BOOK REVIEWS

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Physical Biology of the Cell. Rob Phillips, Jane Kondev, Julie Theriot, and Hernan Garcia. 800 pp. Garland Science, Taylor and Francis Group, London, 2008. Price: $130.00 (paper) ISBN 978-0-8153-4163-5. (Bernard Chasan, Reviewer.)

The authors of this book are, in a very real sense, missionaries. They want to convince a wide audience to share their enthusiasm for and commitment to a more quantitative and scientifically rigorous approach to cell biology than is normally encountered in the teaching literature.

To achieve this goal, they set out a program of quantitative model building based on physical principles. This is by no means a brand new approach. The Hodgkin-Huxley model for action potential propagation on neurons and the Monod–Wyman–Changeaux model for allostery in hemoglobin have been standard topics in biophysics courses for over 50 years.

Nevertheless, what the authors describe (awkwardly but evocatively) as the mathematizing of the semiqualitative models of cell biology (referred to as "cartoons" in some circles) has now become central to cell biology—as evidenced by a half a dozen recent texts and the relatively new and thriving discipline of systems biology. The work being reviewed is the latest and most comprehensive attempt to foster and advocate for this approach.

The first four chapters of this large work (800 pages!), collectively titled "The Facts of Life," are intended to prepare students (and scientists past their student years) coming from both biology and the physical sciences and engineering. The stage is set for the rest of the text.

The physical side gets the benefit of a rather unique introduction to cell biology, which is centered on a narrative about the species (*E. coli*, yeast, the fruit fly), which have played a central role in the development of molecular biology; I suspect that biology students will find this material of great interest as well. The examples are well chosen to foreshadow topics that are treated later in the book. For the biologists, mathematics is very gently introduced. The careful introduction of mathematical methods throughout the book is an attractive feature.

The authors are as concerned with the methodology needed to learn and participate in this quantitative approach as they are in the development of the subject itself—the two concerns are in fact intertwined.

At the center of their approach is the art of model making—well presented with the aid of some excellent figures, which show the choices needed to model proteins, as one example. The main point is that modeling requires a simplifying choice, which emphasizes one view of the protein and essentially ignores others. If it suits your purposes to model the protein as a collection of hydrophobic and hydrophilic amino acid residues—a good model for protein folding—then you cannot at the same time consider the protein as a two state system.

As an aid in evaluating the results of the modeling process, the authors introduce order of magnitude estimation—an approach that has not played much of a role in biology. Physicists generally claim to like this approach, but it does not play as large a role in physics education as it might, so this section will serve all constituencies. Likewise, all readers are well served by a fascinating, detailed study of time scales in biology, a fresh look at a very basic subject that has been rather neglected.

This is a large, formidable book, which will very likely serve as a reference to researchers in the field and as an advanced text. In an AJP review, it is natural to ask: Can this book serve as the text in an introductory undergraduate course? Indeed it can. The first four chapters and a fifth on energy in the cell, perhaps with selected sections from later chapters, would serve very well, particularly since the authors have provided a wealth of good problems on a variety of levels.

True to its intentions, the balance of the work is devoted to its declared mission of mathematization applied to a more or less standard set of topics from molecular biophysics. Two nonstandard topics deserve to be mentioned. Chapter 15 deals with the consequences of crowding in the cell—a subject only recently addressed by biophysicists. Chapter 19 is about gene regulation and the complex networks linking genes and proteins. Here, as elsewhere in this book, the main approach is through equilibrium statistical mechanics, and it is fitting that there is an early chapter devoted to that discipline. The authors worry about the application of equilibrium statistical mechanics to life processes, but they work to justify it in individual cases as much as possible.

Something should be said about the tone of the book. It is a serious work, but the authors are refreshingly lighthearted in their approach. Chapter 2 begins with an Ode to *E. coli*—a very good start to a long journey of discovery.

Professor Chasan, emeritus professor of physics at Boston University, was an active researcher in biophysics. He has taught courses in biophysics on various levels—most recently as designer and lead lecturer in Summer minicourses for minority students offered in 2004 and 2005 under the auspices of the Biophysical Society.

Street-Fighting Mathematics: The Art of Educated Guessing and Opportunistic Problem Solving. Sanjoy Mahajan. 133 pp. The MIT Press, Cambridge, Massachusetts, 2010. Price: $25.00 (paper) ISBN: 978-0-262-51429-3. (John A. Adam, Reviewer.)

It was the first sentence in the Foreword by Carver Mead that stopped me. "Most of us took mathematics courses from mathematicians—Bad Idea!" Something flickered in the back of my mind…, and then I remembered that many moons ago, I was a physics undergraduate. And I took some mathematics courses from (junior faculty) mathematicians in the U.K. university system. So, that started me thinking about the teaching of mathematics to scientists and engineers….

But first, the book.[1] The first sentence in the Preface is, in a sense, isomorphic to that in the Foreword: "Too much mathematical rigor teaches rigor mortis: the fear of making an unjustified leap even when it lands on the correct result. Instead of paralysis, have courage—shoot first and ask questions later." In many ways, this approach reminds me of The Feynman Problem-Solving Algorithm (attributed to Murray Gell-Mann): (1) Write down the problem; (2) think very hard; and (3) write down the answer. But getting the right balance between rigor and intuition is crucial, especially in science. It was the mathematical statistician John Tukey who stated that "it is better to have an approximate answer to the right question than an exact answer to the wrong one." But Aristotle put it even more prosaically: "It is the mark of an instructed mind to rest satisfied with the degree of precision which the nature of the subject permits and not to seek an exactness where only an approximation of the truth is possible" (Nicomachean Ethics). And without wishing to "flog a dead horse," this latter statement is well illustrated by Ray Lee and Alistair Fraser in their comparison of the less accurate Airy theory of the rainbow with the more general and powerful Mie theory. They write, "Our point here is not that the exact Mie theory describes the natural rainbow inadequately, but rather that the approximate Airy theory can describe it quite well… As in many hierarchies of scientific models, the virtues of a simpler theory can, under the right circumstances, outweigh its vices." [*The Rainbow Bridge: Rainbows in Art, Myth and Science* by Lee and Fraser (Pennsylvania State U. P., University Park, PA, 2001).]

Bottom line: This is a very creative book. It contains an eclectic set of topics including dimensional analysis, guessing integrals, the Navier–Stokes equations, estimating populations, estimating derivatives, and summing series…; it is replete with tricks, short cuts, and thought-provoking questions. Indeed, I will find some of the examples very helpful when teaching Calculus II this summer!

There is a lovely section (2.4) devoted to using dimensional analysis to tease out the drag force associated with falling objects (for high Reynolds' number flows) and their terminal speeds. The author even provides a template that can be used to conduct experiments on falling cones. Using the result for the drag force elsewhere (5.2.3), Mahajan utilizes a simple argument to show that driving at 55 mph instead of 65 mph reduces gasoline consumption by about 30%.

Let me focus next on a subsection toward the end of the book entitled "Successive approximation: How deep is the well?" (5.4). Being directionally incompetent, I use this method when driving in an unknown area—I stop and ask directions, drive some more, stop and ask again, and so on. When the process converges rapidly, it is very satisfying. But sometimes it doesn't, and I end up a long way (and time) from my desired destination. It works well for this problem, however: We drop a stone down a well, and hear a splash 4 s later. Neglecting air resistance, we are to find the depth of the well to within 5%. There are two components to this problem of course: The free-fall time and the acoustic travel time, the latter being quite tiny relative to the former. The exact solution is, as a result of using the quadratic equation formula, a bit of a mess. Mahajan calls this a "high-entropy horror" and states that it signals the triumph of symbol manipulation over thought. Nicely put, Sir.

The "low-entropy" part is the free-fall time; it is easy to compute, being equivalent to solving the problem for infinite sound speed. This gives a depth of 80 m, about an 11% overestimate. But next comes the fun part—using that answer to approximate the sound-travel time (about 1/4 second), so recalculating the new free-fall time gives an answer correct to within 1.3%, and so on. I certainly don't need to calculate the depth of the well to several decimal places. The quadratic equation method can in principle do so to any required accuracy. But if we're going to pick nits, the temperature at the bottom of the well may be considerably lower than at the top, so the sound speed will be variable and generally decrease with depth. Air resistance has been neglected. We have assumed the gravitational acceleration from the surface of the Earth to the bottom of the well is a constant (and at 10 m/s^2, a slightly inaccurate one at that). We probably won't find a closed form solution to hide behind. But iterative methods, when appropriately used, can provide solutions, in principle, to any desired degree of accuracy.

In a section entitled "Daunting trigonometric integral" (5.5), a problem from an examination in the former USSR asks the examinee to evaluate the integral

$$\int_{-\pi/2}^{\pi/2} (\cos t)^{100} dt$$

to within 5% in less than 5 min without using a calculator or computer (or presumably a slide rule)! (Warning to calculus students: Do not try and use trigonometric identities please!) Mahajan's edict here is *find the big part*! Replacing $\cos t$ by the first two terms in its Maclaurin expansion, $1-t^2/2$, and noting that for small values of $|z|$, $(1+z)^n \approx e^{nz}$, $(\cos t)^{100} \approx e^{-50t^2}$; so a cosine raised to a high power on this interval is approximately a Gaussian function! By extending the limits to $\pm\infty$ (let's ask our students why) and using another integral ("guessed" in the first chapter),

$$\int_{-\infty}^{\infty} e^{-\alpha t^2} dt = \sqrt{\pi/\alpha},$$

and noting that here $\alpha = 50 \approx 16\pi$, the estimate is 0.25. To eight decimal places, the value is 0.25003696, an error of about 0.015%!

There are several recent books on the market in the general area of "educated guessing" and problem solving, including *Guesstimation: Solving the World's Problems on the Back of a Cocktail Napkin* by Weinstein and Adam (Princeton U. P., Princeton, NJ, 2008) and *How Many Licks? Or, How to Estimate Damn Near Anything* by Santos (Running Press, Philadelphia, PA, 2009). This book, however, goes well beyond the arithmetic/order-of-magnitude approach utilized therein, being more mathematically sophisticated while retaining the same essential philosophy: Why try and solve a hard problem exactly when you can find an approximate answer to a simpler one in much less time?

Definitions of what "applied mathematics" is will vary (especially between the U.S. and the U.K.), but it is safe to say that applied mathematics is what applied mathematicians do. Nevertheless, my working definition of an applied mathematician is someone who is comfortable working on the interface between mathematical rigor and physical intuition, moving back and forth as required, frequently corrugating that interface with nonlinear disturbances! This book is a fine example of such a philosophy and would be an excellent supplement in standard (and still necessary) "mathematical methods of physics" and "methods of applied mathematics" courses.

And what was the result of my "thinking" upon reading the very first sentence in the Foreword? Essentially, that while the distinctions between applied mathematics and "mathematical science" may be merely philosophical ones, those between pure and applied mathematics are not. Consequently, I think that whenever possible, scientists-in-training should be taught mathematics by applied mathematicians, that is, by mathematicians who satisfy the above working definition!

[1] The book is available free of charge on the web at http://mitpress.mit.edu/catalog/item/default.asp?ttype=2&tid=12156, click "Creative Commons Edition" under "Related Links."

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BOOKS RECEIVED

Advanced Mechanics and General Relativity. Joel Franklin. 385 pp. Cambridge U. P., New York, 2010. Price: $75.00 (hardcover) ISBN 978-0-521-76245-8.

Computational Methods in Plasma Physics. Stephen Jardin. 371 pp. CRC Press, Taylor and Francis Group, Boca Raton, FL, 2010. Price: $79.95 (hardcover) ISBN 978-1-4398-1021-7.

Fifty Years of Anderson Localization. Elihu Abrahams (editor). 608 pp. World Scientific, Hackensack, NJ, 2010. Price: $48.00 (paper) ISBN 978-981-4299-07-7.

A Grand and Bold Thing. Ann Finkbeiner. 232 pp. Free Press, New York, 2010. Price: $27.00 (hardcover) ISBN 978-1-4165-5216-1.

Introduction to Microfluids. Patrick Tabeling. 308 pp. Oxford U. P., New York, 2010. Price: $49.50 (paper) ISBN 978-0-19-958816-9.

Numerical Relativity: Solving Einstein's Equations on the Computer. Thomas W. Baumgarte and Stuart L. Shapiro. 716 pp. Cambridge U. P., New York, 2010. Price: $90.00 (hardcover) ISBN 978-0-521-51407-1.

Optically Polarized Atoms: Understanding Light-Atom Interactions. Marcis Auzinsh, Dmitry Budker, and Simon M. Rochester. 386 pp. Oxford U. P., New York, 2010. Price: $79.95 (hardcover) ISBN 978-0-19-956512-2.

The Shape of Inner Space: String Theory and the Geometry of the Universe's Hidden Dimensions. Shing-Tung Yau and Steve Nadis. 393 pp. Basic Books, New York, 2010. Price: $30.00 (hardcover) ISBN 978-0-465-02023-2.

Statistical and Thermal Physics: With Computer Applications. Harvey Gould and Jan Tobochnik. 528 pp. Princeton U. P., 2010. Price: $75.00 (hardcover) ISBN 978-0-691-13744-5.

Three Steps to the Universe: From the Sun to Black Holes to the Mystery of Dark Matter. David Garfinkle and Richard Garfinkle. The U. of Chicago Press, 2010. Price: $16.00 (paper) ISBN 978-0-226-28348-7.

INDEX TO ADVERTISERS