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HARPER'S ILLUSTRATED BIOCHEMISTRY

哈珀图解生物化学

第27版

- Robert K. Murray
- Daryl K. Granner
- Victor W. Rodwell

科学出版社

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Preface

The authors and publisher are pleased to present the twenty-seventh edition of *Harper's Illustrated Biochemistry*. First published as *Review of Physiological Chemistry* in 1939 and revised in 1944, it quickly gained a wide readership. In 1951, the third edition appeared with Harold A. Harper, University of California at San Francisco, as author. Dr. Harper remained the sole author until the ninth edition and co-authored eight subsequent editions. Peter Mayes and Victor Rodwell joined as authors in the tenth edition, Daryl Granner in the twentieth, and Rob Murray in the twenty-first edition. We now bid a fond and grateful farewell to our long-time colleague Peter Mayes, who retired from active authorship after the previous edition. Asked by Harold Harper to review portions of the ninth edition, Peter joined as an author for the tenth through twenty-sixth editions. Peter contributed a unique ability to design diagrams that integrate all key aspects of a metabolic pathway: the enzymes, intermediates, and the mechanisms that guide and regulate metabolic flow. Such skills, his concise and informative prose, and his collegial relationships with the other authors contributed significantly to the continued success of this text. He will be greatly missed by his fellow authors and by readers.

The ever-increasing complexity of biochemical knowledge has led to the addition of several co-authors in recent editions. Peter Mayes' responsibilities now pass to his former collaborators, David Bender and Kathleen Botham, continuing the long-standing trans-Atlantic ties in the authorship of this text. P. Anthony Weil, a co-author with Daryl Granner in the previous edition, continues his invaluable input. Additional co-authors for this and prior editions include Fred Keeley and Margaret Rand with Rob Murray and Peter Kennelly with Victor Rodwell. The senior authors are grateful to their new colleagues for bringing their expertise and fresh perspectives to the text.

CHANGES IN THE TWENTY-SEVENTH EDITION

A major goal continues to be to provide to students of medicine and the health sciences a text that describes and illustrates the basics of biochemistry in a concise, user-friendly, and interesting manner. Significant advances in biochemistry that are of importance in medicine continue to be emphasized. The twenty-sixth edition incorporated drastic revisions, motivated by the fact that many students expressed a desire for a shorter text. Important new features of the twenty-seventh edition include:

- All chapters have been revised, with the inclusion of many new figures and references.
- The origins of the term pH are clearly described.
- The completely new chapter on bioinformatics and computational biology, which emphasizes their impact on present and future medical practice provides valuable insight into these fast growing fields.
- Modern methods of drug discovery that build on advances in genomics and proteomics are emphasized.
- Introduction of the concept of the protein life cycle provides a unified framework for understanding the interrelated processes of the maturation, post-translational modification, regulation, and degradation of proteins.
- The role of mass spectrometry in identification of proteins and small molecules that facilitate the diagnosis of metabolic diseases is emphasized.
- Descriptions of the cell cycle and of the ubiquitin-proteasome pathway of protein degradation have been included.
- The chapter on the respiratory chain and oxidative phosphorylation has been extensively revised.
- Text relating to metabolic disorders of the urea cycle has been revised and updated, and the biosynthesis and metabolic roles of selenocysteine, the twenty-first amino acid, have been introduced.
- New material has been included on lipid rafts, ion channels and voltage-gated channels, glucose transport, and gap junctions.
- With regard to intracellular traffic and sorting of proteins, information on the unfolded protein response and ER-associated degradation has been added.
- The involvement of glycoproteins in many diseases, including peptic ulcer, certain congenital muscular dystrophies, and cystic fibrosis, has been discussed.
- The many newly discovered proteins involved in iron metabolism and hemochromatosis are described.
- Information on hemostasis, thrombosis, and platelet action has been updated.

ORGANIZATION OF THE BOOK

Following two introductory chapters ("Biochemistry & Medicine" and "Water & pH"), the text is divided into

six main sections.

Section I deals with the structures and functions of proteins and enzymes, the workhorses of organisms. Because almost all of the reactions in cells are catalyzed by enzymes, it is vital to understand the properties of enzymes before considering other topics. Section I also contains a new chapter on bioinformatics and computational biology, reflecting the increasing importance of these topics in modern biochemistry, biology, and medicine.

Section II explains how various cellular reactions either utilize or release energy, and traces the pathways by which carbohydrates and lipids are synthesized and degraded. Also described are the many functions of these two classes of molecules.

Section III deals with the amino acids, their many metabolic fates, certain key features of protein catabolism, and the biochemistry of the porphyrins and bile pigments.

Section IV describes the structures and functions of the nucleotides and nucleic acids, and includes topics such as DNA replication and repair, RNA synthesis and modification, protein synthesis, the principles of recombinant DNA and genomic technology, and new understanding of how gene expression is regulated.

Section V deals with aspects of extracellular and intracellular communication. Topics include membrane structure and function, the molecular bases of the actions of hormones, and the key field of signal transduction.

Section VI discusses ten special topics: nutrition, digestion, and absorption; vitamins and minerals; intracellular trafficking and sorting of proteins; glycoproteins; the extracellular matrix; muscle and the cytoskeleton; plasma proteins and immunoglobulins; hemostasis and thrombosis; red and white blood cells; and the metabolism of xenobiotics.

The **Appendix** contains a list of useful web sites and a list of biochemical journals or journals that contain considerable biochemical content. All of the Sections contain numerous illustrations of the medical relevance of biochemistry.

ACKNOWLEDGMENTS

The authors thank Jason Malley for his roles in the planning and actualization of this edition. It has been a pleasure to work with him. We are grateful to Karen Davis for her highly professional and courteous supervising of the editing, her superb skills, and those of her editorial colleagues that ensured that work on this edition proceeded smoothly. We thank Karen Edmonson, Susan Kelly, and Selina Connor for their various contributions to this text. We acknowledge the work of the artists, typesetters, and other individuals not known to us who participated in the production of the twenty-seventh edition of *Harper's Illustrated Biochemistry*. Suggestions from students and colleagues around the world have been most helpful in the formulation of this edition. We look forward to receiving similar input in the future.

Robert K. Murray, Toronto, Ontario, Canada
Daryl K. Granner, Nashville, Tennessee
Victor W. Rodwell, West Lafayette, Indiana

导读前言

本书宗旨及新特点

《哈珀图解生物化学》第27版的主要目的仍然是为医药卫生科学专业的学生提供一本使用方便的参考书，其以简明、生动的方式描述和解析生物化学的基础知识。书中继续强调生物化学中与医学密切相关的一些重要进展。应众多学生希望精减篇幅的要求，对第26版进行了大量的修订。第27版的重要新特点概括如下：

- 所有章节均进行了修订，包括对一些新图片和新参考文献的增加。
- 清楚地描述了pH的由来。
- 新增了关于“生物信息学与计算生物学”一章，该章强调了生物信息学与计算生物学对当前及未来医学实践的影响。
- 强调了建立在基因组学和蛋白质组学发展基础上的发现新药的现代方法。
- 介绍了蛋白质生活周期这个概念，该概念为理解蛋白质成熟、翻译后修饰、调控以及降解相关过程构筑了一个统一框架。
- 强调了质谱分析在鉴定蛋白质以及一些有助于诊断代谢疾病的小分子物质上的应用。
- 书中包含了对细胞周期及降解蛋白质的泛素-蛋白酶体通路的描述。
- 关于“呼吸链和氧化磷酸化”一章节进行了大幅修改。
- 修改和更新了关于尿素循环代谢紊乱的内容，介绍了第二十一种氨基酸（即硒氨酸）的生物合成及其在代谢中的作用。
- 介绍了关于脂质筏、离子通道和电压-门控通道、葡萄糖转运以及缝隙连接等新内容。
- 考虑到蛋白质在胞内的运输与分选，新增了关于未折叠蛋白反应、内质网相关的蛋白质降解等信息。
- 对许多糖蛋白相关疾病，包括消化性溃疡、某些先天性肌萎缩及囊性纤维化病等进行了阐述。
- 介绍了许多新发现的与铁代谢、血色素沉着病相关的蛋白质。
- 更新了关于凝血、血栓形成及血小板功能的信息。

本书纲要

本书的总体结构是：先是两章介绍性内容，继而是全书的核心部分（包括六篇50章）。两章介绍性内容包括“生物化学与医学”和“水与pH”。

第一篇（第3～10章）：重点介绍生命活动的执行者（即蛋白质和酶）的结构与功能。第一篇新增了关于“生物信息学与计算生物学”一章，这也体现出它们在现代生物化学、生物学及医学领域中的重要性日益增加。

第二篇（第11～26章）：重点阐述了细胞的各种反应如何利用或释放能量、糖类和脂类合成与分解途径以及这两类分子的多种功能。

第三篇（第27～31章）：重点讲述氨基酸及其多个代谢去向、蛋白质分解代谢的某些关键特征以及卟啉和胆色素的生物化学。

第四篇（第32～39章）：重点介绍核苷酸和核酸的结构与功能、DNA复制与修复、RNA合成与修

饰、蛋白质合成、重组 DNA 和基因操作技术的原理等基本内容以及关于基因表达调控的一些新知识。

第五篇(第 40 ~ 42 章):重点介绍细胞通信相关内容,包括细胞膜的结构与功能、激素作用的分子基础以及细胞信号转导等。

第六篇(第 43 ~ 52 章):本篇为专题篇,主要就营养及消化与吸收、维生素与矿物质、蛋白质在胞内的转运与分选、糖蛋白、细胞外基质、肌肉与细胞骨架、血浆蛋白与免疫球蛋白、凝血与血栓形成、红细胞与白细胞、非营养物质(如药物、毒物)代谢等十个专题进行论述。

何凤田

2010 年 2 月

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Biochemistry & Medicine

1

第1章 生物化学与医学

Robert K. Murray, MD, PhD

• 生物化学是一门研究存在于活细胞和有机体中的各种分子以及这些分子的化学反应之科学，其从分子水平描述和解释发生于活细胞和有机体的所有化学过程。生物化学与所有生命形式（从相对简单的病毒和细菌到复杂的人类）都密切相关。由于生命依赖于生物化学反应，因此，生物化学已越来越成为所有生命科学的共同语言。

• 生物化学与医学密切联系，二者互相促进彼此的发展。机体健康与否取决于体内生物化学反应是否和谐与平衡，而疾病则反映了体内生物分子、生物化学反应或生物化学过程的异常。生物化学的发展带动了医学诸多领域的发展，反过来，对疾病的研究也经常会为生物化学提出新的问题，进而促进生物化学的发展。

• 生物化学方法常常是阐明疾病起因和制定合理治疗方案的基础。多种生物化学实验室检测技术可用于疾病诊断和治疗效果监测。深入理解生物化学知识以及相关基本规律对于合理地进行医疗实践以及发展相关健康科学都是非常重要的。

• 人类基因组计划所取得的研究成果将对生物化学、未来医学以及其他健康科学产生深远的影响。例如，完整的人类基因组序列的确定将大大促进包括生物化学、生物信息学以及生物技术等所有生物学领域的发展。

INTRODUCTION

Biochemistry can be defined as *the science concerned with the chemical basis of life* (Gk *bios* "life"). The **cell** is the structural unit of living systems. Thus, biochemistry can also be described as *the science concerned with the chemical constituents of living cells and with the reactions and processes they undergo.* By this definition, biochemistry encompasses large areas of **cell biology,** of **molecular biology,** and of **molecular genetics.**

The Aim of Biochemistry Is to Describe & Explain, in Molecular Terms, All Chemical Processes of Living Cells

The major objective of biochemistry is the complete understanding, at the molecular level, of all of the chemical processes associated with living cells. To achieve this objective, biochemists have sought to isolate the numerous molecules found in cells, determine their structures, and analyze how they function. Many techniques have been used for these purposes; some of them are summarized in Table 1-1.

A Knowledge of Biochemistry Is Essential to All Life Sciences

The biochemistry of the nucleic acids lies at the heart of **genetics;** in turn, the use of genetic approaches has been critical for elucidating many areas of biochemistry. **Physiology,** the study of body function, overlaps with biochemistry almost completely. **Immunology** employs numerous biochemical techniques, and many immunologic approaches have found wide use by biochemists. **Pharmacology** and **pharmacy** rest on a sound knowledge of biochemistry and physiology; in particular, most drugs are metabolized by enzyme-catalyzed reactions. Poisons act on biochemical reactions or processes; this is the subject matter of **toxicology.** Biochemical approaches are being used increasingly to study basic aspects of **pathology** (the study of disease), such as inflammation, cell injury, and cancer. Many workers in **microbiology, zoology,** and **botany** employ biochemical approaches almost exclusively. These relationships are not surprising, because life as we know it depends on biochemical reactions and processes. In fact, the old barriers among the life sciences are breaking down, and biochemistry is increasingly becoming their common language.

Table 1-1. The principal methods and preparations used in biochemical laboratories.

Methods for Separating and Purifying Biomolecules[1]
- Salt fractionation (eg, precipitation of proteins with ammonium sulfate)
- Chromatography: Paper; ion exchange; affinity; thin-layer; gas-liquid; high-pressure liquid; gel filtration
- Electrophoresis: Paper; high-voltage; agarose; cellulose acetate; starch gel; polyacrylamide gel; SDS-polyacrylamide gel
- Ultracentrifugation

Methods for Determining Biomolecular Structures
- Elemental analysis
- UV, visible, infrared, and NMR spectroscopy
- Use of acid or alkaline hydrolysis to degrade the biomolecule under study into its basic constituents
- Use of a battery of enzymes of known specificity to degrade the biomolecule under study (eg, proteases, nucleases, glycosidases)
- Mass spectrometry
- Specific sequencing methods (eg, for proteins and nucleic acids)
- X-ray crystallography

Preparations for Studying Biochemical Processes
- Whole animal (includes transgenic animals and animals with gene knockouts)
- Isolated perfused organ
- Tissue slice
- Whole cells
- Homogenate
- Isolated cell organelles
- Subfractionation of organelles
- Purified metabolites and enzymes
- Isolated genes (including polymerase chain reaction and site-directed mutagenesis)

[1] Most of these methods are suitable for analyzing the components present in cell homogenates and other biochemical preparations. The sequential use of several techniques will generally permit purification of most biomolecules. The reader is referred to texts on methods of biochemical research for details.

A Reciprocal Relationship Between Biochemistry & Medicine Has Stimulated Mutual Advances

The two major concerns for workers in the health sciences—and particularly physicians—are the understanding and maintenance of **health** and the understanding and effective treatment of **diseases.** Biochemistry impacts enormously on both of these fundamental concerns of medicine. In fact, the interrelationship of biochemistry and medicine is a wide, two-way street. Biochemical studies have illuminated many aspects of health and disease, and conversely, the study of various aspects of health and disease has opened up new areas of biochemistry. Some examples of this two-way street are shown in Figure 1-1. For instance, a knowledge of protein structure and function was necessary to elucidate the single biochemical difference between normal hemoglobin and sickle cell hemoglobin. On the other hand, analysis of sickle cell hemoglobin has contributed significantly to our understanding of the structure and function of both normal hemoglobin and other proteins. Analogous examples of reciprocal benefit between biochemistry and medicine could be cited for the other paired items shown in Figure 1-1. Another example is the pioneering work of Archibald Garrod, a physician in England during the early 1900s. He studied patients with a number of relatively rare disorders (alkaptonuria, albinism, cystinuria, and pentosuria; these are described in later chapters) and established that these conditions were genetically determined. Garrod designated these conditions as **inborn errors of metabolism.** His insights provided a major foundation for the development of the field of human biochemical genetics. More recent efforts to understand the basis of the genetic disease known as **familial hypercholesterolemia,** which results in severe atherosclerosis at an early age, have led to dramatic progress in understanding of cell receptors and of mechanisms of uptake of cholesterol into cells. Studies of **oncogenes** in cancer cells have directed attention to the molecular mechanisms involved in the control of normal cell growth. These and many other examples emphasize how the study of disease can open up areas of cell function for basic biochemical research.

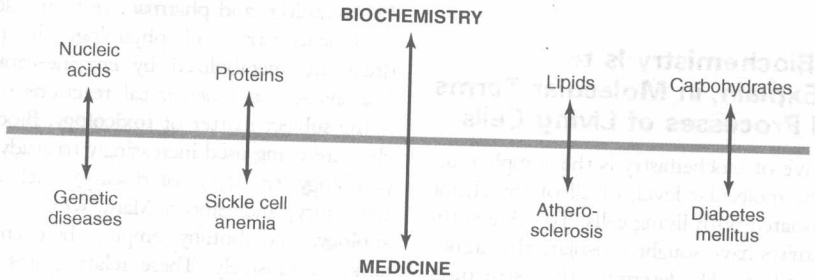

Figure 1-1. Examples of the two-way street connecting biochemistry and medicine. Knowlege of the biochemical molecules shown in the top part of the diagram has clarified our understanding of the diseases shown on the bottom half—and conversely, analyses of the diseases shown below have cast light on many areas of biochemistry. Note that sickle cell anemia is a genetic disease and that both atherosclerosis and diabetes mellitus have genetic components.

The relationship between medicine and biochemistry has important implications for the former. As long as medical treatment is firmly grounded in a knowledge of biochemistry and other basic sciences, the practice of medicine will have a rational basis that can be adapted to accommodate new knowledge. This contrasts with unorthodox health cults and at least some "alternative medicine" practices that are often founded on little more than myth and wishful thinking and generally lack any intellectual basis.

NORMAL BIOCHEMICAL PROCESSES ARE THE BASIS OF HEALTH

The World Health Organization (WHO) defines health as a state of "complete physical, mental and social well-being and not merely the absence of disease and infirmity." From a strictly biochemical viewpoint, health may be considered that situation in which all of the many thousands of intra-and extracellular reactions that occur in the body are proceeding at rates commensurate with the organism's maximal survival in the physiologic state. However, this is an extremely reductionist view, and it should be apparent that caring for the health of patients requires not only a wide knowledge of biologic principles but also of psychologic and social principles.

Biochemical Research Has Impact on Nutrition & Preventive Medicine

One major prerequisite for the maintenance of health is that there be optimal dietary intake of a number of chemicals; the chief of these are **vitamins,** certain **amino acids,** certain **fatty acids,** various **minerals,** and **water.** Because much of the subject matter of both biochemistry and nutrition is concerned with the study of various aspects of these chemicals, there is a close relationship between these two sciences. Moreover, more emphasis is being placed on systematic attempts to maintain health and forestall disease, ie, on **preventive medicine.** Thus, nutritional approaches to—for example—the prevention of atherosclerosis and cancer are receiving increased emphasis. Understanding nutrition depends to a great extent on a knowledge of biochemistry.

Most & Perhaps All Disease Has a Biochemical Basis

We believe that most if not all diseases are manifestations of abnormalities of molecules, chemical reactions, or biochemical processes. The major factors responsible for causing diseases in animals and humans are listed in Table 1-2. All of them affect one or more critical chemical reactions or molecules in the body. Numerous examples of the biochemical bases of diseases will be encountered in this text. In most of these conditions, biochemical studies contribute to both the diagnosis and treatment. Some major uses of biochemical investigations and of laboratory tests in relation to diseases are summarized in Table 1-3.

Table 1-2. The major causes of diseases. All of the causes listed act by influencing the various biochemical mechanisms in the cell or in the body.[1]

1. Physical agents: Mechanical trauma, extremes of temperature, sudden changes in atmospheric pressure, radiation, electric shock.
2. Chemical agents, including drugs: Certain toxic compounds, therapeutic drugs, etc.
3. Biologic agents: Viruses, bacteria, fungi, higher forms of parasites.
4. Oxygen lack: Loss of blood supply, depletion of the oxygencarrying capacity of the blood, poisoning of the oxidative enzymes.
5. Genetic disorders: Congenital, molecular.
6. Immunologic reactions: Anaphylaxis, autoimmune disease.
7. Nutritional imbalances: Deficiencies, excesses.
8. Endocrine imbalances: Hormonal deficiencies, excesses.

Adapted, with permission, from Robbins SL, Cotram RS, Kumar V: *The Pathologic Basis of Disease,* 3rd ed. Saunders, 1984. Copyright © 1984 Elsevier Inc. Reprinted with permission from Elsevier.

Table 1-3. Some uses of biochemical investigations and laboratory tests in relation to diseases.

Use	Example
1. To reveal the fundamental causes and mechanisms of diseases	Demonstration of the nature of the genetic defects in cystic fibrosis.
2. To suggest rational treatments of diseases based on (1) above	A diet low in phenylalanine for treatment of phenylketonuria.
3. To assist in the diagnosis of specific diseases	Use of the plasma enzyme creatine kinase MB (CK-MB) in the diagnosis of myocardial infarction.
4. To act as screening tests for the early diagnosis of certain diseases	Use of measurement of blood thyroxine or thyroid stimulating hormone (TSH) in the neonatal diagnosis of congenital hypothyroidism.
5. To assist in monitoring the progress (ie, recovery, worsening, remission, or relapse) of certain diseases	Use of the plasma enzyme alanine aminotransferase (ALT) in monitoring the progress of infectious hepatitis.
6. To assist in assessing the response of diseases to therapy	Use of measurement of blood carcinoembryonic antigen (CEA) in certain patients who have been treated for cancer of the colon.

Additional examples of many of these uses are presented in various sections of this text.

Impact of the Human Genome Project (HGP) on Biochemistry & Medicine

Remarkable progress was made in the late 1990s in sequencing the human genome. This culminated in July 2000, when leaders of the two groups involved in this effort (the International Human Genome Sequencing Consortium and Celera Genomics, a private company)

announced that over 90% of the genome had been sequenced. Draft versions of the sequence were published in early 2001. With the exception of a few gaps, the sequence of the entire human genome was completed in 2003, 50 years after the description of the double-helical nature of DNA by Watson and Crick. The implications of this work for biochemistry, all of biology, and for medicine are tremendous, and only a few points are mentioned here. Many previously unknown genes have been revealed; their protein products await characterization. New light has been thrown on human evolution, and procedures for tracking disease genes have been greatly refined. The results are having major effects on areas such as proteomics, bioinformatics, biotechnology, and pharmacogenomics. Reference to the human genome will be made in various sections of this text.

SUMMARY

- Biochemistry is the science concerned with studying the various molecules that occur in living cells and organisms and with their chemical reactions. Because life depends on biochemical reactions, biochemistry has become the basic language of all biologic sciences.
- Biochemistry is concerned with the entire spectrum of life forms, from relatively simple viruses and bacteria to complex human beings.
- Biochemistry and medicine are intimately related. Health depends on a harmonious balance of biochemical reactions occurring in the body, and disease reflects abnormalities in biomolecules, biochemical reactions, or biochemical processes.
- Advances in biochemical knowledge have illuminated many areas of medicine. Conversely, the study of diseases has often revealed previously unsuspected aspects of biochemistry. The determination of the sequence of the human genome, nearly complete, will have a great impact on all areas of biology, including biochemistry, bioinformatics, and biotechnology.
- Biochemical approaches are often fundamental in illuminating the causes of diseases and in designing appropriate therapies.
- The judicious use of various biochemical laboratory tests is an integral component of diagnosis and monitoring of treatment.
- A sound knowledge of biochemistry and of other related basic disciplines is essential for the rational practice of medical and related health sciences.
- Results of the Human Genome Project will have a profound influence on the future of medicine and other health sciences.

REFERENCES

Burtis CA, Ashwood ER: *Tietz Fundamentals of Clinical Chemistry*, 5th ed. Saunders, 2001.

Encyclopedia of Life Sciences. John Wiley, 2001. (Contains some 3,000 comprehensive articles on various aspects of the life sciences. Accessible online at www.els.net via libraries with a subscription.)

Fruton JS: *Proteins, Enzymes, Genes: The Interplay of Chemistry and Biology*. Yale Univ Press, 1999. (Provides the historical background for much of today's biochemical research.)

Garrod AE: Inborn errors of metabolism. (Croonian Lectures.) Lancet 1908; 2: 1, 73, 142, 214.

Guttmacher AE, Collins FS: Genomic medicine-A Primer. N Engl J Med 2002; 347: 1512. (This article was the first of a series of eleven monthly articles published in the *New England Journal of Medicine* describing various aspects of genomic medicine.)

Kornberg A: Basic research: The lifeline of medicine. FASEB J 1992; 6: 3143.

Kornberg A: Centenary of the birth of modern biochemistry. FASEB J 1997; 11: 1209.

McKusick VA: *Mendelian Inheritance in Man. Catalogs of Human Genes and Genetic Disorders,* 12th ed. Johns Hopkins Univ Press, 1998. [Abbreviated MIM]

Online Mendelian Inheritance in Man (OMIM): Center for Medical Genetics, Johns Hopkins University and National Center for Biotechnology Information, National Library of Medicine, 1997. http: //www.ncbi.nlm.nih.gov/omim/

(The numbers assigned to the entries in MIM and OMIM will be cited in selected chapters of this work. Consulting this extensive collection of diseases and other relevant entries-specific proteins, enzymes, etc-will greatly expand the reader's knowledge and understanding of various topics referred to and discussed in this text. The online version is updated almost daily.)

Scriver CR et al (editors): *The Metabolic and Molecular Bases of Inherited Disease,* 8th ed. McGraw-Hill, 2001.