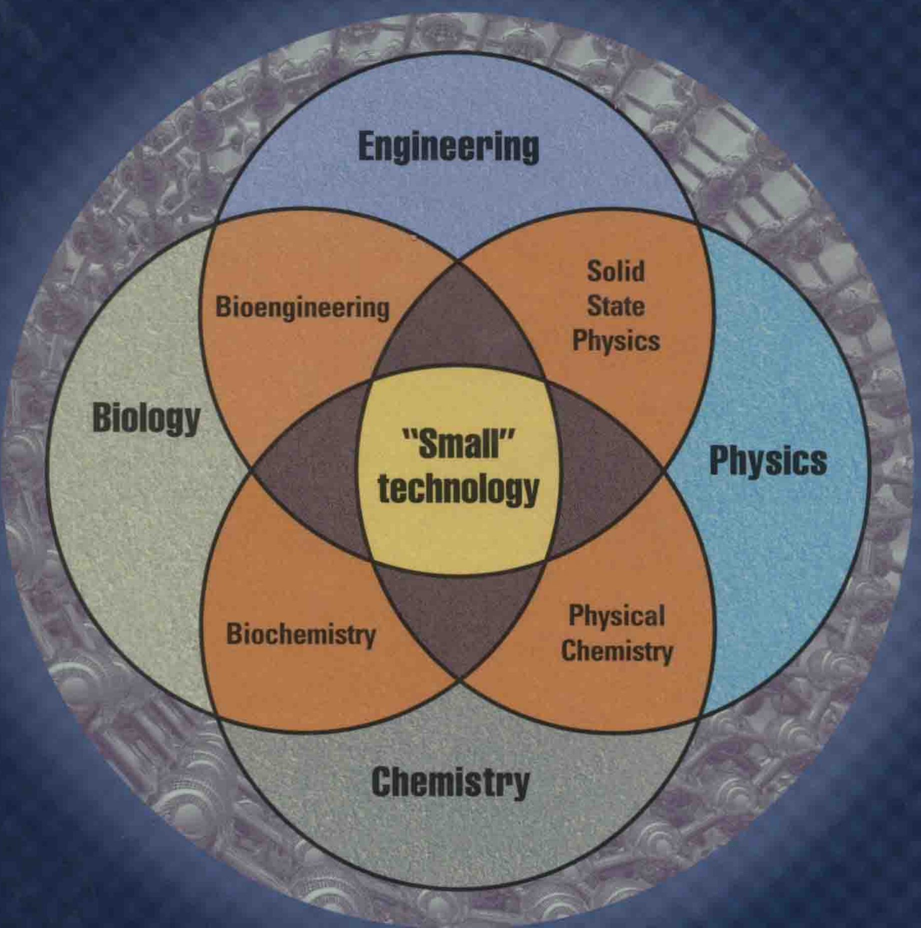
Learning Bio-Micro-Nanotechnology



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Learning Bio-Micro-Nanotechnology

This book is in memory of my late parents (Ben and Bernadine Mendelson) and my teachers, who taught me the importance of lifelong learning and who spent time helping me through the tough times when learning did not come so easy.

The book is dedicated to my wife, Roberta (the baby of all), who saved my life after a heart attack and open heart surgery. She is my soul mate, who never stopped loving me during the difficult years. Without her loyalty and devotion, this book would never have been completed.

Preface

GOALS OF THIS TEXTBOOK

To the author's knowledge, there are no primer textbooks that teach the vocabulary and fundamental concepts of micro- and nanotechnology with multidisciplinary applications in electronics, computers, biomedicine, and chemistry. This textbook, *Learning Bio-Micro-Nanotechnology*, fills this gap, and it can be used as a textbook at the college freshman to sophomore level. The goals of the textbook are threefold: (1) providing an introduction into the small world with a low *fog index*, (2) emphasizing the concepts and using analogies and illustrations to simplify the non-observables, and (3) integrating several disciplines to educate the "whole student." These goals are explained in more detail below.

First and foremost, this textbook is designed for students who lack the cross-disciplinary background and knowledge of micro- and nanotechnology. It is purposely written with a fog index of ~14. Many illustrations have been used to make the concepts more easily understood. There are math reviews (Appendices A–D) and group learning guidelines (Appendix E). There is also a glossary of terms (Appendix F) for the physical and life sciences, and engineering. Although the book is described as a primer, this is not a simple textbook to comprehend, because many of the concepts are advanced. However, it is hoped the writing style and illustrations will allow the student to quickly grasp the concepts.

This textbook is devoted to learning the fundamentals about our small world at a lower level. It offers many thinking exercises and a summary at the end of each chapter. The questions and problems are divided into increased hierarchical learning skills according to Bloom's Taxonomy: (1) remembering and understanding, (2) applying and analyzing, (3) evaluating and creating, and (4) group learning. There is some storytelling, a little humor, and cartoons to remind students that learning science and engineering does not have to be serious. Hopefully, this will make learning more enjoyable in Prof. Feynman's style of teaching. Learning involves critical thinking. Both convergent and divergent thinking will be used throughout this textbook. Convergent thinking pushes students toward one answer, while divergent thinking pushes them toward many answers and interpretations. In addition, there are many references included at the end of each chapter for more in-depth reading.

Many analogies and illustrations are created between things we can see and those we cannot see in the micro- and nanoworlds. The analogies and illustrations are used throughout the chapters to provide an easier, intuitive understanding of the concepts. For example, students have trouble visualizing electron mobility. Often fluid flow (called "e-water") is used as an analogy for electron flow, because students can see fluids flowing. It is not necessary for the students to have a background in advanced mathematics, quantum mechanics, organic chemistry, molecular biology, and microelectronics. In most cases, the mathematics is purposely kept at a low level, and many of the calculations are performed using dimensional analysis from first principles in chemistry, physics, and engineering.

Micro- and nanotechnology are cross-disciplinary areas of technology. This book attempts to break down the boundaries between biology, chemistry, physics, engineering, and ethics. It attempts to merge the disciplines. The book accomplishes this by comingling the vocabulary and concepts of these disciplines. It is the author's belief that integrating the disciplines is necessary to educate the well-rounded student of the twenty-first century.

ORGANIZATION

This textbook is a gentle introduction into the small world that answers three basic questions: What is it (the definition or description)? Why is it important (the significance)? How does it work (the concept)?

The book leans toward biomedical, chemical, electronic, and computer applications. It demonstrates the close relationship between the sciences and engineering. Chapters 1–6 describe the scientific fundamentals of micro-nanotechnology, and Chapters 7–12 cover the engineering applications. The chapters are broken down by discipline in order to easily organize the topics. However, there are many cross-disciplinary topics and examples included in the chapters, because our nanoworld is multidisciplinary. The textbook is organized as follows:

Chapter 1 provides an overview of the textbook. It emphasizes powers of 10, size-scaling, the relationship between big and small, and key definitions.

Chapter 2 covers DNA, RNA, proteins, and cell structures. It includes DNA sequencing and the ways in which micro- and nanotechnology can assist us.

Chapter 3 discusses chemical bonding, surfaces, nanomolecules, macromolecules, colloids, and polymers as they relate to different applications, and it overlaps Chapter 2.

Chapter 4 examines topics in modern physics (surface tension, quantum mechanics, wave–particle duality, electron tunneling, and the electron energy levels in atoms), and it overlaps Chapter 3.

Chapter 5 shows how control systems and digital devices work on a chip. Integrated circuits are explained.

Chapter 6 focuses on different types of microscopes, e.g., light, confocal, transmission and scanning electron, atomic force, and scanning tunneling.

Chapter 7 discusses the fabrication of current integrated circuits on a chip, some recent developments, and possible future directions.

Chapter 8 is devoted to the operation and application of microsensors, microactuators, and biochips (microarrays and microfluidics).

Chapter 9 shows how "small" technology can be used for targeting diseased cells, imaging them, treating them, and destroying cancer.

Chapter 10 suggests the possible risks of micro- and nanotechnology. Many of the risk factors are related to nanoparticle chemistry and surface effects.

Chapter 11 describes various ethics principles and includes some major ethical issues in micro- and nanotechnology, some ethical dilemmas, and case studies.

Chapter 12 discusses self-assembly in the nanoworld and forecasts some directions the technology could take us in the future.

USE OF THE TEXTBOOK

This book has something to offer students in science and engineering—from college freshmen to juniors. It can be used as text to teach a one semester or a two semester course. The prerequisites should be college chemistry (one course) and physics (at least one course). In a one semester course, all the topics cannot be covered; hence, they should be covered selectively. The selection of the topics is left up to the instructor, who should decide which topics will be taught.

This book is very flexible. It can be used for a *one semester course* for different audiences: (1) as a freshman course in chemistry or biology (for engineers) and (2) an introductory freshman/sophomore course in micro-nanotechnology. If it is used for a chemistry course, the following chapters are recommended—Chapters 3 and 4 with selected sections from Chapters 1, 2, 6, 10, 11, and 12. As a biology course for engineers, the following chapters are suggested—Chapters 1 and 2 with selected sections from Chapters 3, 4, 5, 6, 8, 9, 10, and 11.

As an interdisciplinary course in micro-nanotechnology, the textbook can be used for a *two semester course*. For example, Chapters 1–6 can be used for the first semester that covers the basic scientific fundamentals. Then Chapters 7–12 can be used for the second semester that covers engineering applications.

As another example, various topics in the book can also be utilized for a two semester course, where the selected sections of all the chapters can be used. See the table below.

	Two Semester Course	
Chapter	**Fall**	**Spring**
Chapter 1: Thinking small and big	All sections	—
Chapter 2: Biomolecules and cells	2.1 through 2.5	2.5 through 2.9
Chapter 3: Molecular chemistry	3.1 through 3.4	3.5 through 3.8
Chapter 4: Bit of physics	4.1 through 4.4	4.5, 4.6
Chapter 5: Engineering bits and bytes	5.1, 5.2	5.3 through 5.4
Chapter 6: Seeing small things	6.1 through 6.3	6.4 through 6.7
Chapter 7: Nanoelectronics	7.1 through 7.3	7.4 through 7.7
Chapter 8: Microelectromechanical systems	8.1 through 8.3	8.4 through 8.6
Chapter 9: Nanotechnology and cancer	9.1 through 9.4	9.5 through 9.7
Chapter 10: Risks: nano or mega?	10.1 through 10.3	10.4 through 10.7
Chapter 11: Ethics and social relevance	11.1, 11.2	11.3 through 11.5
Chapter 12: Self-assembled future	12.1 through 12.7	12.8 through 12.13

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Mel I. Mendelson was born in San Francisco and raised in San Mateo, California. He received his BS from the University of California, Berkeley, in 1964 and his PhD from Northwestern University in 1973, all in materials science. He has authored over 80 publications in the areas of engineering education, materials science, and nanotechnology. He is a fellow of the Institute for the Advancement of Engineering and the American Ceramic Society. He is also a member of the American Society for Engineering Education (ASEE) and the American Association for the Advancement of Science (AAAS). He has over 15 years industrial experience working in the electronics and aerospace industries. He joined Loyola Marymount University in 1994 and is currently a professor of mechanical engineering. He teaches courses in biotechnology, nanotechnology, information technology, materials science, statistics, and statics. His main interests are in micro- and nanotechnology, multidisciplinary education, and design of experiments.

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