the tools and techniques of biochemistry: "Exploring Proteins" (Chapter 4), "Exploring Genes" (Chapter 6), and "Exploring Evolution" (Chapter 7). Additional experimental techniques are presented elsewhere throughout the text, as appropriate.

Exploring Proteins (**Chapter 4**)

Protein purification Section 4.1

Differential centrifugation Section 4.1.2

Salting out Section 4.1.3

Dialysis Section 4.1.3

Gel-filtration chromatography Section 4.1.3

Ion-exchange chromatography Section 4.1.3

Affinity chromatography Section 4.1.3

High-pressure liquid chromatography Section 4.1.3

Gel electrophoresis Section 4.1.4

Isoelectric focusing Section 4.1.4

Two-dimensional electrophoresis Section 4.1.4

Qualitative and quantitative evaluation of protein purification Section 4.1.5

Ultracentrifugation Section 4.1.6

Mass spectrometry (MALDI-TOF) Section 4.1.7

Peptide mass fingerprinting Section 4.1.7

Edman degradation Section 4.2

Protein sequencing Section 4.2

Production of polyclonal antibodies Section 4.3.1

Production of monoclonal antibodies Section 4.3.2

Enzyme-linked immunosorbent assay (ELISA) Section 4.3.3

Western blotting Section 4.3.4

Fluorescence microscopy Section 4.3.5

Green fluorescent protein as a marker Section 4.3.5

Immunoelectron microscopy Section 4.3.5

Automated solid-phase peptide synthesis Section 4.4

Nuclear magnetic resonance spectroscopy Section 4.5.1

NOESY spectroscopy Section 4.5.1

X-ray crystallography Section 4.5.2

Exploring Proteins (other chapters)

Basis of fluorescence in green fluorescent protein Section 3.6.5

Time-resolved crystallography Section 8.3.2

Using fluorescence spectroscopy to analyze enzyme– substrate interactions Section 8.3.2

Using irreversible inhibitors to map the active site Section 8.5.2

Using transition state analogs to study enzyme active sites Section 8.5.3

Catalytic antibodies as enzymes Section 8.5.4

Exploring Genes (**Chapter 6**)

Restriction-enzyme analysis Sections 6.1.1 and 6.1.2

Southern and Northern blotting techniques Section 6.1.2

Sanger dideoxy method of DNA sequencing Section 6.1.3

Solid-phase analysis of nucleic acids Section 6.1.4

Polymerase chain reaction (PCR) Section 6.1.5

Recombinant DNA technology Sections 6.2-6.4

DNA cloning in bacteria Sections 6.2.2 and 6.2.3

Chromosome walking Section 6.2.4

Cloning of eukaryotic genes in bacteria Section 6.3.1

Examining expression levels (gene chips) Section 6.3.2

Introducing genes into eukaryotes Section 6.3.3

Transgenic animals Section 6.3.4

Gene disruption Section 6.3.5

Tumor-inducing plasmids Section 6.3.6

Site-specific mutagenesis Section 6.4

Exploring Genes (other chapters)

Density-gradient equilibrium sedimentation Section 5.2.2

Footprinting technique for isolating and characterizing promoter sites Section 28.1.1

Chromatin immunoprecipitation (ChIP) Section 31.2.3

Exploring Evolution (**Chapter 7**)

Sequence-comparison methods Section 7.2

Sequence-alignment methods Section 7.2

Estimating the statistical significance of alignments (by shuffling) Section 7.2.1

Substitution matrices Section 7.2.2

Sequence templates Section 7.3.2

Self-diagonal plots for finding repeated motifs Section 7.3.3

Mapping secondary structures through RNA sequence comparisons Section 7.3.5

Construction of evolutionary trees Section 7.4

Combinatorial chemistry Section 7.5.2

Other Techniques

Sequencing of carbohydrates by using MALDI-TOF mass spectrometry Section 11.3.7

Use of liposomes to investigate membrane permeability Section 12.4.1

Use of hydropathy plots to locate transmembrane helices Section 12.5.4

Fluorescence recovery after photobleaching (FRAP) for measuring lateral diffusion in membranes Section 12.6

Patch-clamp technique for measuring channel activity Section 13.5.1

Measurement of redox potential Section 18.2.1

Functional magnetic resonance imaging (fMRI) Section 32.1.3

Animated Techniques: Animated explanations of experimental techniques used for exploring genes and proteins are available at **www.whfreeman.com/biochem5**

Clinical Applications

This icon signals the start of a clinical application in the text. Additional, briefer clinical correlations appear without the icon in the text as appropriate.

Prion diseases Section 3.6.1

Scurvy and collagen stabilization Section 3.6.5

Antigen detection with ELISA Section 4.3.3

Vasopressin deficiency Section 4.4

Action of penicillin Section 8.5.5

Water-soluble vitamins Section 8.6.1

Fat-soluble vitamins in blood clotting and vision Section 8.6.2

Protease inhibitors Section 9.1.7

Carbonic anhydrase and osteopetrosis Section 9.2

Use of isozymes to diagnose tissue damage Section 10.3

Steatorrhea in liver disease Section 22.1.1

Carnitine deficiency Section 22.2.3

Zellweger syndrome Section 22.3.4

Diabetic ketosis Section 22.3.6

Use of fatty acid synthase inhibitors as drugs Section 22.4.9

Effects of aspirin on signaling pathways Section 22.6.2

Cervical cancer and ubiquitin Section 23.2.1

Protein degradation and the immune response Section 23.2.3

Inherited defects of the urea cycle (hyperammonemia) Section 23.4.4

Inborn errors of amino acid degradation Section 23.6

High homocysteine levels and vascular disease Section 24.2.9

Inherited disorders of porphyrin metabolism Section 24.4.4

Anticancer drugs that block the synthesis of thymidylate Section 25.3.3

Pellagra Section 25.5

Gout Section 25.6.1

Lesch-Nyhan syndrome Section 25.6.2

Disruption of lipid metabolism as the cause of respiratory distress syndrome and Tay-Sachs disease Section 26.1.6

Diagnostic use of blood cholesterol levels Section 26.3.2

Hypercholesteremia and atherosclerosis Section 26.3.5

Clinical management of cholesterol levels Section 26.3.6

Rickets and vitamin D Section 26.4.7

Antibiotics that target DNA gyrase Section 27.3.4

Defective repair of DNA and cancer Section 27.6.5

Huntington chorea Section 27.6.6

Detection of carcinogens (Ames test) Section 27.6.7

Molecular Evolution

This icon signals the start of many discussions that highlight protein commonalities or other molecular evolutionary insights that provide a framework to help students organize information.

Why is glucose a prominent fuel? Section 16.0.1

A common binding site in dehydrogenases Section 16.1.10

The major facilitator (MF) superfamily of transporters Section 16.2.4

Isozymic forms of lactate dehydrogenase Section 16.4.2

Evolutionary relationship of glycolysis and gluconeogenesis Section 16.4.3

Decarboxylation of α-ketoglutarate and pyruvate Section 17.1.6

Evolution of succinyl CoA synthetase Section 17.1.7

Evolutionary history of the citric acid cycle Section 17.3.3

Endosymbiotic origins of mitochondria Section 18.1.2

Conservation of cytochrome c structure Section 18.3.7

Common features of ATP synthase and G proteins Section 18.4.5

Related uncoupling proteins Section 18.6.4

Evolution of chloroplasts Section 19.1.2

Evolutionary origins of photosynthesis Section 19.6

Evolution of the C_4 pathway Section 20.2.3

Increasing sophistication of glycogen phosphorylase regulation Section 21.3.3

The α-amylase family Section 21.4.3

A recurring motif in the activation of carboxyl groups Section 22.2.2

Polyketide and nonribosomal peptide synthetases resemble fatty acid synthase Section 22.4.10

Prokaryotic counterparts of the ubiquitin pathway and the proteasome Section 23.2.4

A family of pyridoxal-dependent enzymes Section 23.3.3

Evolution of the urea cycle Section 23.4.3

The P-loop NTPase domain in nitrogenase Section 24.1.1

Recurring steps in purine ring synthesis Section 25.2.3

Ribonucleotide reductases Section 25.3

Increase in urate levels during primate evolution Section 25.6.1

The cytochrome P450 superfamily Section 26.4.3

DNA polymerases Section 27.2.1

Helicases Section 27.2.5

Evolutionary relationship of recombinases and topoisomerases Section 27.5.2

Similarities in transcriptional machinery between archaea and eukaryotes Section 28.2.4

Evolution of spliceosome-catalyzed splicing Section 28.2.4

Classes of aminoacyl-tRNA synthetases Section 29.2.5

Composition of the primordal ribosome Section 29.3.1

Evolution of molecular mimics Section 29.4.4

A family of proteins with common ligand-binding domains Section 31.1.4

Independent evolution of DNA-binding sites of regulatory proteins Section 31.1.5

CpG islands Section 31.2.5

Iron response elements Section 31.4.2

The odorant receptor family Section 32.1.1

Evolution of taste receptor mRNA Section 32.2.5

Photoreceptor evolution Section 32.3.4

The immunoglobulin fold Section 33.2

Relationship of actin to hexokinase and other prokaryotic proteins Section 34.2.2

Tubulins in the P-loop NTPase family Section 34.3.1

Supplements Supporting *Biochemistry*, Fifth Edition

The fifth edition of *Biochemistry* offers a wide selection of high-quality supplements to assist students and instructors.

For the Instructor

Print and Computerized Test Banks NEW

Marilee Benore Parsons, University of Michigan-Dearborn Print Test Bank 0-7167-4384-1; Computerized Test Bank CD-ROM (Windows/Macintosh hybrid) 0-7167-4386-8

The test bank offers more than 1700 questions posed in multiple choice, matching, and short-answer formats. The electronic version of the test bank allows instructors to easily edit and rearrange the questions or add their own material.

Instructor's Resource CD-ROM NEW

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The Instructor's Resource CD-ROM contains all the illustrations from the text. An easy-to-use presentation manager application, Presentation Manager Pro, is provided. Each image is stored in a variety of formats and resolutions, from simple jpg and gif files to preformatted PowerPoint® slides, for instructors using other presentation programs.

Overhead Transparencies

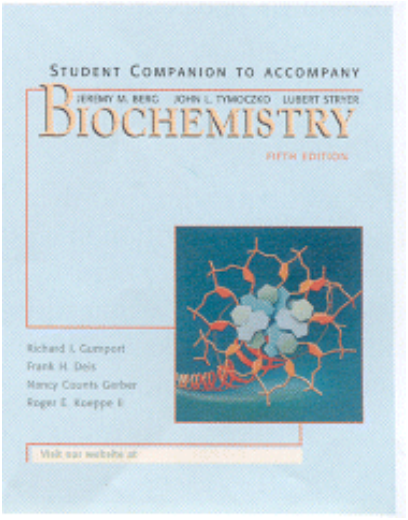
0-7167-4422-8

Full-color illustrations from the text, optimized for classroom projection, in one volume.

For the Student

Student Companion

Richard I. Gumport, College of Medicine at Urbana-Champaign, University of Illinois; Frank H. Deis, Rutgers University; and Nancy Counts Gerber, San Fransisco State University. Expanded solutions to text problems provided by Roger E. Koeppe II, University of Arkansas 0-7167-4383-3

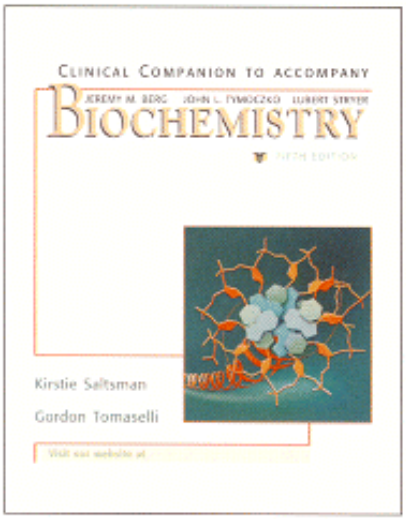


More than just a study guide, the *Student Companion* is an essential learning resource designed to meet the needs of students at all levels. Each chapter starts with a summarized abstract of the related textbook chapter. A comprehensive list of learning objectives allows students to quickly review the key concepts. A self-test feature allows students to quickly refresh their understanding, and a set of additional problems requires students to apply their knowledge of biochemistry. The complete solution to every problem in the text is provided to help students better comprehend the core ideas. Individual chapters of the *Student Companion* can be purchased and downloaded from

www.whfreeman.com/biochem5

Clinical Companion NEW

Kirstie Saltsman, Ph.D., Jeremy M. Berg, M.D., and Gordon Tomaselli, M.D., Johns Hopkins University School of Medicine 0-7167-4738-3



Designed for students and instructors interested in clinical applications, the *Clinical Companion* is a rich compendium of medical case studies and clinical discussions. It contains numerous problems and references to the textbook. Such topics as glaucoma, cystic fibrosis, Tay-Sachs disease, and autoimmune diseases are covered from a biochemical perspective.

Lecture Notebook NEW

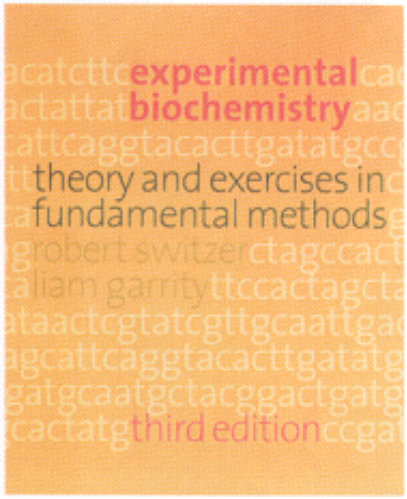
0-7167-4682-4

For students who find that they are too busy writing notes to pay attention in class, the *Lecture Notebook* brings together a black-and-white collection of illustrations from the text, arranged in the order of their appearance in the textbook, with plenty of room alongside for students to take notes.

Experimental Biochemistry, Third Edition

Robert L. Switzer, University of Illinois, and Liam F. Garrity, Pierce Chemical Corporation 0-7167-3300-5

The new edition of *Experimental Biochemistry* has been completely revised and updated to make it a perfect fit for today's laboratory course in biochemistry. It provides comprehensive coverage of important techniques used in contemporary biochemical research and gives students the background theory that they need to understand the experiments. Thoroughly classroom tested, the experiments incorporate the full range of biochemical materials in an attempt to simulate work in a research laboratory. In addition, a comprehensive appendix provides detailed procedures for preparation of reagents and materials, as well as helpful suggestions for the instructor.



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Acknowledgments

There is an old adage that says that you never really learn a subject until you teach it. We now know that you learn a subject even better when you write about it. Preparing the fifth edition of *Biochemistry* has provided us with a wonderful opportunity to unite our love of biochemistry and teaching and to share our enthusiasm with students throughout the world. Nonetheless, the project has also been a daunting one because so many interesting discoveries have been made since the publication of the fourth edition. The question constantly confronted us: What biochemical knowledge is most worth having? Answering this question required attempting to master as much of the new material as possible and then deciding what to include and, even harder, what to exclude.

However, we did not start from scratch. We feel both fortunate and intimidated to be writing the fifth edition of Stryer's *Biochemistry*. Fortunate, because we had as our starting point the best biochemistry book ever produced. Intimidated, because we had as our starting point the best biochemistry book ever produced, with the challenge of improving it. To the extent that we have succeeded, we have done so because of the help of many people.

Thanks go first and foremost to our students at Johns Hopkins University and Carleton College. Not a word was written or an illustration constructed without the knowledge that bright, engaged students would immediately detect vagueness or ambiguity. One of us (JMB) especially thanks the members of the Berg lab who have cheerfully tolerated years of neglect and requests to review drafts of illustrations when they would rather have been discussing their research. Particular thanks go to Dr. Barbara Amann and Kathleen

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Mark Alper

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I. The Molecular Design of Life