

will be able to replicate itself—that is, the information it contains. We all know life can sometimes be irrational, but is there really any difference between Life 3.1 and Life 3.1415...?

There's also a bit too much hagiography of Musk; too many plugs for funding the Future of Life Institute, of which Tegmark is a founder; and too

many photos and lists of people discussing AI at after-workshop dinners. Most of those could easily have been jettisoned to reduce the book's heft and to accentuate other material more essential to Tegmark's arguments.

Alas, Tegmark offers no solutions for AI life-forms that plague us today, such as AI chatbots or irritating Microsoft

paper clips. But he does offer hope, if we act quickly and intelligently. Will there be a Life 4.0, or even a Life 3.1? It's hard to know. Perhaps if humanity takes Tegmark's call to action seriously, there may be more than just hope. There may actually be a chance for a future.

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A pedagogical master class on biological physics

Philip Nelson's book *From Photon to Neuron: Light, Imaging, Vision* completes a trilogy begun by *Biological Physics* (2004) and *Physical Models of Living Systems* (2015). Those works establish Nelson as the preeminent author of textbooks at the intersection of physics and biology. All three books are aimed at upper-level undergraduates who already have studied a year of physics and calculus, but the texts are rich enough for the graduate level too.

From Photon to Neuron covers topics throughout biological physics. For instance, fluorescence microscopy is a theme Nelson introduces early and revisits often. He devotes one chapter to color vision and another to superresolution microscopy. My favorite chapter, "Imaging by X-Ray Diffraction," begins with Rosalind Franklin's iconic x-ray diffraction pattern of DNA and then develops enough theory to explain how James Watson and Francis Crick could, at a glance, obtain the key information they needed to derive their famous double helix structure.

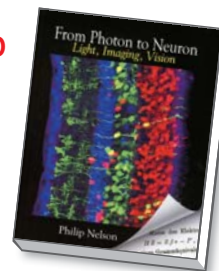
Nelson presents enough electrophysiology to describe how rhodopsin's absorption of a photon causes a voltage signal across the neural membrane and enough physical optics to explain the iridescence of butterfly wings. The network diagrams of signaling cascades are a little dry, but that may reflect my own tastes rather than Nelson's presentation. Other topics include photosynthesis, fluorescence resonance energy transfer (FRET), and two-photon imaging. David Goodsell's beautiful drawings (right) further enhance the material.

Instructors considering *From Photon to Neuron* may wonder if it is best suited for physicists interested in biology or biologists interested in physics. In my opinion, physics students will gain the most from this book, as they should be able to handle most of the mathematics. Biology majors will be challenged—Nelson includes, for example, the Fresnel integral—but the book will improve their quantitative skills. Instructors should also be aware that part 3 contains some advanced topics, such as the quantum mechanical analysis of the harmonic oscillator, that seem out of place in an undergraduate book. Students with a weak command of calculus and no desire to improve it may find Sönke Johnsen's excellent *The Optics of Life* (2011) more palatable.

The wave and particle properties of

From Photon to Neuron
Light, Imaging, Vision

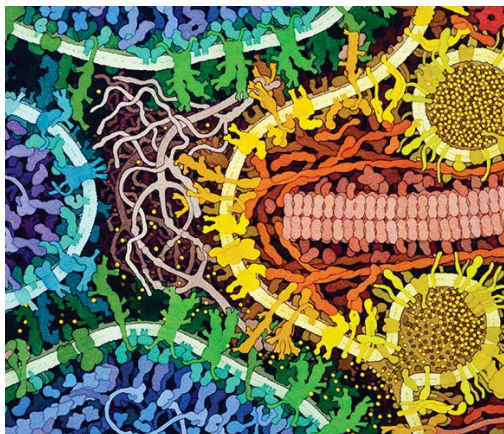
Philip Nelson
Princeton U. Press,
2017. \$110.00



light are both crucial to biology. For instance, diffraction limits visual acuity, but a rod cell in the retina responds to a single photon. Nelson adopts a perspective like the one Richard Feynman presented in *QED: The Strange Theory of Light and Matter* (1985): Photons are governed by a probability amplitude that obeys a stationary-phase principle. That powerful point of view highlights the intimate relationship between quantum mechanics, probability, and vision. Physics students will appreciate it; I am not sure what biology students will make of it. For me, it works. Its disadvantage is that you must add a lot of $e^{i\phi}$ terms to explain simple concepts like reflection and refraction.

Readers who are interested in vision but have little concern for light or imaging might prefer Robert Rodieck's masterpiece *The First Steps in Seeing* (1998). The books by Rodieck and Nelson share several characteristics: eloquent prose, outstanding artwork, and a quantitative approach that most biology textbooks lack. Nelson's book, however, is more useful for teaching; it includes homework problems, end-of-chapter summaries, and recommendations for additional reading.

Nelson's emphasis on computer code—or at least his insistence that the students write their own code—also sets his books apart. Many of his homework exercises



A NEURAL SYNAPSE. Painting by David S. Goodsell, as published in *From Photon to Neuron: Light, Imaging, Vision* by Philip Nelson. Copyright © 2017 by Philip C. Nelson. Reprinted by permission of Princeton U. Press.

require analyzing data that you can download from the author's website (www.physics.upenn.edu/~pcn). To do those exercises, you must know how to program a computer using MATLAB or similar software, and you can download Nelson's free Student Guide to MATLAB from his website. Computerphobes may hesitate initially, but they will gain the most from numerical modeling. Nelson uses words, pictures, formulas, and code to teach students how to construct mod-

els and interpret data. His books provide a master class in how to integrate those four different approaches into a complete learning experience.

Overall, I found *From Photon to Neuron* to be an outstanding textbook and a worthy successor to *Biological Physics* and *Physical Models of Living Systems*. Philip Nelson has done it again.

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The standard model in 271 pages

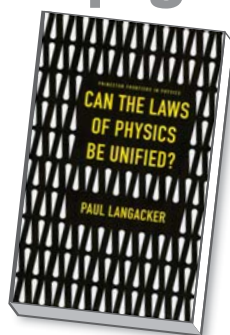
Princeton University Press recently began a Frontiers in Physics series whose purpose is to provide "short introductions to some of today's most exciting and dynamic research areas." The first few volumes focused on astronomy, but the series' latest offering deals with mainstream physics and carries the intriguing title, *Can the Laws of Physics Be Unified?* The author is Princeton University senior scientist and University of Pennsylvania emeritus professor Paul Langacker, who published a respected scholarly book, *The Standard Model and Beyond*, in 2010, with a second edition issued in 2017.

The audience for *The Standard Model and Beyond* is graduate students and researchers in elementary-particle physics. In the introduction to *Can the Laws of Physics Be Unified?*, however, Langacker writes that he has in mind a much broader readership: "This book is written for an undergraduate physics student, a practicing scientist in a related field, or any interested reader familiar with the basic ideas of classical physics, quantum theory, and relativity." Since the standard model is one of the crowning achievements of modern science, Langacker's goal is admirable. But it is also a challenging one, given that the standard model is expressed in the language of relativistic quantum field theory and requires the knowledge of gauge theories.

At 271 pages, the book is short and sweet and is published in a nice 5- by 8-inch size that encourages casual reading—I brought my copy along on vacation. Although I can attest to the accuracy of the text, it is not clear that I am the best judge of how the book will be received by its

Can the Laws of Physics Be Unified?

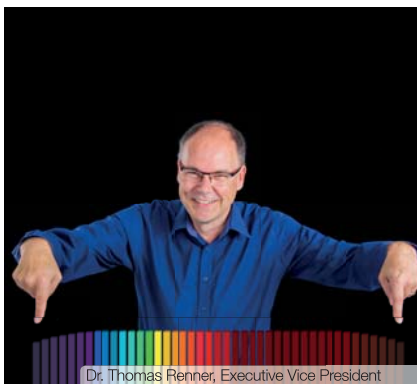
Paul Langacker
Princeton U. Press,
2017. \$35.00



intended audience. The author and I are about the same age (seventyish), and our careers have coincided with the golden years of particle physics, beginning in the late 1960s. Today we know that the standard model describes nearly all aspects of elementary-particle interactions.

Thus, as I read through the 80 pages introducing readers to the standard model and its implications, I was comfortable with the presentation and could fill in the blanks when Langacker simplified things. It was a pleasure to have those matters described by someone who really understands them.

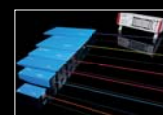
The casual reader, however, may be dismayed by the plethora of ideas being offered—gauge theory, asymptotic freedom, quarks, gluons, nonabelian fields, creation and annihilation operators, spontaneous symmetry breaking, the Higgs mechanism, Yang-Mills theory, color, quantum chromodynamics, accelerators, electroweak theory, *CP* (charge conjugation-parity symmetry) violation, and quark and neutrino mixing, to name just a few. I have had nearly half a century of study to assemble all those ideas into a coherent package in my mind. Absorbing them all in an afternoon would be considerably more challenging.



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