教育部高等教育司推荐
国外优秀生命科学教学用书

Cell and Molecular Biology
Concepts and Experiments

分子细胞生物学 影印版

Third Edition

• Gerald Karp

高等教育出版社
Higher Education Press
John Wiley & Sons, Inc.

图字：01-2002-2930 号

Cell and Molecular Biology, 3rd ed.

By Gerald Karp

图书在版编目(CIP)数据

分子细胞生物学 = Cell and Molecular Biology/(美)卡普(Karp,G.)著. —3 版. —北京：高等教育出版社,2002.11
ISBN 7-04-011247-7

Ⅰ.细… Ⅱ.卡… Ⅲ.①细胞生物学-英文②分子生物学-英文 Ⅳ.Q

中国版本图书馆 CIP 数据核字(2002)第 046092 号

策　　划 吴雪梅　　**封面设计** 王凌波　　**责任印制** 陈伟光

Cell and Molecular Biology, Third Edition
Gerald Karp

出版发行	高等教育出版社	**购书热线**	010-64054588
社　　址	北京市东城区沙滩后街 55 号	**免费咨询**	800-810-0598
邮政编码	100009	**网　　址**	http://www.hep.edu.cn
传　　真	010-64014048		http://www.hep.com.cn
经　　销	新华书店北京发行所		
印　　刷	北京民族印刷厂		
开　　本	889×1240　1/16	**版　　次**	2002 年 11 月第 1 版
印　　张	53.75	**印　　次**	2002 年 11 月第 1 次印刷
字　　数	1500 000	**定　　价**	65.00 元

本书如有缺页、倒页、脱页等质量问题，请到所购图书销售部门联系调换。

出 版 前 言

随着克隆羊的问世和人类基因组计划的完成，生命科学成为21世纪名副其实的领头学科，生物高新技术产业逐步成为高科技产业的核心。生物科技和生物产业的发展对世界科技、经济、政治和社会发展等方面产生着深刻的影响，这也是我国赶超世界发达国家生产力水平最有前途和希望的领域。生命科学与技术全方位的发展呼唤高等教育培养更多高水平的复合型科技人才。

为此，教育部在《关于加强高等学校本科教学工作　提高教学质量的若干意见》[教高（2001）4号文件]中提出，高等学校要大力提倡编写、引进和使用先进教材，其中信息科学、生命科学等发展迅速、国际通用性强、可比性强的学科和专业可以直接引进先进的、能反映学科发展前沿的原版教材。教育部高等教育司还于2001年11月向全国主要大学和出版社下发了“关于开展‘国外生命科学类优秀教学用书’推荐工作的通知”，有力推动了生命科学类教材的引进工作。

高等教育出版社对国外生命科学教材进行了充分的调研，并委托教育部高等学校生物科学与工程教学指导委员会的专家教授开展了“引进国外优秀生命科学教材及其教学辅助材料专项研究”，并就国内外同类教材进行了比较，提出了具体的引进教材书目。经过版权谈判，目前我社已经购买了 Pearson Education, McGraw-Hill, John Wiley & Sons, Blackwell Science, Thomson Learning, Cambridge University Press, Lippincott Williams & Wilkins 等出版的13种教材的影印权，学科领域涉及生物化学、细胞生物学、遗传学、微生物学、生态学、免疫学、神经科学、发育生物学、解剖学与生理学、分子生物学、普通生物学等。这些教材具有以下特点：（1）所选教材基本是近2年出版的，及时反映了学科发展的最新进展，在国际上使用广泛，具有权威性和时代感；（2）内容简明，篇幅适中，结构合理，兼具一定的深度和广度，适用范围广；（3）插图精美、丰富，既有很强的艺术性，又不失严谨的科学性，图文并茂，与正文相辅相成；（4）语言简练、流畅，十分适合非英语国家的学生阅读。其中9种已入选教育部高等教育司推荐“国外优秀生命科学教学用书”。

考虑到中国国情，为了让学生买得起，同时又能让学生看到原版书彩色精美的插图，我们在引进学生用原版教材时，一方面采用黑白影印，最大限度地降低定价，另一方面随书附赠含有原书彩色插图的光盘，以充分体现原教材的风格、特色，为读者提供方便。

引进国外优秀生命科学教学用书是我社一项长期的重点工作，因此，我们衷心希望广大专家教授和同学提出宝贵的意见和建议，如有更好的教材值得引进，请与高等教育出版社生命科学分社联系，联系电话：010-68344002，E-mail 地址：lifesciences-hep@x263.net。

高等教育出版社

2002年11月

国外优秀生命科学教学用书

（影印教材）

Biochemistry (2nd ed.)	生物化学
Cell and Molecular Biology (3rd ed.)	分子细胞生物学
Essentials of Genetics (4th ed.)	遗传学基础
Microbiology (5th ed.)	微生物学
Ecology: concepts and applications (2nd ed.)	生态学
Roitt's Essential Immunology (10th ed.)	Roitt 免疫学基础
Neuroscience： Exploring the Brain (2nd ed.)	神经科学
Essential Developmental Biology	发育生物学基础
Understanding Human Anatomy and Physiology (4th ed.)	人体解剖生理学
Gene Cloning and DNA Analysis (4th ed.)	基因克隆和 DNA 分析
Principles of Gene Manipulation (6th ed.)	基因操作原理
An Introduction to Genetic Engineering (2nd ed.)	遗传工程导论
Essential Biology	生物学导论

To Patsy and Jenny

About the Author

Gerald C. Karp received a bachelor's degree from UCLA and a Ph.D. from the University of Washington. He conducted postdoctoral research at the University of Colorado Medical Center before joining the faculty at the University of Florida. Karp is the author of numerous research articles on the cell and molecular biology of early development. His interests have included the synthesis of RNA in early embryos, the movement of mesenchyme cells during gastrulation, and cell determination in slime molds. For 13 years, he taught courses in molecluar, cellular, and developmental biology at the University of Florida. During this period, Gerry coauthored a text in developmental biology with N. John Berrill and authored a text in cell and molecular biology. Finding it impossible to carry on life as both full-time professor and author, Gerry gave up his faculty position to concentrate on writing. He hopes to revise this text every three years.

About the Cover

The cover of this text displays a brightly stained endothelial cell—a type of cell that lines the inner surface of blood vessels. This cell is square because it has spread itself over a tiny square-shaped patch of an adhesive protein called fibronectin that was applied to a culture dish. The cell appears to be mounted in a green frame because it was treated with a green fluorescent antibody that binds to the cytoplasmic protein actin, which makes up part of the cell's "skeleton." Studies with these square-shaped cells have provided valuable information about an important subject in cell biology, namely cell death. Most cells are programmed to commit suicide under certain adverse conditions, as might occur, for example, if a cell were struck with a high dose of DNA-damaging radiation. Cells that adhere to a very small island of square-shaped fibronectin are unable to spread out, which triggers a program leading to the death of the cell. In contrast, cells that are able to spread over a larger fibronectin surface, as is the case depicted on the cover, do not commit suicide. Instead, such cells undergo chromosome duplication in preparation for cell division (see pages 249, 366, and 662 for discussion of these subjects). (*Reprinted from* Trends Cell Biol. *vol. 9, Christopher S. Chen, Clifford Brangwynne, and Donald E. Ingber, Squaring up to the cell-shape debate, p. 283, Copyright 1999, with permission from Elsevier Science.*)

Preface for the Third Edition

Before I began work on the *first* edition of this text, I drew up a number of basic guidelines regarding the type of book I planned to write.

- I wanted a text suited for a course that ran either a single semester or 1-2 quarters that would be taken in the sophomore or junior year. I set out to draft a text about 800 pages that would not overwhelm or discourage students at this level.
- I wanted a text that elaborated on fundamental concepts, such as the relationship between molecular structure and function, the dynamic character of cellular organelles, the use of chemical energy in running cellular activities and ensuring accurate macromolecular biosynthesis, unity and diversity at the macromolecular and cellular levels, and the mechanisms that regulate cellular activities.
- I wanted a text that was grounded in the experimental approach. Cell and molecular biology is an experimental science and, like most instructors, I believe students should gain some knowledge of how we know what we know. With this in mind, I decided to approach the experimental nature of the subject in two ways. As I wrote each chapter, I included enough experimental evidence to justify many of the conclusions that were being made. Along the way, I described the salient features of key experimental techniques and referred the reader to a more detailed discussion in the last chapter on methodologies. Chapters 8 and 9, for example, contain introductory sections on techniques that have proven most important in the analysis of cytomembranes and the cytoskeleton, respectively. I included brief discussions of selected experiments of major importance in the body of the chapters to reinforce the experimental basis of our knowledge.

  For students and instructors that wanted to explore the experimental approach in greater depth, I included the "Experimental Pathways," at the end of each chapter. Each of these narratives describes some of the key experimental findings that have led to our current understanding of a particular subject that is relevant to the chapter at hand. Because the scope of the narrative is limited, the design of the experiments can be considered in some detail. The figures and tables provided in these sections are often those that appeared in the original research article, which provides the reader an opportunity to examine original data and to realize that its analysis is not beyond their means. The Experimental Pathways also illustrate the stepwise nature of scientific discovery, showing how the result of one study raises questions that provide the basis for subsequent studies.
- I wanted a text that was interesting and readable. To make the text more relevant to undergraduate readers, particularly premedical students, I included The Human Perspective. These sections illustrate that virtually all human disorders can be traced to disruption of activities at the cellular and molecular level. Furthermore, they reveal the importance of basic research as the pathway to understanding and eventually treating most disorders. In Chapter 11, for example, The Human Perspective describes how ribozymes may prove to be an important new tool in the treatment of cancer and viral diseases, including AIDS. In this same chapter, the reader will learn how ribozymes were first discovered in studies on the processing of ribosomal RNA in a protozoan. It becomes evident that one can never predict the practical importance of basic research in cell and molecular biology. I have also tried to include relevant information about human biology and clinical applications throughout the body of the text.
- I wanted a high-quality illustration program that helped students visualize complex cellular and molecular processes. To meet this goal, many of the illustrations have been "stepped-out" so that information can be more easily broken down into manageable parts. Events occurring at each step are described in the figure legend and/or in the corresponding text. I also sought to include a large number of micrographs to enable students to see actual representations of most subjects being discussed. Included among the photographs are many fluorescence micrographs that illustrate either the dynamic properties of cells or provide a means

to localize a specific protein or nucleic acid sequence. Wherever possible, I have tried to pair line art drawings with micrographs to help students compare idealized and actual versions of a structure.

I have been gratified by the mail I have received from teachers and students containing both praise and criticism of the first two editions. These communications, together with the numerous fine reviews of the current manuscript, have guided the preparation of the third edition. The most important changes in the third edition can be delineated as follows.

- The body of information in cell and molecular biology is continually changing, which provides much of the excitement we all feel about our selected field. Even though only three years have passed since the publication of the second edition, nearly every discussion in the text has been modified to a greater or lesser degree. This has been done without allowing the chapters to increase significantly in length. In addition to revising and updating, new topics have been added throughout the text. These include: the use of molecular techniques to discover previously unsuspected prokaryote diversity (Chapter 1); energy landscape models of protein folding (Chapter 2); determining the three-dimensional organization of membrane proteins in the absence of data from X-ray crystallography (Chapter 4); the mechanism by which energy stored in the proton gradient across the inner mitochondrial membrane can be used to drive the rotary machinery of the ATP synthase (Chapter 5); photoinhibition of the photosynthetic machinery of chloroplasts by bright light (Chapter 6); the discovery of protocadherins and their apparent role in providing specificity during the formation of synaptic junctions (Chapter 7); the use of green fluorescent protein and cell-free systems in the study of membrane trafficking (Chapter 8); recent models of the mechanism of nonmuscle motility based on actin polymerization (Chapter 9); recent insights from the sequencing of the human genome (Chapter 10); our enhanced understanding of the mechanism of translation following publication of the X-ray crystallographic structure of the ribosome (Chapter 11); the use of DNA microarrays in monitoring changes in gene expression as cells undergo basic changes in metabolism (Chapter 12); the role of a recently discovered class of DNA polymerases that function in replication at sites of DNA lesions (Chapter 13); the role of condensin and cohesin complexes in chromosome compaction and sister-chromatid separation during mitosis (Chapter 14); the role of G protein-coupled receptors in vision, taste, and smell (Chapter 15); the results of successful clinical trials for cancer therapies utilizing dendritic cell vaccines, tyrosine kinase inhibitors, and genetically modified lytic viruses (Chapter 16); proposed mechanisms for positive and negative selection of T cells in the thymus (Chapter 17). The content of the text has been updated through February of 2001.
- Two discussions have been moved. The import of proteins into peroxisomes, mitochondria, and chloroplasts is now discussed in Chapter 8 and tied into the general subject of protein trafficking within the cell. The discussion of protein degradation by proteasomes has been moved to Chapter 12 and considered as a mechanism of posttranslational regulation.
- Several of the Experimental Pathways from the 2nd edition have been removed from the text and placed on the World Wide Web. Of the 17 Experimental Pathways from the 2nd edition, 10 have been retained in the text (Chapters 1, 2, 3, 4, 8, 10, 11, 14, 16, and 17), whereas the other 7 can be found on the web at www.wiley.com/college/karp. The latter Experimental Pathways are indicated by a "web icon" where they are referred to in the text. Experimental Pathways have been updated where appropriate.
- Instructors reported that their students responded very positively to the Human Perspectives. Additional Human Perspectives on stem cells and their potential use in cell transplantation and the role of protein misfolding in the development of Alzheimer's disease have been added.
- The illustration program received high marks and I have continued with the same approach in the third edition. Now that line art illustrations are drawn by computer and stored electronically, they are much easier to render and modify than in earlier days. Every illustration in the second edition has been scrutinized and many of those that were reutilized in the third edition have been modified to some extent. A number of illustrations in the first and second editions were hand painted and unavailable for the instructor's CD; all of these illustrations have been redrawn as electronic pieces and are now present on the CD. Many of the drawings from the second edition have been deleted to make room for approximately 90 new pieces, numerous of which follow the stepped-out model. Instructors have expressed particular approval for figures that juxtapose line art and micrographs, and this style of illustration has been expanded in the third edition. Altogether, the third edition contains approximately 90 new micrographs and computer-derived images, all of which were provided by the original source.
- **The student CD** The CD contains animations based on various illustrations presented in the text. Those subjects that have been animated are indicated in the text by a new "animation icon."

Supplements

Cell View CD-ROM

Many of the illustrations presented in the text have been animated and placed on a CD-ROM to add to the clarity and depth of student understanding. Those subjects that have been animated are indicated within the text

with a new "animation icon." These images can also be easily used for classroom presentation. In addition to the animations of the art program from the text, students can test their understanding of the concepts for each chapter by working through the quiz questions on the CD-ROM. Cell View is included in every new text purchased.

Web Site (www.wiley.com/college/karp)
This text-specific web site provides students with additional resources and extends the chapters of the text to the resources of the World Wide Web.

Instructor's Resource CD-ROM (0-471-09052-2)
Prepared by Joel Piperberg of Millersville University, this multi-platform CD-ROM includes the entire Instructor's Manual and PowerPoint Slides. The Instructor's Manual is a comprehensive resource that includes for each text chapter: Chapter Objective, Lecture Outline, Lecture Hints, Critical Thinking Questions, Experimental Pathways Questions, Human Perspectives Questions and Art Questions.

PowerPoint Slides (0-471-09052-2)
Every illustration from the text is provided in PowerPoint format for classroom presentation and can be found on the Instructor's Resource CD-ROM. They are available both as a pre-set presentation and as graphic files for easy inclusion in other presentation tools.

Full Color Transparencies (0-471-12770-1)
Full-color acetates for key illustrations are provided for classroom presentation. The images have been enlarged and fonts bolded for better projection and clarity in the classroom.

Take Note! (0-471-12775-2)
A spiral bound notebook that contains noteworthy figures from the text, allowing students to take notes directly on the page during class or lecture. This is a perfect student companion to presentations using PowerPoint slides or Transparencies.

Student Study Guide: (0-471-09029-8)
Written by Nancy L. Pruitt of Colgate University. The study guide offers students a great way to review materials from the text and test their knowledge. Each chapter in the text has a corresponding chapter in the study guide. The following six tools have been included to help students master the material: Learning Objectives, Key Terms and Phrases, Reviewing the Chapter, Key Figures, Questions for Thought, Review Problems.

Laboratory Investigations in Cell and Molecular Biology, Fourth Edition, by Allyn Bregman, State University of New York, New Paltz (0-471-20133-2)—This lab manual contains over 20 projects which cover key concepts in cell and molecular biology, such as: biochemistry and cytochemistry; organelles and their physiology; and more advanced molecular topics, including restriction mapping strategies.

To the Student

At the time I began college, biology would have been at the bottom of a list of potential majors. I enrolled in a physical anthropology course to fulfill the life science requirement by the easiest possible route. During that course, I learned for the first time about chromosomes, mitosis, and genetic recombination, and I became fascinated by the intricate activities that could take place in such a small volume of cellular space. The next semester, I took Introductory Biology and began to seriously consider becoming a cell biologist. I am burdening you with this personal trivia so you will understand why I wrote this book and to warn you of possible repercussions.

Even though many years have passed, I still find cell biology the most fascinating subject to explore, and I still love spending the day reading about the latest findings by colleagues in the field. Thus, for me, writing a text in cell biology provides a reason and an opportunity to keep abreast with what is going on throughout the field. My primary goal in writing this text is to help generate an appreciation in students for the activities in which the giant molecules and minuscule structures that inhabit the cellular world of life are engaged. Another goal is to provide the reader with an insight into the types of questions that cell and molecular biologists ask and the experimental approaches they use to seek answers. As you read the text, think like a researcher; consider the evidence that is presented, think of alternate explanations, plan experiments that could lead to new hypotheses.

You might begin this approach by looking at one of the many electron micrographs that fill the pages of this text. To take this photograph, you would be sitting in a small, pitch-black room in front of a large metallic instrument whose column rises several meters above your head. You are looking through a pair of binoculars at a vivid, bright green screen. The parts of the cell you are examining appear dark and colorless against the bright green background. They are dark because they've been stained with heavy metal atoms that deflect a fraction of the electrons within a beam that is being focused on the viewing screen by large electromagnetic lenses in the wall of the column. The electrons that strike the screen are accelerated through the evacuated space of the column by a force of tens of thousands of volts. One of your hands may be gripping a knob that controls the magnifying power of the lenses. A simple turn of this knob can switch the image in front of your eyes from that of a whole field of cells to a tiny part of a cell, such as a few ribosomes or a small portion of a single membrane. By turning other knobs, you can watch different parts of the specimen glide across the screen, giving you the sensation that you're driving around inside a cell. Once you have found a structure of interest, you can turn a handle that lifts the screen out of view, allowing the electron beam to strike a piece of film and produce a photographic image of the specimen.

Since the study of cell function generally requires the use of considerable instrumentation, the investigator is physically removed from the subject being studied. To a large degree, cells are like tiny black boxes. We have developed many ways to probe the boxes, but we are always groping in an area that cannot be fully illuminated. A discovery is made or a new technique is developed and a new thin beam of light penetrates the box. With further work, our understanding of the structure or process is broadened, but we are always left with additional questions. We generate more complete and sophisticated constructions, but we can never be sure how closely our views approach reality. In this regard, the study of cell and molecular biology can be compared to the study of an elephant as conducted by six blind men in an old Indian fable. The six travel to a nearby palace to learn about the nature of elephants. When they arrive, each approaches the elephant and begins to touch it. The first blind man touches the side of the elephant and concludes that an elephant is smooth like a wall. The second touches the trunk and decides that an elephant *is round like a snake.* The other members of the group touch the tusk, leg, ear, and tail of the elephant, and each forms his impression of the animal based on his own limited experiences. Cell biologists are limited in a similar manner to what they can learn by using a particular technique or experimental approach. Although each new piece of information adds to the preexisting body of knowledge to provide a better concept of the activity being studied, the total picture remains uncertain.

Before closing these introductory comments, let me take the liberty of offering the reader some advice: Don't accept everything you read as being true. There are several reasons for urging such skepticism. Undoubtedly, there are errors in this text that reflect the author's ignorance or misinterpretation of some aspect of the scientific literature. But, more importantly, we should consider the nature of biological research. Biology is an empirical science; nothing is ever proved. We compile data concerning a particular cell organelle, metabolic reaction, intracellular movement, etc., and draw some type of conclusion. Some conclusions rest on more solid evidence than others. Even if there is a consensus of agreement concerning the "facts" regarding a particular phenomenon, there are often several possible interpretations of the data. Hypotheses are put forth and generally stimulate further research, thereby leading to a reevaluation of the original proposal. A theory is constructed in terms of the concepts and prevailing perspectives of the time. As new techniques and information become available, new insights are made. Most hypotheses that remain valid undergo a sort of evolution and, when presented in the text, should not be considered wholly correct or incorrect. Remain skeptical.

Acknowledgments

Many people contributed to the development of this book. I want to express my deepest gratitude to Michelle North-Klug, who prepared all of the new illustrations for the second edition of this text and nearly all those for the present edition. Michelle is a remarkably creative artist, capable of turning a near-scribble into a striking electronic illustration. Her talents speak for themselves on most pages of the text. Michelle dedicated herself for many months to this project, driven by a feeling of personal responsibility that every piece meet with my satisfaction and be completed on time. Working with Michelle put some fun in a long, difficult project. I am also indebted to the production staff at John Wiley & Sons, who are absolutely top-notch. Barbara Russiello is a remarkably skillful production editor, who was responsible for coordinating the work of all the myriad people involved in this project. Despite a relentless storm of impossible deadlines, Barbara managed to keep the ship afloat and headed toward port, which at the time of this writing is still well beyond the horizon. If this book should happen to be published on time, Barbara deserves most of the credit. I am also indebted to Hilary Newman and Anna Melhorn, who were responsible for the photo and line-art programs, respectively. I've worked with Hilary on all three editions of this text, and am always impressed anew at her skill and perserverance. I don't think there's a photo in existence that Hilary can't track down—and have it cropped, labeled, and positioned as needed. This was the first time I've worked with Anna, and I really enjoyed our interaction. Anna is great fun to deal with and dedicated to producing the best possible illustration program. Keri Whitman, my new biology editor, joined the company in the middle of the project. Keri has given her enthusiastic support to the book and provided a wealth of useful ideas. I was fortunate, once again, to have Harry Nolan as the senior designer. Harry has directed a vibrant style for the chapters and an elegant design for the cover. Thanks in advance to Clay Stone, the marketing manager for the text, whose work lies mostly ahead. Thanks also to Laura Ierardi, who handled the page layout. Laura is extremely good at this undertaking, which is crucially important yet often goes unappreciated. I would also like to thank the artists at Imagineering for creating a number of illustrations and Jack Haley, in particular, for playing such an important role in coordinating the art program. Thanks also to Professors David Asai and Ken Robinson of Purdue University for providing a number of interesting analytic questions in Chapters 2–5. I would also like to thank Kelli Coaxum and Geraldine Osnato, who handled most of the editorial communications; Joseph Pastore, who copy edited the manuscript; Dottie Jahoda, who prepared the index; and Dr. Elizabeth Coolidge-Stolz, who wrote the glossary.

I am especially grateful to the many biologists who have contributed micrographs for use in this book; more than any other element it is these images that bring the study of cell biology to life on a printed page. Finally, I would like to apologize, in advance, for any errors that may occur in the text, and express my heartfelt embarrassment. Any comments or criticisms from readers would be greatly appreciated. They can be directed to: Biology Editor, John Wiley & Sons, 605 Third Avenue, New York, NY 10158.

In preparing the final version of the manuscript for the third edition, I sought the advice of numerous scientists whose work I have admired. I asked these individuals to review a chapter or two, and most were very gracious in agreeing to help with the project. I am grateful for the constructive criticism and sound advice from the following reviewers:

LINDA AMOS
MRC LABORATORY OF MOLECULAR BIOLOGY

GERALD T. BABCOCK
MICHIGAN STATE UNIVERSITY

JAMES BARBER
IMPERIAL COLLEGE OF SCIENCE—WOLFSON LABORATORIES

JOHN D. BELL
BRIGHAM YOUNG UNIVERSITY

DANIEL BRANTON
HARVARD UNIVERSITY

THOMAS R. BREEN
SOUTHERN ILLINOIS UNIVERSITY

K. H. Andy Choo
Royal Children's Hospital—The Murdoch Institute
Ronald H. Cooper
University of California—Los Angeles
Michael Edidin
The Johns Hopkins University
Robert Fillingame
University of Wisconsin Medical School
Arthur Horwich
Yale University School of Medicine
Joel A. Huberman
Roswell Park Cancer Institute
Werner Kühlbrandt
Max-Planck-Institut für Biophysik
James Lake
University of California—Los Angeles
Vishwanath R. Lingappa
University of California—San Francisco
Ardythe A. McCracken
University of Nevada—Reno
Mike O'Donnell
Rockefeller University
Hugh R. B. Pelham
MRC Laboratory of Molecular Biology
Johathan Pines
Wellcome/CRC Institute
Randy Schekman
University of California—Berkeley
Sandra Schmid
the Scripps Research Institute
Jennifer W. Schuler
Wake Forest University
Rod Scott
Wheaton College
Bruce Stillman
Cold Springs Harbor Laboratory
Nigel Unwin
MRC Laboratory of Molecular Biology
Chris Watters
Middlebury College

Thanks are still owed to the following reviewers from the second edition:

David J. Asai
Purdue University
John D. Bell
Brigham Young University
Barbara Berg
University of Puget Sound
Niels Bols
University of Waterloo, Ontario, Canada
Thomas R. Breen
Southern Illinois University—Carbondale
David K. Bruck
San Jose State University
Mitchell Chernin
Bucknell University
Thomas C. Chiles
Boston College
Randy W. Cohen
California State University—Northridge
Dennis O. Clegg
Univeristy of California—Santa Barbara
Guy E. Farish
Adams State College
Susannah Gal
SUNY, Binghamton
Francine S. Glazer
Kean University
Margaret Johnson
University of Alabama
David Knecht
University of Connecticut—Storrs
Robert N. Leamnson
University of Massachusetts—Dartmouth
Esther M. Leise
University of North Carolina—Greensboro
Alan C. Leonard
Florida Institute of Technology
Edward J. Macarak
University of Pennsylvania
Luis A. Materon
University of Texas—Pan American
Elizabeth J. Moore
Rowan University
Dennis G. Searcy
University of Massachusetts
Diane Shakes
College of William and Mary
David H. Vickers
University of Central Florida
Anne E. K. Zayaitz
Kutztown University

Reviewers of First Edition

Robert E. Bast
Cleveland State University
Catherine P. Chia
University of Nebraska—Lincoln
Sherri Clark
Eastern New Mexico University
Julia Dragolovich
University of Maryland
Karl Drlica
Public Health Research Institute
Terrence G. Frey
San Diego State University

David Fromson
California State University—Fullerton

David S. Gilmour
Pennsylvania State University—University Park

R. Jane Hanas
University of Central Oklahoma

Thomas Kistenmacher
Johns Hopkins University

Hallie M. Krider
The University of Connecticut

Mary Lee S. Ledbetter
College of the Holy Cross

Joel Piperberg
Millersville University of Pennsylvania

Nancy L. Pruitt
Colgate University

Thomas M. Roberts
Florida State University

Robert Seagull
Hofstra University

Joel Sheffield
Temple University

Sheldon Shen
Iowa State University

John Tyson
Virigina Polytechnic Institute

Fred Warner
Syracuse University

Xilin Zhao
Public Health Research Institute

Gerald Karp

Nobel Prizes Awarded for Research in Cell and Molecular Biology Since 1958

Year	*Recipient**	*Prize*	*Area of Research*	*Pages in Text*
2000	Arvid Carlsson Paul Greengard Eric Kandel	M & P**	Synaptic transmission and signal transduction	170 628
1999	Günter Blobel	M & P	Protein trafficking	290
1998	Robert Furchgott Louis Ignarro Ferid Murad	M & P	NO as intercellular messenger	660
1997	Jens C. Skou	Chemistry	Na^+/K^+-ATPase	159
	Paul Boyer John Walker		Mechanism of ATP synthesis	203
	Stanley B. Prusiner	M & P	Protein structure of prions	67
1996	Rolf M. Zinkernagel Peter C. Doherty	M & P	Recognition of virus-infected cells by the immune system	730
1995	Edward B. Lewis Christiane Nüsslein-Volhard Eric Wieschaus	M & P	Genetic control of embryonic development	EP12
1994	Alfred Gilman Martin Rodbell	M & P	Structure and function of GTP-binding (G) proteins	629
1993	Kary Mullis	Chemistry	Polymerase chain reaction (PCR)	781
	Michael Smith		Site-directed mutagenesis (SDM)	776
1992	Edmond Fischer Edwin Krebs	M & P	Alteration of enzyme activity by phosphorylation/dephosphorylation	113, 629
1991	Erwin Neher Bert Sakmann	M & P	Measurement of ion flux by patch-clamp recording	153
1989	J. Michael Bishop Harold Varmus	M & P	Cellular genes capable of causing malignant transformation	697
	Thomas R. Cech Sidney Altman	Chemistry	Ability of RNA to catalyze reactions	487
1988	Johann Deisenhofer Robert Huber Hartmut Michel	Chemistry	Bacterial photosynthetic reaction center	227
1987	Susumu Tonegawa	M & P	DNA rearrangements responsible for antibody diversity	716
1986	Rita Levi-Montalcini Stanley Cohen	M & P	Factors that affect nerve outgrowth	390
1985	Michael S. Brown Joseph L. Goldstein	M & P	Regulation of cholesterol metabolism and endocytosis	327
1984	Georges Köhler Cesar Milstein	M & P	Monoclonal antibodies	784
	Niels K. Jerne		Antibody formation	707
1983	Barbara McClintock	M & P	Mobile elements in the genome	422
1982	Aaron Klug	Chemistry	Structure of nucleic acid-protein complexes	74
1980	Paul Berg	Chemistry	Recombinant DNA technology	770
	Walter Gilbert Frederick Sanger		DNA sequencing technology	781
	Baruj Bennacerraf Jean Dausset George D. Snell	M & P	Major histocompatibility complex	719

Year	*Recipient**	*Prize*	*Area of Research*	*Pages in Text*
1978	Werner Arber Daniel Nathans Hamilton Smith	M & P	Restriction endonuclease technology	427
	Peter Mitchell	Chemistry	Chemiosmotic mechanism of oxidative phosphorylation	195
1976	D. Carleton Gajdusek	M & P	Prion-based diseases	67
1975	David Baltimore Renato Dulbecco Howard M. Temin	M & P	Reverse transcriptase and tumor virus activity	696
1974	Albert Claude Christian de Duve George E. Palade	M & P	Structure and function of internal components of cells	282, 284
1972	Gerald Edelman Rodney R. Porter	M & P	Immunoglobulin structure	712
	Christian B. Anfinsen	Chemistry	Relationship between primary and tertiary structure of proteins	64
1971	Earl W. Sutherland	M & P	Mechanism of hormone action and cyclic AMP	632
1970	Bernard Katz Ulf S. von Euler	M & P	Nerve impulse propagation and transmission	167
	Luis F. Leloir	Chemistry	Role of sugar nucleotides in carbohydrate synthesis	295
1969	Max Delbrück Alfred D. Hershey Salvador E. Luria	M & P	Genetic structure of viruses	22, 434
1968	H. Gobind Khorana Marshall W. Nirenberg	M & P	Genetic code	471
	Robert W. Holley		Transfer RNA structure	475
1966	Peyton Rous	M & P	Tumor viruses	695
1965	Francois Jacob Andre M. Lwoff Jacques L. Monod	M & P	Bacterial operons and messenger RNA	517, 441
1964	Dorothy C. Hodgkin	Chemistry	Structure of complex organic molecules	764
1963	John C. Eccles Alan L. Hodgkin Andrew F. Huxley	M & P	Ionic basis of nerve membrane potentials	166
1962	Francis H. C. Crick James D. Watson Maurice H. F. Wilkins	M & P	Three-dimensional structure of DNA	406
	John C. Kendrew Max F. Perutz	Chemistry	Three-dimensional structure of globular proteins	58
1961	Melvin Calvin	Chemistry	Biochemistry of CO_2 assimilation during photosynthesis	234
1960	F. MacFarlane Burnet Peter B. Medawar	M & P	Clonal selection theory of antibody formation	707
1959	Arthur Kornberg Severo Ochoa	M & P	Synthesis of DNA and RNA	556, 442
1958	George W. Beadle Joshua Lederberg Edward L. Tatum	M & P	Gene expression	440
	Frederick Sanger	Chemistry	Primary structure of proteins	56

*In a few cases, corecipients whose research was in an area outside of cell and molecular biology have been omitted from this list.

**Medicine and Physiology

1

Introduction to the Study of Cell and Molecular Biology

Cells, and the structures they comprise, are too small to be directly seen, heard, or touched. Yet, in spite of this tremendous handicap, cells are the subject of thousands of publications each year, with virtually every aspect of their minuscule structure coming under scrutiny. In many ways, the study of cell and molecular biology stands as a tribute to human curiosity for seeking to discover, and to human creative intelligence for devising the complex instruments and elaborate techniques by which these discoveries can be made. This is not to imply that cell biologists have a monopoly on these noble traits. At one end of the scientific spectrum, astronomers are learning of objects at the outer fringe of the universe that have properties very different from those on Earth. At the other end of the spectrum, nuclear physicists are focusing their attention on particles of subatomic dimensions that have equally inconceivable properties. Clearly, our universe consists of worlds within worlds, all aspects of which make for fascinating study.

As will be apparent throughout this book, cellular and molecular biology is *reductionist*; that is, it is based on the view that knowledge of the parts of the whole can explain the character of the whole. When viewed in this way, our feeling for the wonder and mystery of life may be replaced by the need to explain everything in terms of the workings of the "machinery" of the living

Scanning electron micrograph of cellular aggregates of a mutant strain of the slime mold Dictyostelium discoideum *in the process of forming fruiting bodies.* (COURTESY OF MARK GRIMSON, SCIENCES ELECTRON MICROSCOPY LABORATORY, TEXAS TECH. UNIVERSITY.)