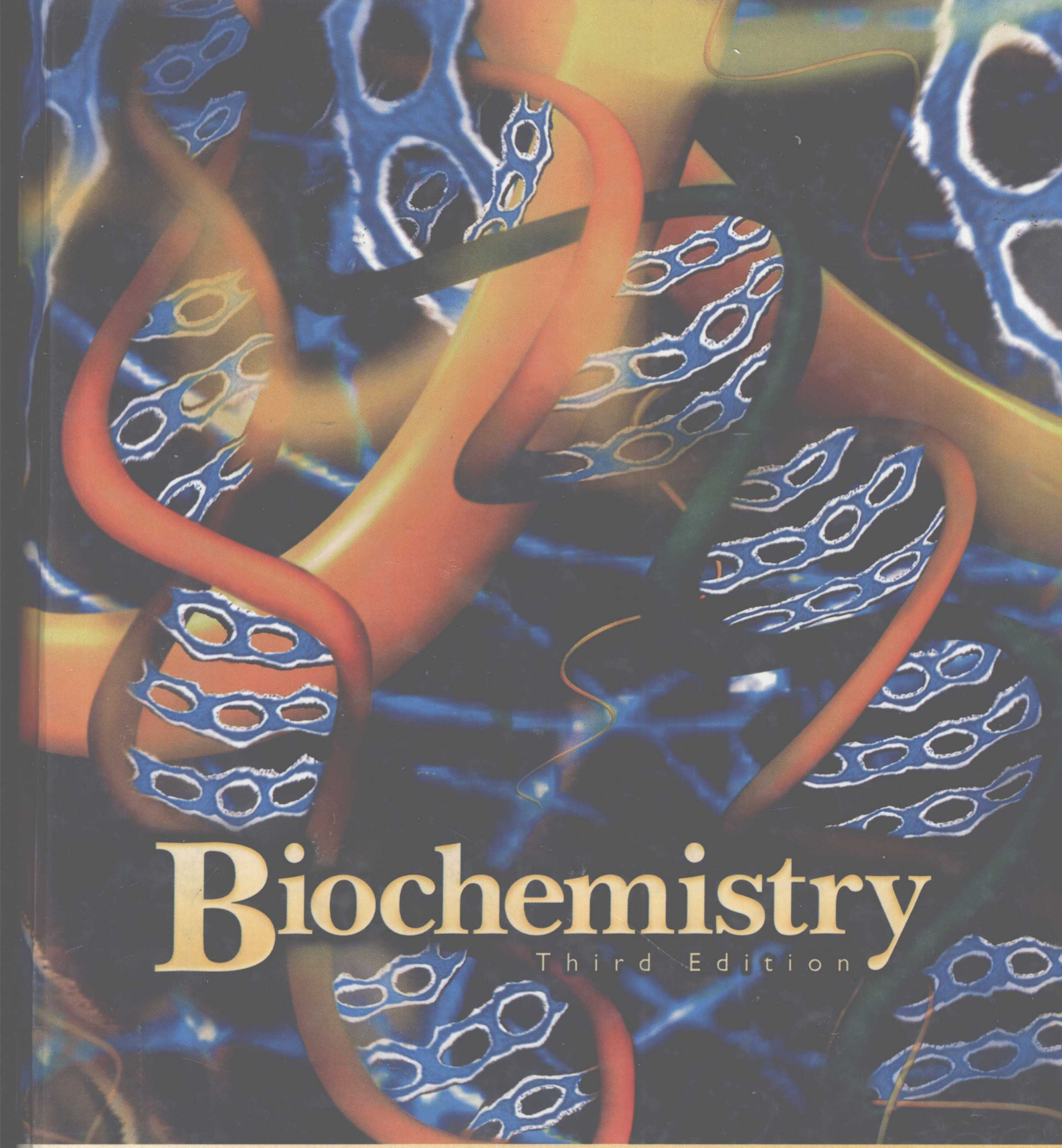

Biochemistry

Third Edition

Campbell

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Third Edition

Mary K. Campbell

Mount Holyoke College

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LIST OF ABBREVIATIONS

A	Adenine
ACAT	Acyl-CoA cholesterol acyl transferase
ACP	Acyl carrier protein
ADP	Adenosine diphosphate
AIDS	Acquired immunodeficiency syndrome
AMP	Adenosine monophosphate
ATCase	Aspartate transcarbamoylase
ATP	Adenosine triphosphate
bp	Base pairs
C	Cytosine
cAMP	Cyclic adenosine monophosphate
CAP	Catabolite activator protein
CDP	Cytidine diphosphate
Chl	Chlorophyll
CMP	Cytidine monophosphate
CoA (CoA-SH)	Coenzyme A
CoQ	Coenzyme Q
CTP	Cytidine triphosphate
d	Deoxy
DNA	Deoxyribonucleic acid
DNase	Deoxyribonuclease
DV	Daily value
EF	Elongation factor
ER	Endoplasmic reticulum
FAD	Flavin adenine dinucleotide (oxidized form)
$FADH_2$	Flavin adenine dinucleotide (reduced form)
fMet	*N*-Formylmethionine
FMN	Flavin mononucleotide
G	Guanine
GDP	Guanosine diphosphate
GMP	Guanosine monophosphate
GSH	Glutathione (reduced form)
GSSG	Glutathione (oxidized form)
GTP	Guanosine triphosphate
Hb	Hemoglobin
HDL	High-density lipoprotein
HIV	Human immunodeficiency virus
HMG-CoA	β-Hydroxy-β-methylglutaryl-CoA
HPLC	High-performance liquid chromatography

IF	Initiation factor
K_M	Michaelis constant
LDL	Low-density lipoprotein
Mb	Myoglobin
NAD^+	Nicotinamide adenine dinucleotide (oxidized form)
NADH	Nicotinamide adenine dinucleotide (reduced form)
$NADP^+$	Nicotinamide adenine dinucleotide phosphate (oxidized form)
NADPH	Nicotinamide adenine dinucleotide phosphate (reduced form)
P_i	Phosphate ion
PAGE	Polyacrylamide gel electrophoresis
PCR	Polymerase chain reaction
PEP	Phosphoenolpyruvate
PIP_2	Phosphatidylinositol *bis*phosphate
PKU	Phenylketonuria
Pol	DNA polymerase
PP_i	Pyrophosphate ion
PRPP	Phosphoribosylpyrophosphate
PS	Photosystem
RF	Release factor
RFLPs	Restriction-fragment-length polymorphisms
RNA	Ribonucleic acid
RNase	Ribonuclease
mRNA	Messenger RNA
rRNA	Ribosomal RNA
tRNA	Transfer RNA
snRNP	Small nuclear ribounuclear protein
S	Svedberg unit
SCID	Severe combined immune deficiency
SSB	Single-strand binding protein
SV40	Simian virus 40
T	Thymine
TDP	Thymidine diphosphate
TMP	Thymidine monophosphate
TTP	Thymidine triphosphate
U	Uracil
UDP	Uridine diphosphate
UMP	Uridine monophosphate
UTP	Uridine triphosphate
V_{max}	Maximal velocity

This book is dedicated to the achievements of Mary Lyon, An Early Chemical Educator

Mary Lyon (1797–1849) was the founder of Mount Holyoke College in South Hadley, Massachusetts, and a pioneer in women's education. Lyon, whose specialty was chemistry, opened the school in 1837 and served as its principal until her death in 1849. Mount Holyoke flourished under her guidance, opening the doors to higher education — especially in the sciences — for women in the United States and around the world.

Although Lyon left school at age thirteen to work on her family's farm, she never stopped learning, gaining "knowledge by the handful" whenever and wherever she could. She became a gifted and respected educator and taught at a variety of schools around New England. In 1834 she stopped teaching to raise funds for the school that opened in 1837 as Mount Holyoke Female Seminary.

An image from Mt. Holyoke's website of Mary Lyon. (Jim Gipe and Mt. Holyoke College)

Lyon's lofty goals for her new school distinguished Mount Holyoke from other female seminaries, many of which taught such "ladylike" subjects as drawing and needlework to young women from wealthy families. Far ahead of her time, Lyon instead sought to give women the same curriculum that men's colleges offered. She stipulated a minimum entrance age of seventeen and set rigorous entrance examinations. To keep their tuition low, students lived frugally and performed their own domestic work.

Lyon also required seven courses in mathematics and science for graduation. Under her guidance, women learned science in a "new and unusual" way — performing their own laboratory experiments in chemistry, for example. She led students on field trips to collect rocks, plants, and other specimens for laboratory work and to inspect geological formations and newly discovered dinosaur tracks. She invited distinguished scientists to lecture at the college and encouraged women to pursue careers in the sciences as college teachers and researchers.

Lyon's emphasis on the sciences continues at Mount Holyoke to this day. The college's alumnae and faculty have distinguished track records in the sciences. In fact, Mount Holyoke has educated more women who went on to earn Ph.D.s in chemistry than has any other college or university in the United States! (Reprinted with permission from *Chemical Heritage,* Vol. 15, No. 1, Fall 1997)

About the Author

Mary K. Campbell

Mary K. Campbell is a professor of chemistry at Mount Holyoke College, where she frequently teaches the one-semester biochemistry course and advises undergraduates working on biochemical research projects. Her interests in writing led to the publication of the first two editions of this highly successful textbook for biochemistry. She received her Ph.D. from Indiana University and did postdoctoral work in biophysical chemistry at Johns Hopkins University. Professor Campbell's research interests are in the area of the physical chemistry of biomolecules, specifically, spectroscopic studies of protein–nucleic acid interactions.

Mary Campbell can be found frequently hiking the Appalachian trail with her Bernese mountain dogs, Lolly and Jake.

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. My main goal in writing this book is to make biochemistry as clear and as interesting as possible and to familiarize all science students with the major aspects of biochemistry. For students of biology, chemistry, physics, geology, nutrition, 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.

This text attempts to give an overview of important topics of interest to biochemists and to show how the remarkable recent progress of biochemistry impinges on other scientists. The length is intended to allow instructors a choice of favorite topics, but not to be so long as to be overwhelming for the limited amount of time available in one semester.

SPECIAL FEATURES

New to This Edition

Features

Several pedagogical features have been changed or are completely new. Each chapter now begins with a map of key concepts intended to pull together the key words and how they relate to one another. Because students are always keenly interested in the applications of biochemistry, the number of special interest boxes has been expanded. Professors are always looking for new problems and so the number of chapter-end exercises has increased; there are at least 25 problems in each chapter. A new feature is the essential information marginal notes. These are intended to be reminders to students of the very key information contained in the chapter. To reinforce the terms from the concepts map, each chapter now ends with a list of the key terms with references to the section in which they appear.

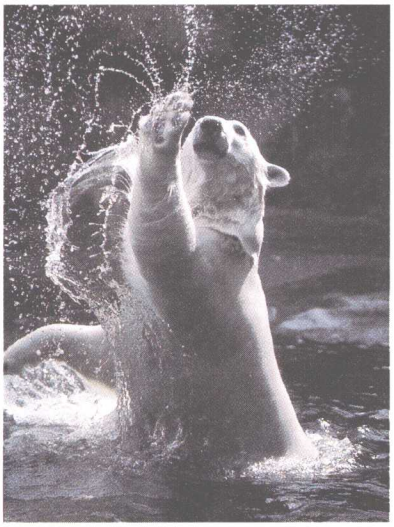
Content

There is a new ordering of some topics. A section on the fundamentals of thermodynamics has been added to the first chapter so that these ideas can be used in subsequent chapters. The material on molecular biology now constitutes a single section, directly following the material on protein structure and enzyme behavior. The chapter on nucleic acids and biotechnology has been updated and now concludes the molecular biology section. The chapter on photosynthesis has also been updated significantly. More material has been included on plant biochemistry, particularly where there are agricultural applications. Coverage of nutrition has been expanded and updated. Throughout, chemical equations and structures have received more visual emphasis, improving clarity and facilitating learning.

ORGANIZATION

Because biochemistry is a multidisciplinary science, the first task in presenting it to students of widely different backgrounds is to put it in context. Part I provides the necessary background and connects biochemistry to the other sciences. Part II focuses on the structure and dynamics of important cellular components. Molecular biology is covered in Part III. The final part of the book is devoted to intermediary metabolism. Some topics are discussed several times; an example is the control of carbohydrate metabolism. The second (or subsequent) discussion makes use of information that students have learned since the first discussion and builds upon it. It is particularly useful to return to a topic after students have had time to assimilate it and reflect upon it.

In Part 1, an introduction, two chapters relate biochemistry to other fields of science. Chapter 1 deals with some of the less obvious relationships, such as the connections of biochemistry with physics, astronomy, and geology, mostly in the context of the origins of life. Functional groups on organic molecules are discussed from the point of view of their role in biochemistry. This chapter goes on to the more readily apparent linkage of biochemistry with biology, especially with respect to the distinction between prokaryotes and eukaryotes, as well as the role of organelles in eukaryotic cells. Chapter 2 builds on material familiar from general chemistry, such as buffers and the solvent properties of water, but emphasizes the biochemical point of view toward such material.



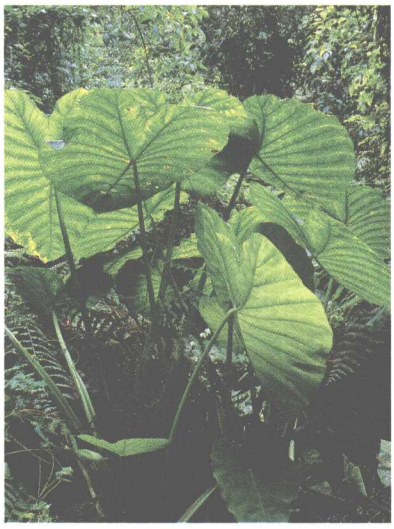
Gary Braasch/Tony Stone Images

Part 2, on the structure of cellular components, focuses on the structure and dynamics of proteins and membranes in addition to giving an introduction diction to some aspects of molecular biology. Chapters 3 through 5 deal with amino acids, peptides, and the structure and action of proteins. Chapter 6 treats the structure of membranes and their lipid components.

The third section, Chapters 7 through 10 (Part 3), deals with molecular biology. Chapter 7 treats the structure of nucleic acids. In Chapter 8, the replication of DNA and the translation of the genetic message in RNA provide the focus of discussion. The ultimate translation of the genetic message in the synthesis of proteins is the subject of Chapter 9. Chapter 10 deals with the methods that biotechnology uses to manipulate DNA.

Part 4, on metabolism, opens with a chapter (Chapter 11) on chemical principles that provide some unifying themes. Thermodynamic concepts

learned earlier in general chemistry are applied to specifically biochemical topics such as coupled reactions and hydrophobic interactions. In addition, this chapter explicitly makes the connection between metabolism and electron transfer (oxidation-reduction) reactions. Coenzymes are introduced in this chapter and are discussed in later chapters in the context of the reactions in which they play a role. A chapter on carbohydrates is followed by one on glycolysis. Glycogen metabolism, gluconeogenesis, and the pentose phosphate pathway provide bases for treating control mechanisms in carbohydrate metabolism. Discussion of the citric acid cycle is followed by the electron transport chain and oxidative phosphorylation. Photosynthesis rounds out the discussion of carbohydrate metabolism. The catabolic and anabolic aspects of lipid metabolism are dealt with in the same chapter, as is the case with the metabolism of nitrogen-containing compounds such as amino acids, porphyrins, and nucleobases. A summary chapter (Chapter 20) gives an integrated look at metabolism, including a treatment of hormones and second messengers. The overall look at metabolism includes a brief discussion of nutrition and a somewhat longer one of the immune system.



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ALTERNATIVE TEACHING OPTIONS

The order in which individual chapters are covered can be changed to suit the needs of specific groups of students. The portions of Chapter 11 that deal with thermodynamics can be covered before discussion of protein structure, an option preferred by many instructors. The whole molecular biology unit 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.

Features and Learning Aids

Visual Impact

One of the most distinctive features of this text is its visual impact. Its extensive four-color art program includes artwork by Irving Geis and by John and Bette Woolsey. The illustrations convey meaning so powerful that many have become, or are certain to become, standard presentations in the field. Also included are over 100 photographs chosen to complement the text.

Chapter Overviews

Originally written by Irving Geis for the first edition and revised by the author for this edition, the introductory paragraphs serve as overviews for each chapter. These chapter-opening paragraphs tie together the material from previous chapters with the topics to be discussed. They serve as building blocks for new ideas.

Interviews

Each of the four parts opens with an interview with a biochemist, whose experiences range from a newly granted Ph.D. to a scientist with over 1000 research publications. These outstanding scientists talk about a broad range of topics, including, but not limited to, their research. The interviews include a brief look at both their professional and personal lives and are included to encourage students to look closely at a career in science.

Biochemical Connections

Essays on special topics, frequently ones with clinical implications such as cancer and AIDS, highlight points of particular interest to students. Some of the essay titles include *Omega-3 Fatty Acids and Platelets in Heart Disease* and *The Human Genome Projects: Prospects and Possibilities.* The number of boxes has been significantly increased in this edition.

Practice Sessions

The practice sessions are designed to give students experience in problem solving. The topics chosen for this treatment are those with which students usually have the most difficulty. Solutions are now included, giving examples of the problem-solving approach needed for specific material.

Essential Information

In the margins of the book, there are boxes containing very important information. By flipping through a chapter and reading these boxes, a student can get a picture of the key ideas.

End-of-Chapter Problems and Summaries

Each chapter closes with a concise summary, a list of key terms, a broad selection of exercises, and an annotated bibliography. The number of exercises has been greatly expanded for this edition to include at least 25 per chapter. The problems are also now divided into two parts, one asking for recall of information from the chapter and the other asking students to use the information to solve problems or to contemplate consequences of biochemistry.

Interchapter

An interchapter goes into detail about the anabolism of nitrogen-containing compounds. This interchapter follows Chapter 19.

Glossary and Answers

The book ends with an answer section, a glossary of important terms and concepts, and a detailed index.

SUPPLEMENTS

This text is accompanied by the following supplements:

- CAMPBELL'S COMPANION AND PROBLEMS BOOK by William M. Scovell (Bowling Green State University) accompanies and complements the text, with the objective of helping students gain a more comprehensive understanding of biochemistry.
  1. Each chapter begins with an introductory paragraph outlining the major topics discussed in the text.
  2. Each chapter contains Learning Objectives to help focus attention on important concepts.
  3. The heart of the book is the additional problems with detailed explanations and answers. These are intended to develop a fuller understanding of general concepts and, in some cases, focus on important details of a structure, reaction, mechanism, metabolic

cycle, or pathway. In addition, some problems go beyond the text material to provide a glimpse of rapidly evolving areas.

4. A section is included that reviews many of the important organic reactions underlying the anabolic and catabolic reactions in biochemistry. This section provides a foundation for clearly realizing that biochemistry is simply "chemistry in living systems."
5. A number of important topics, which are currently experiencing rapid if not explosive development, are "SPOTLIGHTED" to point out their role and impact on today's burgeoning understanding of the molecular basis of biology.

- INSTRUCTOR'S MANUAL and TEST BANK by Mary Campbell. Includes chapter summaries, lecture outlines, answers to all exercises, and a bank of 25 multiple-choice test questions for each chapter.
- OVERHEAD TRANSPARENCIES. One hundred twenty-five full-color figures from the text.
- COMPUTERIZED TEST BANK. Available in IBM, Macintosh, and Windows versions, it contains 25 multiple-choice questions for each chapter.
- Saunders Media-Active CD-ROM contains all the images from the book as well as images from many of the other Saunders College Publishing chemistry texts, related to Biochemistry.
- Saunders Web site for Biochemistry, available for fall of '98, can be accessed through the following address, www.saunderscollege.com. It includes 700 Power Point Lecture images.
- Interactive Biochemistry CD-ROM includes three-dimensional protein graphics, virtual reality animations, and hundreds of interactive learning exercises. Available for a fee.

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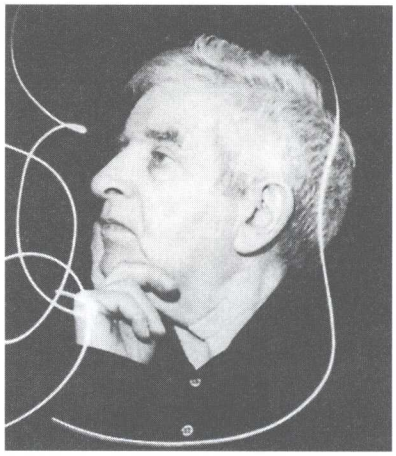
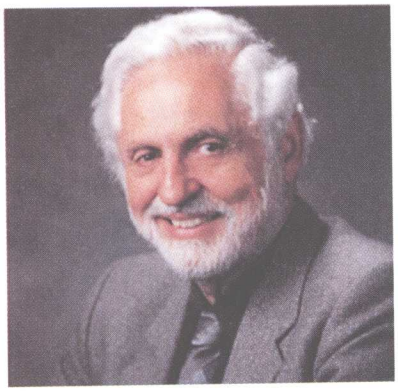


Irving Geis, illustrator

Mary K. Campbell
Mount Holyoke College
July 1998

Contents Overview

Manual A. Navia, p.4

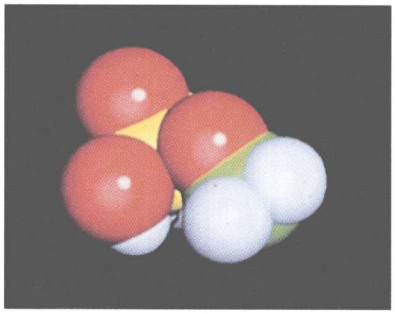


Carl Djerassi, p. 72

Alanna Schepartz, p. 238 (Ernest Carpenter, Chemical and Engineering News)

David Crane Bowen, p. 388

Table of Contents



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