Preface

This book is an introductory textbook/learning tool for biological physics, not a survey of current knowledge in biophysics. When faced with competing descriptions that are (1) simple and didactic or (2) more complex, accurate and correct, the authors have chosen the former. The book addresses a common need of university students enrolled in physical and biological science and engineering programs to learn the physical and quantitative aspects of biological systems, especially on a micro- and nanoscale, as a counterpart to descriptive and genetic approaches developed in other courses. A task typically assigned to the "biophysics" faculty in a physics department is to teach introductory biophysics to a single class with both undergraduate and graduate students. Among these students may be sophomore to senior physics students; senior biology, chemistry, and engineering students; and a mix of chemistry, biochemistry, and physics grad students. Preparations in math, physics, and biochemistry vary widely. This book is for students who have taken at least a year of calculus-based physics. Readers will be aided by supplementary resources (see www.crcpress.com/9781138633414), including "active" versions of graphs and diagrams in the text, along with links to mathematical and biological/biochemical source data.

FOCUS AND APPROACH

This book contains material for an introductory undergraduate course covering the biological physics of macromolecules, subcellular structures, and whole cells, including interactions with light. This quantitative, intermediate-level textbook emphasizes the following:

1. Mathematical and computational tools—graphing, calculus, simple differential equations, diagrammatic analysis, and visualization tools
2. Randomness, variation, statistical mechanics, distributions, and spectra
3. The biological micro- and nanoworld: structures, processes, and the physical laws
4. Quantum effects—photosynthesis, UV damage, electron and energy transfer, and spectroscopic characterization of biological structures
5. Experimental methods—an overview of important methods in biophysics, plus a chapter on atomic force microscopy (AFM). This is a new addition to the second edition.

Besides the treatment of quantum effects, lacking in most general biophysics textbooks, this text includes online supplementary materials, with multimedia learning tools such as graphs, video clips, and animations that illustrate intrinsically dynamic processes. This multimedia component serves as a guide to reading and understanding the written text. The video clips and active graphs emphasize what is most obvious about biological systems: *living things move.*

Quantitative Understanding of Biosystems is a learning tool, not a repository of current research knowledge, and does not attempt to be comprehensive. Appendix materials point students to reviews of subject areas not covered in the text. This text also uses some of the "effective learning" ideas incorporated into most first-year general physics textbooks. These include graph- and diagram-centered physics and math, frequent checks of understanding and "tool training," and repetition of important ideas at higher levels or from different points of view. The multimedia aspect described above supports this learning approach.

Throughout the text, we focus on the behavior and properties of microscopic structures that underlie living systems. Students should gain significant computational and project experience and become competent at mastering higher-level software and quantitatively characterizing biosystems.

Biophysics and genetic engineering? The impact and relation of the genetic engineering and biophysics, addressed at the beginning of Chapter 1, should be discussed early in the course. "CRISPR/cas9," a gene-editing tool largely unknown to bioscientists in 2011, is now familiar to many high school science students. Because CRISPR gives detailed control of the biological synthetic apparatus to the investigator at relatively low cost, it would appear most structure/function and cause/effect questions—the soul of the biophysics enterprise—could be ceded to genetic engineers. Is there no longer a need for the detailed and sometimes expensive nano-structural investigations (e.g., atomic force microscopy) carried out by the biophysicist? Several chapters in this second edition will address the role of CRISPR in biophysical investigations.

TARGET AUDIENCE

The target audience of this book is the advanced *undergraduate student*, including physics, chemistry, biology/biochemistry, and biomedical engineering majors who have had one full year of physics, a year of general chemistry, plus an additional two to three semesters of science courses including coverage of the following areas: modern physics or physical chemistry, basic statistical mechanics, biochemistry, or biomolecular structure. Math or applied math majors with biological interests will also find a useful learning experience in this text. The level of math will be the equivalent of concurrent enrollment in an ordinary differential equations course. For the physics major or *graduate student* fascinated by but ignorant of the physics of biological systems, and for the chemistry, biochemistry, or bioengineering major who wants to learn about quantum and nanometer effects in biology, this book will provide an introduction sufficient to enter graduate programs in the biosciences or for employment in many biotech companies. This course is often cross-listed as an undergraduate/graduate course, with graduate students typically expected to complete more advanced problems and projects.

OMITTED TOPICS

This book is designed for the large majority of undergraduate physics programs that can offer, at most, one semester of biophysics. (As noted below in "Course Features and Suggestions to Instructors," it can be turned into a two-semester course by an experienced biophysics instructor.) Hard choices among important topics must be made. Our philosophy has been to choose topics and coverage (1) that constitute a self-contained, coherent *one*-semester course, (2) that give the "non-biophysics career" student a picture of the power and use of physics in this multidisciplinary field, as well as some serious computational experience in covered areas, and (3) that gives the biophysics career-bound student a solid foundation to enter bioscience graduate programs or gain employment in biotech firms. Finally, this work encourages active, long-term learning; i.e., students are asked to perform computations, simulations, and/or miniprojects in the areas covered, with the goal that they remember it for years to come.

Following is a list of important topics in biological physics that have been slighted.

1. Electrostatics, ion flow and nerve function. The contribution of electrostatic terms to free energy is introduced in Chapter 14. While some homework problems highlight the electric work done in moving ions across a typical membrane potential, as well as control of flow in ion channels, this second edition does not seriously deal with this extremely complex topic that is central to neuroscience.
2. Evolution, genetics, systems biology. Though Chapters 1 and 7 address recent developments in computational evolution and their integration with experimental genetic engineering, these three topics are largely left to other courses.
3. Human vision. Ray optics of the eye is covered in first-year physics textbooks. Chapter 15 on light-driven reactions describes the fundamental quantum-detection aspect of vision.
4. Brain function. This topic is much too large, multidisciplinary, and difficult to provide more than surface-level treatment, if given only a short time.

COURSE FEATURES AND SUGGESTIONS TO INSTRUCTORS

1. Know yourself and your students. The majority of your 2017 students probably do not address learning and academic challenges the same way as those from 2007. While the approach of physics is to work out answers and applications from basic principles, today's students have been trained from childhood to search for answers using online tools. Online tools are extremely valuable in biophysics and are used frequently in this text, but they are, indeed, *tools*, not a way of thinking.
2. Form small "working groups" of students with differing backgrounds (e.g., physics and biochemistry majors). Require them to collaborate on certain course projects. The goal is to exploit the strengths and strengthen the weaknesses of each. If possible, set aside a weekly period for collaborative computational, experimental (e.g., video microscopy), and presentational work.
3. Assign homework and projects. Three types of assignments are available: normal and advanced Problems, and Miniprojects. Advanced calculations are typically for graduate students (extra credit for undergraduate) and Miniprojects demanding 1–4 hours of research (open-ended, typically requiring reading of recent articles, development of a spreadsheet calculation, or simulations) can be assigned to pairs or groups of students with mixed backgrounds. Problems added to the second edition are often open-ended, with students and instructor determining the proper scope of the answers.
4. Be aware of student level. The text can be used for students ranging from bright sophomores to graduate students. It is designed to be appropriate for physics, as well as chemistry/biochemistry and biology students. The reading level is directed to undergraduates, with referrals to the supplementary CD for further explanations and practice in difficult areas. Chapter 3, on mathematical methods, should not normally be covered in its entirety. Graduate students in physics, math, or engineering may not need any of it; undergraduate or graduate students in biology may need much of it.[1] Use it selectively to address individual student needs.
5. Teach students to read the text and check that they do. Students must go through (1) preparing to read a section (knowing what to expect, what to understand if everything else escapes you, where to go if the math is overwhelming); (2) reading the section; (3) completing a guided exercise; (4) checking understanding through short-answer questions with solutions provided; (5) reading again, if necessary; and (6) completing assigned problems and projects, at graded levels (sophomore to graduate).
6. Focus on quantitative understanding. Quantitative analysis is what physics is good for. Written, qualitative descriptions are forgotten within a few months and cannot take the place of quantitative tasks and understanding. Calculating the effectiveness of sunscreen X from its spectrum and absorption coefficient will lead to better understanding than reading that sunscreen X has an SPF of 30. Encourage students to reason, calculate, and connect, not just remember.
7. Use computational and other computer-based problems and projects. Frequent use of common software such as Microsoft Excel is made, because most students know the basics, most employers expect such expertise, and such software reinforces understanding of data points and distribution functions. Molecular structure software, freely available on the Web and easy to learn, will facilitate dealing quantitatively with complex biomolecular structures. Miniprojects at the ends of many chapters often employ such methods. Online software and its interaction with web browsers and plugins change frequently. Before the course begins, the instructor should check how files in the Supplementary Resources (available online at http://textbooksonline.tandf.co.uk/), as well as the online software in Chapter 5, behave on both Windows and Mac computers with the latest and with older operating systems and software. If necessary, arrange for student access to institutional computers preloaded with appropriate operating systems and software.

The author believes this textbook demands an "expert" biophysics instructor less than some other texts, owing to its structure and resources. The coverage—physics, chemistry, biology, and math—is unusually broad for a "physics" textbook, but none of it is particularly difficult.

The software is basic and typically available to all students: NGL, Protein Workshop, JsMol/Jmol, PV, Simple Viewer, Ligand Explorer, 3DNA, RNAView, and other online visualization tools. Common software such as Microsoft Excel will be used, with "live" spreadsheets rather than static graphs (Mathematica, Maple, SigmaPlot, etc. can also be used) to exploit common computer expertise and to encourage understanding of connections between a function or distribution and the values on the graph axes.

[1] The student who is unfamiliar with more than half of Chapter 3 should be encouraged to learn more math before enrolling in the biophysics course. In extreme cases, offer a separate course section that excludes Chapter 8 and quantum-intensive sections of Chapters 9 through 11. Be aware, however, that this course constitutes a rare opportunity for a student to learn the relevance of quantum mechanics to biology.

8. Embrace quantum effects. This text takes a diagrammatic approach to understanding quantum effects in biological systems, with differential equation extensions for advanced students. Physical aspects of photobiophysics and photosynthesis, neglected topics of our day with connections to renewable energy, can then be handled with quantum treatments that have applications to other biophysical and biomedical phenomena.
9. Adjust coverage to the particular goals of your course. A typical application is a one-semester core course for physics majors in a biophysics track, a recommended elective for biomedical engineering and biochemistry majors, and a recommended elective for biology majors in a quantitative track. The text could serve as the basis for a two-semester course: Part III or IV could be placed into a second semester, possibly with additional material. A second semester might be appropriate, for example, for students who need more time to learn quantum physics and experimental methods, and who want to more thoroughly explore nanobiophysics and its relation to nanotechnology.

Suggested chapter coverage: one-semester course, well-prepared students

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Chapters	1, 2	4	5	6	7	8	9	10 or 11	12	13	14	15	16	17 or 18	19

See the book's dedicated webpage at the publisher's site for online supplements, including full-color images available to download: www.crcpress.com/9781138633414.

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The MathWorks, Inc.
3 Apple Hill Drive
Natick, MA 01760-2098 USA
Tel: 508 647 7000
Fax: 508-647-7001
E-mail: info@mathworks.com
Web: www.mathworks.com