

readers also learn how to take the shortest path between two points, which can have both physical consequences on a plane flight and metaphorical implications in life.

I don't want to make it sound like *The Biggest Ideas in the Universe* is solely a book about math, because it isn't. But it's just so refreshing to read a popular-science book that doesn't hide the math. Instead of shying away from the nitty-gritty calculations that led to the biggest leaps in our physical understanding of the universe, Carroll leans on the beauty of the

math to show readers why it's an integral part of the physics we do. And he does so in a remarkably unpretentious manner: At one point, he explains that guessing is a respectable path to a breakthrough. (My students don't believe me when I tell them that sometimes you just need to guess the solution. Of course, physical intuition helps.)

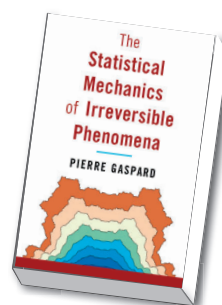
The Biggest Ideas in the Universe reminds me of popular mathematics books that I read in high school when I was deciding between a career in physics or mathematics. (I settled on theoretical physics, which

uses a lot of math!) I'm sure Carroll's book will inspire many math-inclined students to pursue science, and I'm looking forward to the next two volumes. I recommend it to all students who are interested in physics so that they can get an idea of what it's like to work in science. If it gets translated into Turkish, I would love to give it to my family so that I can finally explain to them what I actually do at work.

Seyda Ipek
Carleton University
Ottawa, Ontario, Canada

The Statistical Mechanics of Irreversible Phenomena

Pierre Gaspard
Cambridge U. Press,
2022. \$99.99



complex systems and statistical physics at the Free University of Brussels in Belgium.

Nearly 25 years after the publication of his first book, Gaspard has written a follow-up, *The Statistical Mechanics of Irreversible Phenomena*. An advanced-level textbook, it presents an overview of a broad range of nonequilibrium phenomena, including traditional subjects—such as Langevin dynamics, chemical reactions, and the kinetic theory of rarefied gases—and more novel topics like transport in open quantum systems and the motion of active particles and molecular motors.

Such a huge amount of material could easily fill several volumes. But Gaspard's clear, concise writing presents all the important ideas and their theoretical formalism in only 15 neat chapters and six appendices. For example, the first three chapters, which cover thermodynamics, statistical mechanics, and hydrodynamics, not only lay out those fundamental theories and settle on notation conventions but also include discussions of research areas where developments have been made in the past few decades, including fluctuations, nonequilibrium steady states, ergodicity, and coarse graining.



One famous source of fluctuations—both financial and emotional—is the stock market, as illustrated in this 1799 etching by the English caricaturist Thomas Rowlandson, who based it on a drawing by the caricaturist George Moutard Woodward.

The power of fluctuation relations

During his long career, Pierre Gaspard has made a name for himself as a leader in the field of nonlinear dy-

namics: His highly cited 1998 book *Chaos, Scattering and Statistical Mechanics* is a classic, and he heads the unit that studies

Those chapters set the stage nicely for the main part of the book, which reviews a huge body of work on fluctuation relations and irreversibility. Fluctuation relations establish a connection between forward and reverse processes that have different initial conditions. The time asymmetry from their varying initial conditions allows us to better understand irreversible processes. Because fluctuation relations can be used to describe many different phenomena and systems, they are the book's central leitmotif and act as a helpful guide for readers. They're also fascinating to examine.

Gaspard is an expert in the study of fluctuation relations, and he proclaims toward the beginning of the book that one of his goals is to demonstrate that they provide a unifying framework with which to describe nonequilibrium systems that are fully nonlinear. But some readers might question if he succeeds in that aim. He is correct when he claims that the theory of fluctuation relations is no longer restricted to the linear regime when systems are close to equilibrium.

Depending on the reader's background,

that assertion may evoke associations with the groundbreaking 1962 monograph by S. R. de Groot and P. Mazur, *Non-Equilibrium Thermodynamics*, which provided the field with a complete description of linear, nonequilibrium thermodynamic systems. Despite significant effort, however, researchers do not generally agree upon a theory that provides a complete description of nonequilibrium systems that are fully nonlinear—and I don't think that fluctuation relations will be able to furnish us with such a theory.

Having said that, the book does demonstrate the broad applicability and success of fluctuation relations. After all, the nonlinear regime of nonequilibrium processes is such a huge, diverse, and enormously complicated field in which general principles are extremely hard to find. Even if they aren't a fully unifying framework, fluctuation relations are an astonishingly broad principle.

Moreover, Gaspard's mastery of the impressive range of fields he discusses makes the book stand out. The chapter on fluctuating chemohydrodynamics—

the theory that combines fluctuating hydrodynamics with diffusion–reaction processes—is a case in point. Although not every reader will be intimately familiar with it, Gaspard conveys the ideas and theory of fluctuating chemohydrodynamics clearly by providing a detailed description of fluctuation relations for diodes and transistors. Using that approach, he seamlessly covers how fluctuations relate to topics as varied as surface reactions, ion transportation, and Brownian particles in fluids.

The Statistical Mechanics of Irreversible Phenomena convincingly demonstrates that fluctuation relations allow us to study nonequilibrium systems beyond the linear irreversible regime. A comprehensive and self-contained overview of a considerable amount of recent progress in the field, it is one of the best sources available to learn about the state of the art in nonlinear dynamics. I have no doubt that graduate students and researchers will enjoy reading it.

Patrick Ilg

University of Reading
Reading, UK



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