Quantifying and mimicking life

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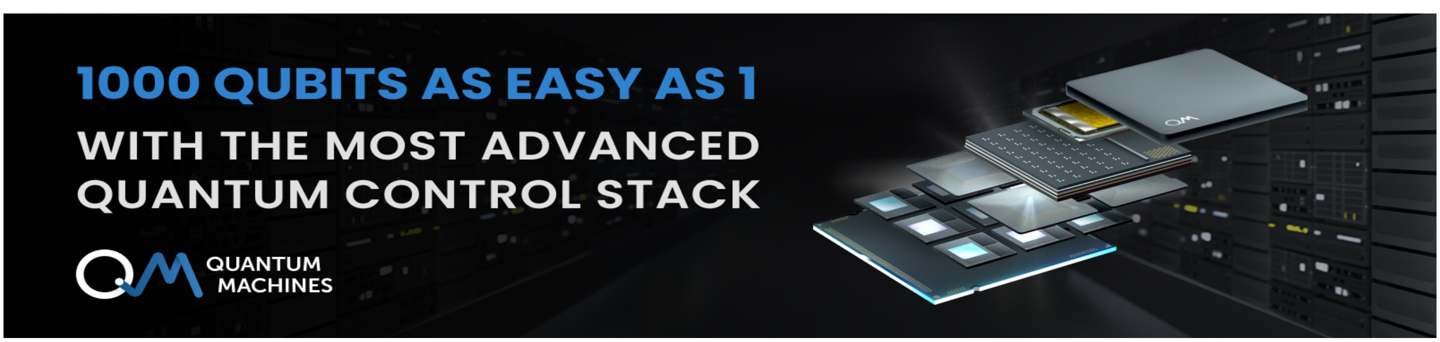

as theoretical physicists. Michael Faraday and James Clerk Maxwell introduced us to fields, a concept that formed the bedrock for Albert Einstein's theory of relativity and thereby the version of relativistic quantum mechanics that physicists use today.

In the later chapters, Dine switches to discussing developments in theoretical physics from his own vantage point. Memorable conversations, seminars he attended, and his own scientific collaborations form the common thread as the journey proceeds through two superstring revolutions to the current state of the field. Dine gives modest descriptions of theorems that bear his name, such as Affleck–Dine baryogenesis and the Dine–Seiberg problem in string theory, as well as anecdotes about colleagues. Notably absent, however, is Dine's seminal work with Ann Nelson, for which they shared the prestigious J. J. Sakurai Prize for Theoretical Particle Physics in 2018.

Woven through the book is a so-called journey through powers of 10, from the tiny scales at which the quantum nature of matter cannot be ignored to the vast scales ruled by Einstein's gravity. Even though the author provides examples to help readers imagine the enormous differences in scale, it might have been helpful if Dine had included illustrations in those sections.

The book occasionally touches on the sociology of science and the unfair exclusion of women and minorities from the academy. When Richard Feynman is first introduced, for example, a brief description of his career is accompanied by a footnote that refers to the current understanding of his misogyny. Although descriptions of early woman pioneers mention the hardships they faced, those remarks remain largely parenthetical. In short, the question of who gets to do science and at what cost is not a central theme in the book.

This Way to the Universe is an accessible and impressively complete account of the history and current state of research in theoretical physics. Dine's infectious enthusiasm about the quest for nature's underlying truths is obvious on every page. Fellow science enthusiasts will enjoy this book and its unusual peek into the journey of a theoretical physicist.

Djuna Croon
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Starlings flock in the sky above the Otmoor wetlands in Oxfordshire, England.

JAMES WAINSCOAT/UNSPLASH

Quantifying and mimicking life

When does matter become alive? Can the laws of physics describe living systems? To answer those vexing questions, early natural philosophers invoked notions of vitalism. But now we know better. Describing the living state is as much a physical problem as a biological one, and the modern tools of condensed-matter and nonequilibrium physics are two of the microscopes of choice for attacking it.

At the end of the 20th century, the field of active matter emerged as scientists increasingly and successfully treated living systems as materials. Broadly put, active matter refers to a large class of self-driven systems, each composed of many interacting entities that can independently and locally convert ambient free energy into sustained work or motion. In his latest book, *Active Matter Within and Around Us: From Self-Propelled Particles to Flocks and Living Forms*, the well-known author and complex-systems scientist Len Pismen provides a bird's-eye view of the young but rapidly growing field.

As the book's title suggests, active matter is pervasive throughout the natural world. It ranges in scale from the thermally buffeted motions of motor proteins in a cell to the mesmerizing swirls formed by large flocks of birds. In the past decade and a half, researchers have developed synthetic and artificial active systems that use such inanimate components as colloids, grains, or robots to ingeniously mimic lifelike behavior.

The science underlying active matter spans physics, biology, and materials science, and covering it all in a 200-page book is a difficult task. But it's one that Pismen takes up admirably. *Active Matter Within and Around Us* presents a curated display of recent developments in the field of active matter from the vantage point of an experienced surveyor.

The book's eight chapters can be roughly grouped into three parts. The first is devoted to large-scale and continuum models of active fluids that display polar and nematic orientational order. Well-known models of flocking physics and active liquid crystals are described alongside their basic phenomenology and some experimental realizations. Phase separation caused by crowding makes a brief appearance, and the dynamic role played by topological defects that are often present in active fluids is appropriately emphasized.

Although some open theoretical issues are highlighted, they are often quite technical and at times inaccurate or misleading. For instance, the book claims that the Toner–Tu equations—which are used to describe flocks as a continuum fluid—rely on momentum conservation, Galilean invariance, and an equation of state for pressure. But those assumptions were explicitly broken in the model's formulation.

The focus shifts in the second part to microscopic active agents, both synthetic and biological. Mechanisms for propelling colloids and drops through viscous fluids are discussed, as are the particles' interactions and collective effects in suspensions. Chapter 4 dives straight into the movements of microorganisms and their mechanisms, including swarming, biofilm formation, and flagellar and ciliary motility. It also covers how the synchronization of flagella and cilia affects bacterial swimming.

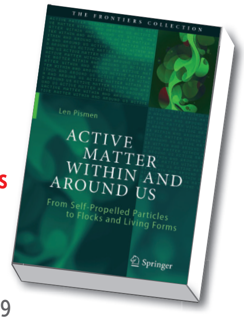
Eukaryotes are covered next in a lightning-fast review of the cytoskeletal components and architecture, the dynamics and patterns present within a cell, and the role those factors play in cellular

Active Matter Within and Around Us

From Self-Propelled Particles to Flocks and Living Forms

Len Pismen

Springer, 2021. $89.99



locomotion. That background motivates coarse-grained active-gel models that permit theoretical descriptions of mechanics and dynamics at both the single-cell and tissue levels. A brief excursion into how shape change emerges from growth and plasticity seems a bit tangential, but it perhaps portends the final two chapters.

The third part delves deeper into biology by covering such topics as tumor invasion; the dynamics of collective cell migration; and the spreading, jamming, folding, and shaping of tissues. Fundamental ideas of morphogenesis are highlighted—including positional information, symmetry breaking, morphogen gradients, and mechanical feedback—but the discussion remains brief. I appreciate the inclusion of sections on plant tissues. The book concludes, perhaps a bit abruptly, with a short digression into biomimetic systems and soft robotics.

Overall, *Active Matter Within and Around Us* manages to fulfill its promise of emphasizing the physical, biological, and technological aspects of active matter—at least to the extent that can be expected in 200 pages. Nonetheless, it is not a casual read, nor is it a pedagogical introduction to active matter. For the latter, the many extensive review articles that have been written on the subject remain the best option.

Because of the book's brisk pace, its heavy bias toward theory, and its often-impressionistic descriptions of phenomena without equations, it is unlikely to be useful to beginners except perhaps to whet their appetites for further study. But for attentive and motivated readers who are willing to dive into the literature, *Active Matter Within and Around Us* hints at many open questions and problems that are waiting to be solved.

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