Biology unified by physics FREE

The Molecular Switch: Signaling and Allostery. , Rob Phillips, Princeton U. Press, 2020, $85.00 Buy on Amazon

Sangjin Kim

Physics Today **74** (8), 52–53 (2021);
https://doi.org/10.1063/PT.3.4817

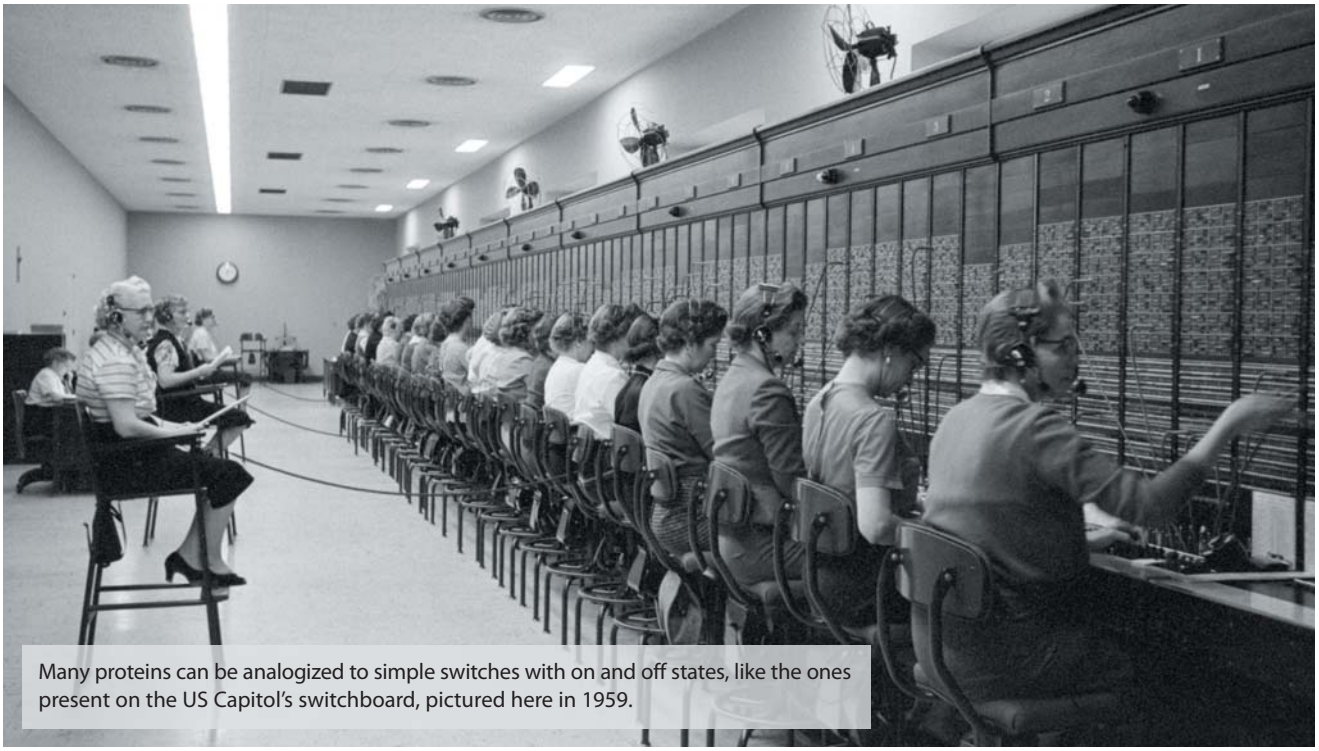
Einstein was being polite to Michelson, as Michelson had invited him to give that speech. Spence also claims that Einstein referred to Michelson's experiment in his 1905 paper "On the electrodynamics of moving bodies," but that is not the case. Although Einstein did allude to "unsuccessful attempts to discover any motion of the earth relatively to the 'light medium,'" historians like Gerald Holton have shown that he was not specifically referring to Michelson.

Spence points out that we now live in a moment where the concept of measuring the speed of light has been turned on its head. Einstein's work elevated c to a fundamental constant of nature, and in 1983 the General Conference on Weights and Measures gave it an exact value. Previously, the speed of anything had been measured by the distance—traditionally defined by the length of a platinum bar preserved in a vault in Paris—that it traveled over time, traditionally defined as a fraction of the day. But the conference has scrapped the platinum bar and effectively defined the speed of light as exactly 299 792 458 meters per second, meaning that the speed of light now determines the length of a meter.

Spence ends the book by asking whether there is any possibility of information moving faster than the speed of light. He then presents a lengthy discussion of Bell's theorem and spooky action at a distance, but notes that the question remains unresolved. He also mentions that the process of writing the book changed his own position on the matter.

Lightspeed has the tone of an exuberant physics lecture, complete with a lab exercise at the end that involves measuring the speed of light with pizza dough. The book's strength is its clear and thorough explanation of the underlying physics, which does not necessarily assume any prior knowledge of the subject but quickly accelerates to a high level. For that reason, it is hard to imagine someone sticking with Spence if they haven't already decided that they like physics. But for those of us who do, *Lightspeed* is an animated account that vividly evokes the numerous and often outsized personalities who contributed to figuring out just how fast light travels.

Theresa Levitt
University of Mississippi
Oxford



LIBRARY OF CONGRESS, LC-U9-1924-25

Many proteins can be analogized to simple switches with on and off states, like the ones present on the US Capitol's switchboard, pictured here in 1959.

Biology unified by physics

Biology is often taught with diagrams. But you can also teach it with equations, the language of physics. In his new book, *The Molecular Switch: Signaling and Allostery*, biophysicist Rob Phillips does just that, explaining allostery—a biological enigma—using the formalism of statistical physics.

Phillips is a professor of biophysics, biology, and physics at Caltech. He has authored or coauthored several books that creatively combine concepts from biology, physics, and materials science, including *Crystals, Defects and Microstructures: Modeling Across Scales* (2001); *Physical Biology of the Cell* (2nd edition,

The Molecular Switch
Signaling and Allostery
Rob Phillips
Princeton U. Press, 2020. $85.00

2012); and *Cell Biology by the Numbers* (2016). *The Molecular Switch* is another fantastic book in that vein. It is an elegant demonstration of how physics can be used to explain a biological concept and unify a wide range of biological phenomena. The book is a great introduction to biophysics for both physicists and biologists and a versatile reference for advanced undergraduate and graduate biophysics courses.

Proteins are the building blocks and functional molecular units of living cells. For cells to operate properly, proteins must function in a controlled manner. But how do they do that? Richard Feynman acknowledged in his 1963 lectures on physics that "everything that living things do can be understood in terms of the jigglings and wigglings of atoms." His maxim also holds true for proteins. They fold into elaborate three-dimensional structures and can interact with other molecules. Those intra- and intermolecular changes are dynamic and affect a protein's function over time.

If its activity changes on the binding of a small molecule, a protein is said to be allosteric, a term originally coined by Jacques Monod and François Jacob in 1961. Many, if not all, proteins are expected to be allosteric. Because its consequences are so profound, allostery has been called the second secret of life after the genetic code.

Despite its broad impact in the field, allostery is explained rather briefly in most biology textbooks, with just one example—namely, the cooperative binding of oxygen in hemoglobin, the protein that carries the molecule in our blood. The primary achievement of Phillips's new book is twofold: It expands the discussion of allostery to almost everything in nature and suggests a new paradigm for studying it.

As illustrated on the book's cover, that new paradigm is based on switches. Because many proteins can be likened to switches with on and off or active and inactive states, cellular functions can be viewed as input–output responses of those molecular switches. The switch analogy allows biophysicists to ignore the microscopic details of different allosteric molecules and analyze protein functions in terms of discrete states through the formalisms of equilibrium statistical physics.

Using that paradigm, Phillips aims to communicate with audiences from both biology and physics. He tactfully achieves that goal through his straightforward and logical organization. In chapters 1 and 2, Phillips explains allostery from the perspectives of biology and physics so that all readers are on the same page. He lays out basic statistical-physics concepts so that his model can be easily derived. In chapter 3, he uses the simple example of ion channels to demonstrate how statistical physics can be used to describe a molecular switch and experimentally measurable behaviors such as leakiness and dynamic range.

Phillips then applies that formalism with depth, breadth, and clarity to various biological topics, including the swimming of bacteria in response to a chemoattractant, cell signaling in such processes as photon detection in the eye, and gene regulation by transcription factors or nucleosomes. Those examples are presented not as information to be memorized but as a series of applications of the mathematical framework presented in the earlier chapters. Phillips also takes readers over multiple scales of biology, from animals to cells and molecules, and thus highlights the significance and universality of allostery in nature.

Teaching a biophysics course can be challenging because students have mixed backgrounds and expectations. Students from physics may be overwhelmed by biological details, which can prevent them from seeing biophysics' bigger picture. On the other hand, students from biology might feel frustrated by physics equations. *The Molecular Switch* serves students from both fields, who will be happy to see that a simple physical model can explain so many different and seemingly disparate phenomena. Another educational benefit of the book is that it teaches students how to develop effective theories to describe biological phenomena, which will be crucial for future collaborations between physicists and biologists.

The concept of allostery has been around for several decades. But who would have thought it could be used to create a physical law that unifies biology? Phillips does just that in *The Molecular Switch*. Anyone who likes the beauty of unification will appreciate his ingenious approach.

Sangjin Kim
University of Illinois at Urbana-Champaign