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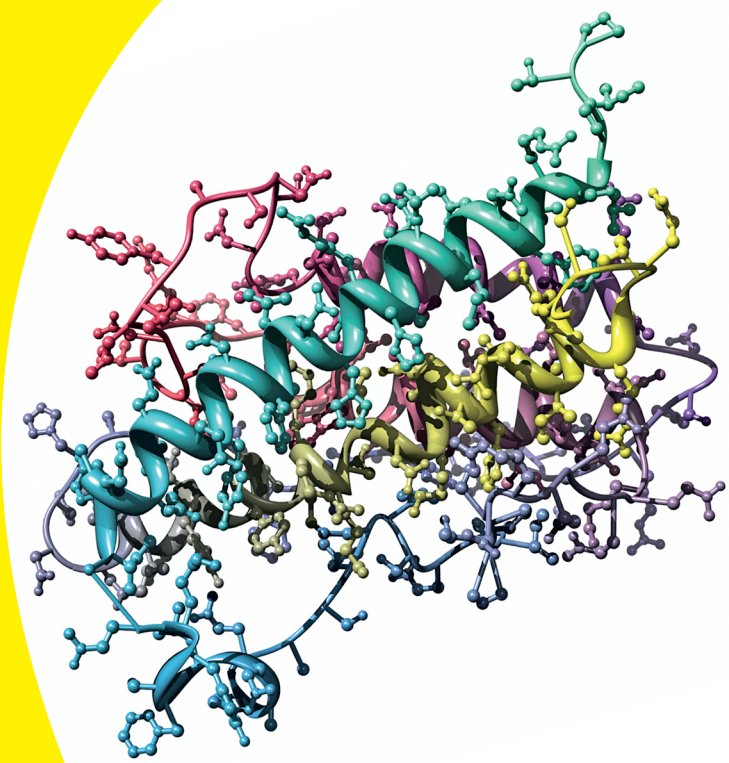

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Author of Chemistry For Dummies

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Biochemistry FOR DUMMIES®

2ND EDITION

by John T. Moore, EdD, and Richard Langley, PhD

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About the Authors

John Moore grew up in the foothills of western North Carolina. He attended the University of North Carolina at Asheville, where he received his bachelor's degree in chemistry. He earned his master's degree in chemistry from Furman University in Greenville, South Carolina. After a stint in the U.S. Army, he decided to try his hand at teaching. In 1971 he joined the chemistry faculty of Stephen F. Austin State University in Nacogdoches, Texas, where he still teaches chemistry. In 1985 he started back to school part time, and in 1991 he received his doctorate in education from Texas A&M University. He has been the co-editor (along with one of his former students) of the "Chemistry for Kids" feature of *The Journal of Chemical Education.* In 2003 his first book, *Chemistry For Dummies* (Wiley), was published, soon to be followed by *Chemistry Made Simple* (Broadway Books). John enjoys cooking and making custom knife handles from exotic woods.

Richard Langley grew up in southwestern Ohio. He attended Miami University in Oxford, Ohio, where he received bachelor's degrees in chemistry and mineralogy and then a master's degree in chemistry. His next stop was the University of Nebraska, where he received his doctorate in chemistry. Afterward, he took a postdoctoral position at Arizona State University in Tempe, Arizona, followed by a visiting assistant professor position at the University of Wisconsin at River Falls. In 1982, he moved to Stephen F. Austin State University. For the past several years, he and John Moore have been graders for the free response portion of the AP Chemistry Exam. He and John have collaborated on several writing projects, including *5 Steps to a 5 on the AP: Chemistry* (McGraw-Hill), *Chemistry for the Utterly Confused* (McGraw-Hill), and *Organic Chemistry II For Dummies* (Wiley). Rich enjoys jewelry making and science fiction.

Dedication

To my wife, Robin; sons, Matthew and Jason; my wonderful daughter-in-law, Sara; and the two most wonderful grandkids in the world, Zane and Sadie. I love you guys. — John

To my mother. — Rich

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Contents at a Glance

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Introduction

Welcome to the second edition of *Biochemistry For Dummies!* We're certainly happy you've decided to delve into the fascinating world of biochemistry. Biochemistry is a complex area of chemistry, but understanding biochemistry isn't really complex. It takes hard work, attention to detail, and the desire to know and to imagine. Biochemistry, like any area of chemistry, isn't a spectator sport. You must interact with the material, try different explanations, and ask yourself why things happen the way they do.

Work hard and you'll get through your biochem course. More important, you may grow to appreciate the symphony of chemical reactions that take place within a living organism, whether it's a one-celled organism, a tree, or a person. Just as each individual instrument contributes to an orchestra, each chemical reaction in an organism is necessary, and sometimes its part is quite complex. However, when you combine all the instruments and each instrument functions well, the result can be a wonder to behold. If one or two instruments are a little out of tune or aren't played well, the orchestra still functions, but things are a little off. The sound isn't quite as beautiful or there's a nagging sensation of something being wrong. The same is true of an organism. If all the reactions occur correctly at the right time, the organism functions well. If a reaction or a few reactions are off in some way, the organism may not function nearly as well. Genetic diseases, electrolyte imbalance, and other problems may cause the organism to falter. And what happens then? Biochemistry is often the field in which ways of restoring the organism to health are found and cures for many modern medical maladies are sought.

About This Book

Biochemistry For Dummies is an overview of the material covered in a typical college-level biochemistry course. In this second edition we attempted to update the material and correct the errors and omissions that crept into the first edition. We hope that this edition is of even more help than the first. We've made every attempt to keep the material as current as possible, but the field is changing ever so quickly. The basics, however, stay the same, and that's where we concentrate our efforts. We also include information on some of the applications of biochemistry that you read about in your everyday life, such as forensics, cloning, gene therapy, genetic testing, and genetically modified foods.

As you flip through this book, you see a lot of chemical structures and reactions. Much of biochemistry revolves around knowing the structures of the molecules involved in biochemical reactions. Function follows form. If you're in a biochemistry course, you've probably had at least one semester of organic chemistry. You'll recognize many of the structures, or at least the functional groups, from your study of organic chem. You'll see many of those mechanisms that you loved (and hated) here in biochemistry.

If you're taking a biochemistry course, use this rather inexpensive book to supplement that very expensive biochemistry textbook. If you bought this book to gain general knowledge about a fascinating subject, try not to get bogged down in the details. Skim the chapters. If you find a topic that interests you, stop and dive in. Have fun learning something new.

Conventions Used in This Book

We organize this text in a logical progression of topics that may be used in a biochemistry course. Along the way, we use the following conventions to make the presentation of information consistent and easy to understand:

- New terms appear in *italic* and are closely followed by their definition.
- We use **bold text** to highlight keywords in bulleted lists.

We also make extensive use of structures and reactions. While reading, try to follow along with the associated figures.

What You're Not to Read

Don't read what you don't need. Concentrate on the area(s) in which you need help. If you're interested in real-world applications of biochemistry, by all means read those sections (indicated by the Real World icon). However, if you just need help on straight biochemistry, feel free to skip the applications.

We also include some interesting topics in sidebars, the shaded boxes you find in many chapters. In those, you get a more in-depth look at some nonessential areas of biochem.

You don't have a whole lot of money invested in this book, so don't feel obligated to read everything. When you're done, you can put it on your bookshelf alongside *Chemistry For Dummies, The Doctor Who Error Finder,* and *A Brief History of Time* as a conversation piece.

Foolish Assumptions

We assume — and we all know about the perils of assumptions — that you're one of the following:

- A student taking a college-level biochemistry course
- A student reviewing your biochemistry for some type of standardized exam (the MCAT, for example)
- An individual who wants to know something about biochemistry
- A person who's been watching way too many forensic TV shows

If you fall into a different category, we hope you enjoy this book anyway.

How This Book Is Organized

Here's a very brief overview of the topics we cover in the various parts of this book. Use these descriptions and the table of contents to map out your strategy of study.

Part I: Setting the Stage: Basic Biochemistry Concepts

This part deals with basic aspects of chemistry and biochemistry. In the first chapter you find out about the field of biochemistry and its relationship to other fields within chemistry and biology. You also get a lot of info about the different types of cells and their parts. In Chapter 2 we review some aspects of water chemistry that have direct applications to the field of biochemistry, including pH and buffers. Finally, you end up with a one-chapter review of organic chemistry, from functional groups to isomers.

Part II: The Meat of Biochemistry: Proteins

In this part we concentrate on proteins. We introduce you to amino acids, the building blocks of proteins. Having the building blocks in hand, in the next chapter we show you the basics of amino acid sequencing and the different types of protein structure. We finish this part with a discussion of enzyme kinetics, both catalysts (which speed up reactions) and inhibitors (which slow them down).

Part III: Carbohydrates, Lipids, Nucleic Acids, and More

In this part we show you a number of biochemical species. You'll see that carbohydrates are far more complex than that doughnut you just ate may lead you to believe, but we do show you some biochemistry that is just as sweet! Then we jump over to lipids and steroids. Next are nucleic acids and the genetic code of life with DNA and RNA. Then it's on to vitamins (they're involved more than once a day) and hormones (no humor here — it would just be too easy).

Part IV: Bioenergetics and Pathways

It all comes down to energy, one way or another. In these chapters we look at energy requirements and where that energy goes. This is where you meet our friend ATP and battle the formidable citric acid cycle. Finally, because you'll be hot and sweaty anyway, we throw you into the really smelly bog of nitrogen chemistry.

Part V: Genetics: Why We Are What We Are

In this part we tell you all about making more DNA, the processes of replication, and several of the applications related to DNA sequencing. Then it's off to RNA and protein synthesis.

Part VI: The Part of Tens

In this final part of the book we discuss ten great applications of biochemistry to the everyday world and reveal ten not-so-typical biochemical careers.

Icons Used in This Book

If you've ever read a *For Dummies* book (such as the wonderful *Chemistry For Dummies*), you'll recognize most of the icons used in this book, but here are their meanings anyway:

The Real World icon points out information that has a direct application in the everyday world. These paragraphs may also help you understand the bigger picture of how and why biochemical mechanisms are in place.

This icon is a flag for those really important points that you shouldn't forget as you go deeper into the world of biochemistry.

We use this icon to alert you to a tip on the easiest or quickest way to learn a concept. Between the two of us, we have almost 70 years of teaching experience. We've learned a few tricks along the way and we don't mind sharing.

The Warning icon points to a procedure or potential outcome that can be dangerous. We call it our Don't-Try-This-At-Home icon.

Where to Go from Here

The answer to where you should start really depends on your prior knowledge and goals. As with all *For Dummies* books, this one attempts to make all the chapters discrete so that you can pick a chapter containing material you're having difficulty with and get after it, without having to have read other chapters first. If you feel comfortable with the topics covered in general and organic chemistry, feel free to skip Part I. If you want a general overview of biochemistry, skim the remainder of the book. Dive deeper into the gene pool when you find a topic that interests you.

And for all of you, no matter who you are or why you're reading this book, we hope that you have fun reading it and that it helps you increase your understanding of biochemistry.

Part I

Setting the Stage: Basic Biochemistry Concepts

The 5th Wave By Rich Tennant

"I love this time of year when the biochem students start exploring new and exciting ways for bonding carbon atoms."

In this part . . .

We go over some basic aspects of chemistry, organic chemistry, and biochemistry. First we survey the field of biochemistry and its relationship to other disciplines within chemistry and biology. We cover several different types of cells and their parts. Then we look at some features of water chemistry that apply to biochemistry, paying attention to pH and buffers. In the end, you get a brush-up on your organic chemistry, which sets the stage for Part II.

Chapter 1

Biochemistry: What You Need to Know and Why

In This Chapter

- Understanding the importance of biochemistry
- Looking at the parts and functions of animal cells
- Seeing the differences between animal and plant cells

If you're enrolled in a biochemistry course, you may want to skip this chapter and go right to the specific chapter(s) in which we discuss the material you're having trouble with. But if you're *thinking* about taking a course in biochemistry or just want to explore an area that you know little about, keep reading. This chapter gives you basic information about cell types and cell parts, which are extremely important in biochemistry.

Sometimes you can get lost in the technical stuff and forget about the big picture. This chapter sets the stage for the details.

Why Biochemistry?

We suppose the flippant answer to the question "Why biochemistry?" is "Why not?" or "Because it's required."

That first response isn't a bad answer, actually. Look around. See all the living or once living things around you? The processes that allow them to grow, multiply, age, and die are all biochemical in nature. Sometimes we sit back and marvel at the complexity of life, fascinated by the myriad chemical reactions that are taking place right now within our own bodies and the ways in which these biochemical reactions work together so we can sit and contemplate them.

When John learned about the minor structural difference between starch and cellulose, he remembers thinking, "Just that little difference in the one linkage between those units is basically the difference between a potato and a tree." That fact made him want to learn more, to delve into the complexity of the chemistry of living things, to try to understand. We encourage you to step back from the details occasionally and marvel at the complexity and beauty of life.

What Is Biochemistry and Where Does It Take Place?

Biochemistry is the chemistry of living organisms. Biochemists study the chemical reactions that occur at the molecular level of organisms. Biochemistry is normally listed as a separate field of chemistry. However, in some schools it's part of biology and in others it's separate from both chemistry and biology.

Biochemistry really combines aspects of all the fields of chemistry. Because carbon is the element of life, *organic chemistry* plays a large part in biochemistry. Many times biochemists study how fast reactions occur — that's an example of *physical chemistry.* Often metals are incorporated into biochemical structures (such as iron in hemoglobin) — that's *inorganic chemistry.* Biochemists use sophisticated instrumentation to determine amounts and structures — that's *analytical chemistry.* And biochemistry is also similar to *molecular biology;* both fields study living systems at the molecular level, but biochemists concentrate on the chemical reactions that occur.

Biochemists may study individual electron transport within the cell, or they may study the processes involved in digestion. If it's alive, biochemists study it.

Types of Living Cells

All living organisms contain cells. A *cell* is not unlike a prison cell. The working apparatus of the cell is imprisoned within the "bars" — known as the *cell membrane.* Just as a prison inmate can still communicate with the outside world, so can the cell's contents. The prisoner must be fed, so nutrients must be able to enter every living cell. The cell has a sanitary system for the elimination of waste. And, just as inmates may work to provide materials for society outside the prison, a cell may produce materials for life outside the cell.

Cells come in two types: prokaryotes and eukaryotes. (Viruses also bear some similarities to cells, but these are limited. In fact, many scientists don't

consider viruses "living.") Prokaryotic cells are the simplest type of cells. Many one-celled organisms are prokaryotes.

The simplest way to distinguish between these two types of cells is that a *prokaryotic cell* contains no well-defined nucleus, whereas the opposite is true for a *eukaryotic cell.*

Prokaryotes

Prokaryotes are mostly bacteria. Besides the lack of a nucleus, a prokaryotic cell has few well-defined structures. The prison wall has three components: a cell wall, an outer membrane, and a plasma membrane. This wall allows a controlled passage of material into and out of the cell. The materials necessary for proper functioning of the cell float about inside it, in a soup known as the *cytoplasm.* Figure 1-1 depicts a simplified version of a prokaryotic cell.

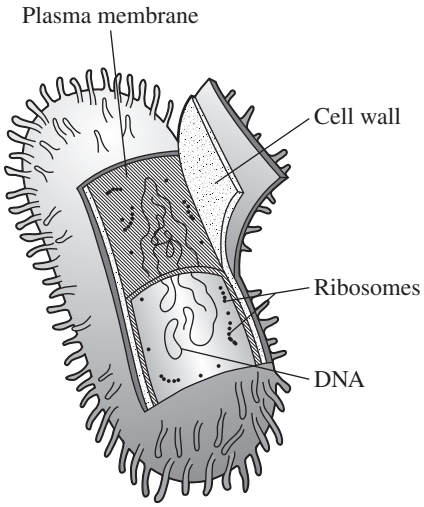

Figure 1-1: Simplified prokaryotic cell.

Eukaryotes

Eukaryotes are animals, plants, fungi, and *protists* (any organism that isn't a plant, animal, or fungus; many are unicellular organisms, while others are multicellular, like algae). *You* are a eukaryote. In addition to having a nucleus, eukaryotic cells have a number of membrane-enclosed components known as *organelles.* Eukaryotic organisms may be either unicellular or multicellular. In general, eukaryotic cells contain much more genetic material than prokaryotic cells.

Animal Cells and How They Work

All animal cells (which, as you now know, are eukaryotic cells) have a number of components, most of which are considered to be organelles. These components, and a few others, are also present in plant cells (see the section "A Brief Look at Plant Cells" later in the chapter). Figure 1-2 illustrates a simplified animal cell.

The primary components of animal cells include

- **Plasma membrane:** This separates the material inside the cell from everything outside the cell. The *plasma* or *cytoplasm* is the fluid inside the cell. For the sake of the cell's health, this fluid shouldn't leak out. However, necessary materials must be able to enter through the membrane, and other materials, including waste, must be able to exit through the membrane. (Imagine what a cesspool that cell would become if the waste products couldn't get out!)

  Transport through the membrane may be active or passive. *Active transport* requires that a price be paid for a ticket to enter (or leave) the cell. The cost of the ticket is energy. *Passive transport* doesn't require a ticket. Passive transport methods include *diffusion, osmosis,* and *filtration.*

- **Centrioles:** These behave as the cell's "train conductors." They organize structural components of the cell like *microtubules,* which help move the cell's parts during cell division.

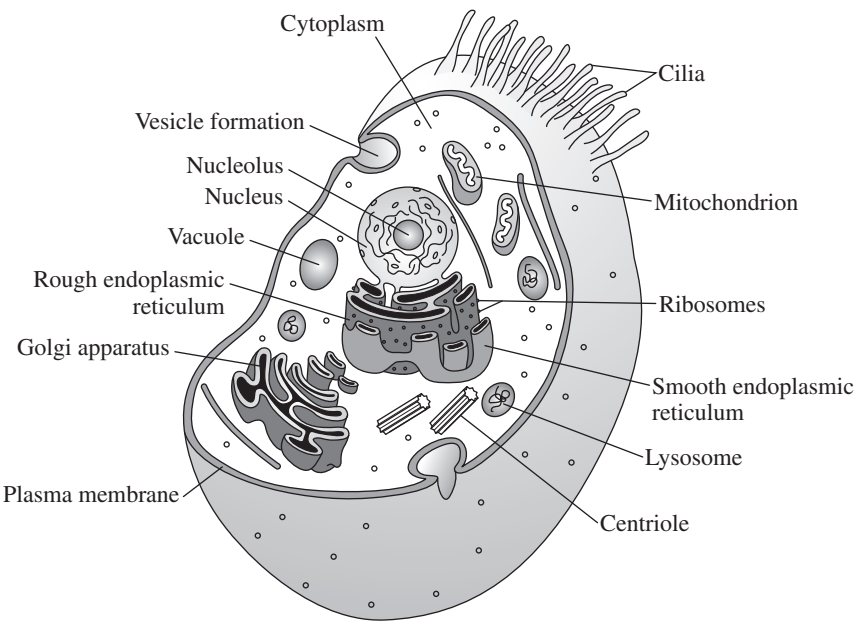

Figure 1-2: Simplified illustration of an animal cell.