Biochemistry

A Textbook for Medical Students

Chief editor: Zhao Baochang
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生物化学

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内 容 简 介

本书是我国高等医学院校留学生本科教学和中、英双语教学班教学的生物化学教材，内容为医学专业学生应该掌握的基础理论、基本知识与基本技能，同时也兼顾了国家执业医师考试的要求。全书共21章，内容包括蛋白质、核酸和酶的结构与功能；糖、脂、氨基酸和核苷酸的代谢，以及生物氧化和代谢调节；DNA、RNA和蛋白质的生物合成，基因表达的调控及DNA技术；生物膜、糖复合物与细胞外基质、细胞信号转导，癌基因、抑癌基因与生长因子；肝胆、血液、维生素与无机物的生物化学。全书有插图348幅，表69个。本书特别注重在华留学生和双语教学的需要，重要的英文生化专业名词与术语均在其后标出相应的中文，并在书后附有名词释义，给出简洁、准确的概念。各章后均有中、英文内容摘要。

本书适用于高等医学院校各专业本科留学生和中、英双语教育的学生使用。

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本书使用说明

随着我国的改革开放和国际声誉与地位的不断提高，招收外国留学生和开设双语教学的高等医学院校日益增多。为了适应各高校留学生本科和中、英双语教学班生物化学教学的需要，特编写此教材。本书的适用对象是高等医学院校基础医学、临床医学、预防医学、口腔医学等专业本科学生，特别是在各高校就读上述专业的外国留学生和接受中、英双语教育的中国学生。

本书的内容为医学专业学生应该掌握的基础理论、基本知识与基本技能，同时也兼顾了国家执业医师考试的要求。全书共21章，内容包括4个板块。第一部分是生物大分子的结构与功能，包括蛋白质、核酸和酶的结构与功能。第二部分是代谢部分，包括糖、脂、氨基酸和核苷酸的代谢，以及生物氧化和代谢调节。第三部分是遗传信息的传递与调节，包括DNA、RNA和蛋白质的生物合成，基因表达的调控。我们把与遗传信息传递相关的重要技术及其应用列为一章，即DNA技术，这有利于教学的系统性和学生对有关知识的连贯掌握。第四部分有两方面的内容：一是信号转导相关内容，二是肝与血液的组织器官生化知识。细胞接受外来信号刺激并作出应答需要一系列的细胞结构与分子保障，所以本书先阐述生物膜与相关的生物大分子（糖复合物与细胞外基质），然后再讨论信号转导，最后再描述癌基因、抑癌基因与生长因子。各校可以根据自身的教学计划和与相关学科的衔接关系，对生物膜和糖复合物内容进行适当的取舍。最后一章是维生素与无机物，许多学校对这一章都不单独讲授，而是在讲授有关章节时适当地插入相关的内容。例如，对一些维生素，可以在讲授酶的辅酶和生物氧化时加以提及。

本着面向现代化、面向世界、面向未来的精神，书中适当地增加了一些生命科学的热点内容和新的进展、一些与医学临床密切相关的内容，以及具有代表性的经典实验。这些内容有利于激发学生学习的自觉性，培养学生独立分析、解决问题的能力及创新精神。教师可酌情对学生必须掌握的、熟悉的、可一般了解的内容加以区分，以引导学生学习。

本书特别注重在华留学生和双语教学的需要，重要的英文生化专业名词与术语在其后标出相应的中文，并在书后附有名词释义，给出简洁、准确的概念。各章后均有中、英文内容摘要，索引也采用英-中对照方式。用英语给留学生讲课的老师可以不理会书中的中文，但书中的中文可以激发留学生学习中文的兴趣和积极性，帮助他们逐步掌握中文专业词汇。接受双语教学的中国学生可以借助书中的中文名词正确掌握英语专业名词的翻译规律。

由于各高校的教学计划和教学安排的差异，使用本书时可以灵活掌握各章的顺序与内容。

编　者

2009年2月

PREFACE

Biochemistry is the most common course for medical students embarking on study in medical sciences. The authors of this textbook are very pleased to present the *Biochemistry: a textbook for medical students*. The purposes of this textbook are to present a precise and concise teaching material of biochemistry to the abroad students and the Chinese students who are being educated with double languages, as well as the teachers who are teaching biochemistry to those students in the medical universities or colleges of China. Despite the ever-increasing complexity of biochemical knowledge and ever-increasing importance of biochemistry for the medical sciences, as a teaching material, we could not match the increased volume of knowledge in this field by an increased size of the textbook. We designed the textbook by selecting the contents sufficiently covering most of the important topics in a medical biochemistry course. It is clear and concise enough for students to master the basic biochemical theories, rudimentary knowledge, and fundamental skills in biochemistry.

The textbook is organized and written so that the sequences of chapters are most appropriate for keeping their inherent regularity and connections, and for the students to read from the easy to the difficult and complicated. In this textbook, the twenty one chapters can be divided into four parts. The first part includes the first three chapters dealing with the structure and function of proteins, nucleic acids, and enzymes. Nucleic acids are related to the storage and transmission of genetic information. The function of proteins is the embodiment of the life. Enzymes catalyze almost all of the chemical reactions in cells. It is vital to understand these properties of the macrobiomolecules before studying the following chapters. The second part explains how the organism metabolizes carbohydrates, lipids, and amino acids for releasing and utilizing energy, or providing the building blocks. The third part describes the transmission of genetic information including DNA replication and repair, RNA transcription and modification, protein synthesis, regulation of gene expression, and DNA technology. The last part discusses seven special topics dealing with extracellular and intracellular communication (membrane, glycoconjugates, signal transduction, oncogenes, tumor suppressor genes and growth factors), blood and liver biochemistry, and vitamins and minerals. Glossary and appendix provide the students and teachers with very useful basic knowledge to facilitate the learning and teaching.

The authors thank the Medical College of Qing Dao University, the International Education College of Dalian Medical University, and the universities and colleges where they are teaching for the enthusiastic supports. We are grateful to Li Yue, the editor in Sciences Press, and Li Gang, the professor in Medical Libratory of Beijing University for their friendly help. During the writing and editing, suggestions from colleagues and students have been helpful in the formulation of this book. We look forward to receiving more suggestions and comments in the future.

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February 2009

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Introduction

The thousands of different lifeless and lives on the Earth are made from the simple elements and compounds. Life is one of the motive patterns of materials. The remarkable common properties of living organisms distinguishing from nonliving materials are the capacity for precise self-renewal (metabolism), and self-replication and self-assembly (expression and transmission of genetic information), although they maintain and perpetuate themselves to conform to all the physical and chemical laws that govern the nonliving universe. Biochemistry is the chemistry of life, the aim is to describe and explain, in molecular terms, all chemical processes in living cells.

Biochemistry seeks to explain life at the molecular level, its knowledge is essential to all life sciences. Biochemistry of nucleic acids locates at the heart of genetics. Biochemistry overlaps with physiology, the study of body functions. Pharmacology, pharmacy, and toxicology lie at the basic knowledge of biochemistry; in particular, most drugs and poisons rely on the biochemical processes for their function and are metabolized and biotransformed by enzymatic reactions. Most subjects of life sciences employ biochemical approaches almost exclusively to break down their technical barriers and biochemical theory to explain various phenomena at molecular level. Biochemistry is increasingly becoming the common language of those subjects.

The reciprocal relationship between biochemistry and medicine has promoted their mutual advances. The normal biochemical processes are the basis of body health, and all diseases have a biochemical basis. Biochemical studies have been enormously accelerating the development of both of the understanding and maintenance of health, and the understanding and effective treatment of diseases. The study of various aspects of medicine has been opening up new areas of biochemistry.

The achievements of biochemical investigation catalyze the birth of several new disciplines. Bioinformatics, for example, represents a new growing area of science that employs computational approaches to answer biological questions, and efficiently guides experimental design in laboratories.

Biochemistry describes the following contents.

1. The chemical constituents of living organisms, and the structures and functions of biomolecules (Static Biochemistry). About 30 of the more than 90 naturally occurring chemical elements are essential to the living organisms, and most of the 30 elements are lighter elements including the four most abundant elements: hydrogen, oxygen, nitrogen, and carbon, which together make up more than 99% of the mass of most cells. The organic compounds, which constitute humane body and/or play important roles for maintaining normal living activities, are named biomolecules.

Proteins, nucleic acids, and polysaccharides with the molecular weight of mostly more than 10 000 Da are termed biomacromolecules which are polymers constructed by their own basic units. Proteins consist of hundreds to thousands of linked amino acid residues by peptide bonds; 3′,5′-phosphodiester bonds linked nucleotides and deoxynucleotides are the basic units of RNA and DNA, respectively. Most enzymes are proteins with catalytic activities. The primary structure of biomacromolecule is the basis of their spatial structures, and the latter are the basis of their functions. The structure and function of proteins are the material bases and embodiment of living activities; nucleic acids store and transmit genetic informations. The normal structure and function of these macromolecules are essential for maintenance of body under control.

2. Metabolism and its regulation (Dynamic Biochemistry). Living organisms have the ability to construct and renew themselves by extracting and digesting nutrients from and excreting the end products to their environments. Many consecutive chemical reactions catalyzed by a series of enzymes responsible for a certain function constitute metabolic pathways. Metabolism is the sum of all the chemical transformations or the net of pathways taking place in a cell or organism. Metabolism, one of the very important characteristics of life, can be divided into two major phases: catabolism (degradation) and anabolism (biosynthesis). The energy required by anabolism (an endergonic process) is provided by catabolism (exergonic process). Metabolic pathways are regulated at several levels. The disorder of metabolism may cause various diseases.

3. Storage, expression, and transmission of genetic information (Molecular Biology). Self-replication and transmission of genetic information are another one of the basic characteristics of living

organisms. As the repository of the genetic information, DNA is the most material basis of the heredity, while genes are the functional segments of DNA. The central dogma of molecular biology comprises the three major processes in the cellular utilization of genetic information: replication, transcription, and translation. Reverse transcription is a profitable replenishment of the dogma. The expression of genes is strictly regulated at many points. Cells have the ability to respond the surrounding signals, which are detected by specific receptors and converted to a cellular response. Signal transduction is a universal property of living cells. Many signal transductive pathways constitute crosstalk to control growth, proliferation, differentiation, and aging of the living organisms. Any abnormality of both the transmission and regulation of genetic information, and signal transduction can cause various diseases.

4. Biochemistry of tissues and organs (Functional Biochemistry). In addition to the common types of metabolic pathways, organs or tissues have their own metabolic patterns for their distinguish functions. It is very important for medical students to get the knowledge of some medically important organs and tissues such as the liver, blood, and so on. The liver locates in the center of carbohydrate, lipid, and protein metabolism, and also metabolizes xenobiotics and bile pigments. The liver is also the largest exocrine organ for excreting bile acids and other metabolites. Impaired liver function compromises many metabolic processes leading to serious pathology. Blood circulation is the traffic line for nutrients, metabolites, regulators, end products, as well as oxygen and carbon dioxide. Blood circulation connects tissues and organs for crosstalking. Plasma components and blood cells are important for carrying out their specific functions. Blood samples can provide critical information about body functions and help physicians to diagnose some diseases.

The modern biochemistry is a young but fast growing field of investigation. The term "biochemistry" seems to be first used in 1882, it was generally accepted in 1903. In the 19th and early 20th centuries biochemistry dealt more with extracellular chemistry, such as the discovery of glycerol, citrate, malate, lactate and uric acid, the chemistry of digestion and of body fluids. In the first fifty year period of the 20th century, biochemistry discussed more with the constituents of the body, metabolism and its regulation, and biochemical nutrition. The research achievements about the structures and functions of vitamins, coenzymes and hormones, the kinetics of enzymatic reactions, metabolic pathways of carbohydrate, β-oxidation of fatty acids, ornithine cycle and citric acid cycle , and so on were the major contributions in this period. The basic framework of biochemistry was established.

Since the middle of 20th century, biochemistry was growing fast to a golden age, and ushered in a new era of molecular biology. This was epitomized by the discovery of the double-helical structure of DNA, postulated by James Watson and Francis Crick in 1953. Recombinant DNA technology paved the way to the modern field of genomics and proteomics, the study of genes and proteins on the scale of whole cells and organisms. The development of practical DNA sequencing methods inspired the confidence in scientists for sequencing the entire 3 billion base pairs of the human genome. The Human Genome Project started in 1990, and the completed sequence of the human genome was published in April 2003. The effort eventually included significant contributions from 20 sequencing centers in six nations: the United States, Great Britain, Japan, France, China, and Germany. Human Genome Project marked the culmination of 20th century biology, and promised a vastly changed scientific landscape for the new century. The artificially alterations of genome from animals or plants by biotechnology may produce new species. Detection of individual genome can facilitate the diagnosis of some diseases, and design the strategy of gene therapy. Recombinant DNA technology can yield new products and challenges, discover new pharmaceuticals.

Now the post-genomics era has been placed on the agenda. The investigation on proteome, the complement of proteins expressed by a genome is called proteomics. Other fields are transcriptomics, an investigation on entire mRNA expressed in organism and its responses to environmental changes; metabonomics, quantitative understandings of the metabolite complement in organism and its responses to environmental changes; glycomics, the investigation on the structure and function of glycans. There are some derivatives from those omicses, such as pharmacometabonomics, medicometabonomics, and so on. Achievements in these investigations inevitably arouse revolutional changes in many fields. Once the mystery of the nature of life is uncovered, it will give much great influences on the understanding of nature of life, pathogenesis, prevention, and therapy of diseases, anti-aging, and development of new medicines and so on.

(Zhao Baochang)