# Void

## The Strange Physics of Nothing

**James Owen Weatherall**

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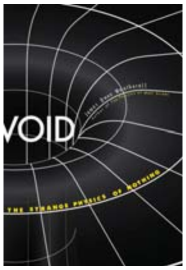
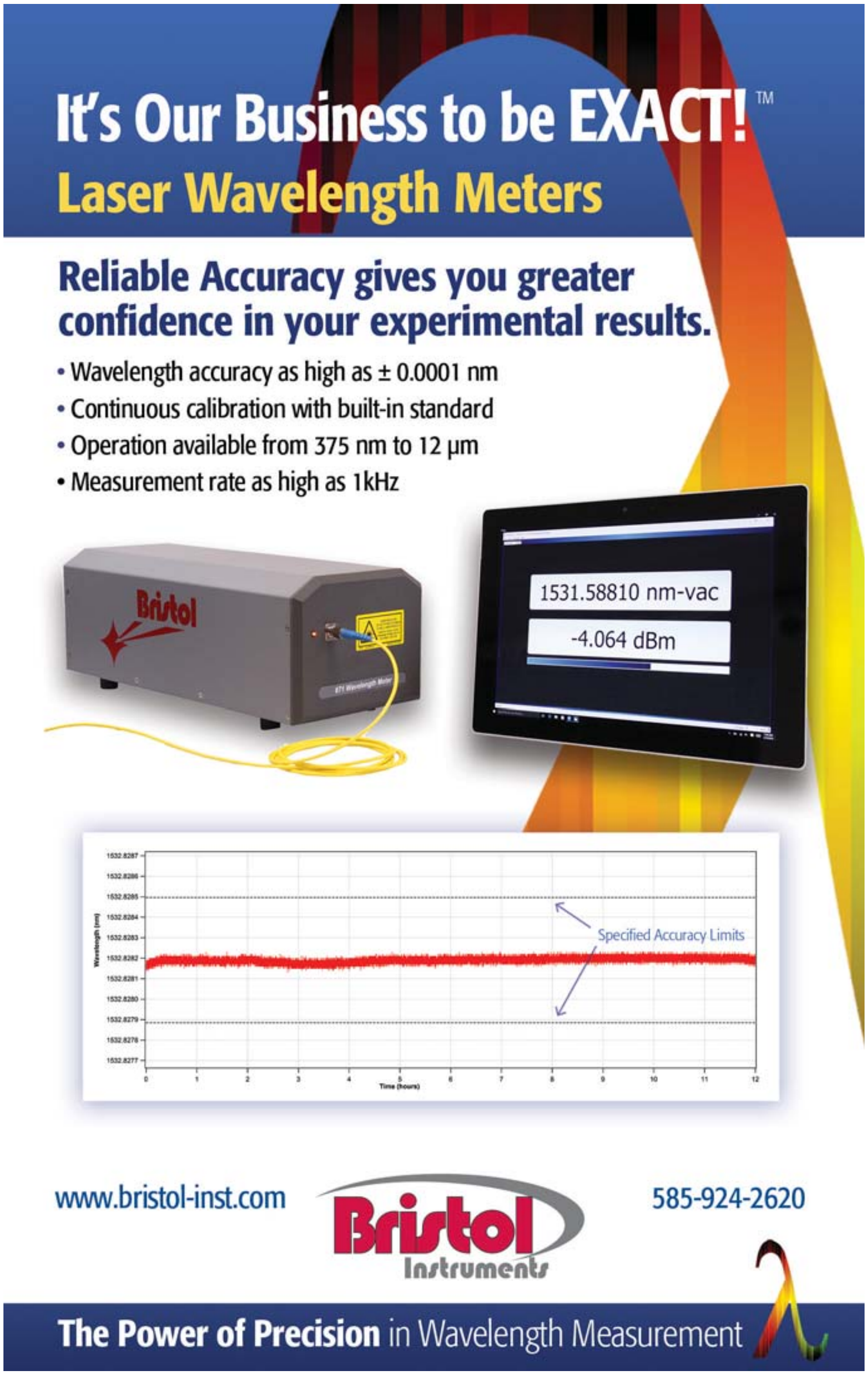


Yale University Press's Foundational Questions in Science series takes the following as its credo: "At its deepest level, science becomes nearly indistinguishable from philosophy." Those words, I think, are crucial to understanding *Void: The Strange Physics of Nothing*, a small but lively volume in the series. Arguably, the deepest level of contemporary science is the physical theory of "nothing," a word actually applied to various, not necessarily distinct non-nothings. For example, in quantum field theory, "nothing" refers to the vacuum, or ground state, with respect to which other physical states are defined. In general relativity, it describes matter-free spacetimes, whereas in quantum gravity, it is a hypothetical state with no classical spacetime.

Of course, oracular pronouncements and disputes over "nothing" are not new to philosophers or scientists. Medieval philosophers argued that *nihil fit ex nihilo* (Latin for "out of nothing comes nothing"). Thomas Aquinas added that *creatio non est mutatio* ("creation is not change"), thus distinguishing between creation, the domain of theology, and change, the domain of science. Isaac Newton, Gottfried Leibniz, and their followers argued over empty space: Is it a primitive something, endowed with its own structure, or a derivative entity, best understood in terms of a separation between bodies?

James Clerk Maxwell filled the void with an ethereal medium deemed necessary for the propagation of electromagnetic energy across space. Albert Einstein abolished Maxwell's ether but reinstated one of his own, the metric field. Martin Heidegger opined in 1929 that science cannot dismiss the nothing "with a lordly wave of the hand," unaware that a year before, the lordly hand of Paul Dirac had filled the void with an infinite sea of negative-energy electrons. Much of the ado about nothing turns out to have been merely verbal, arising from an understandable but faulty assumption that space empty of stuff—that is, the perceptible absence of matter in the familiar sense—is nothing. Contemporary physics tells us that nothing could be further from the truth.

James Owen Weatherall, author of a popular account of how mathematical models are used to predict financial markets (*The Physics of Wall Street: A Brief History of Predicting the Unpredictable*, Houghton Mifflin Harcourt, 2013), takes up the topic of nothing in three chapters. Trained as both a physicist and a philosopher, Weatherall is an engaging writer, and he provides a readable tour of how the physics of nothing has developed. Chapter 1 discusses the early 18th-century conflict between Newton and Leibniz over absolute space. Leibniz maintained that space and time were ideal relations between material bodies. Newton, however,



argued that space and time were absolute entities that exist even in the absence of bodies or material processes. In keeping with the practice of many contemporary philosophers of physics, Weatherall argues that the controversy was motivated by Newton's implicit recognition that mechanics requires a space and time to define the notion of inertial structure. Such a rational reconstruction, however, downplays the highly nontrivial theological reasons underlying Newton's insistence on absolute space and time.

Chapter 2 discusses empty space in relativity theory, from the geometrical structure of Minkowski spacetime to empty-space solutions of the field equations of general relativity, Schwarzschild black holes, Einstein's discovery of wavelike solutions, and his infamous 1936 paper with Nathan Rosen denying the existence of gravitational waves. The chapter fittingly concludes with the Laser Interferometer Gravitational-Wave Observatory's detection of a gravitational wave in September 2015.

The third chapter is devoted to quantum field theory and the notion of the vacuum state, a seething cauldron of virtual particle–antiparticle pairs popping into existence and then disappearing before energy conservation is violated. Mostly a history of early quantum electrodynamics, it is organized around two pairs of theoreticians: Dirac and Pascual Jordan, and Richard Feynman and Julian Schwinger. The chapter is the highlight of the book, for Weatherall tells his story convincingly and brings back into prominence the vital contributions of physicists such as Jordan and Schwinger, who are largely neglected in lay scientific literature. The epilog discusses the so-called string landscape or multiverse, the plethora of vacuum states allowed by string theory—according to Weatherall, "approximately $10^{500}$ *different* ways for there to be nothing."

Two observations: First, for much of the book, "nothing" is characterized as the absence of "stuff." But a principal conclusion of the third chapter is that the vacuum state, according to quantum field theory, "is very much a kind of *stuff*." Despite the absence of particles, it is dynamic, hardly an attribute of nothing. Thus the vacuum state ensures, as Weatherall puts it, "a chance of finding stuff even when there's nothing there." The proper conclusion to draw may be that the dialectical trope of "stuff" versus "nothing" has simply become archaic.

Second, can one really say "if *anything* in quantum field theory is well understood, mathematically speaking, it is the vacuum"? A note refers interested readers to the characterization of special-relativistic vacuum states in algebraic quantum field theory. I think it is fair to say that the vacuum of renormalizable quantum field theories is mathematically understood in the absence of gravity. Without gravity, vacuum energy is not an observable; it cancels out in any measurable quantity and so can be defined to be zero. In the presence of gravity, however, no unique vacuum state exists in general, and it is not clear what the correct renormalization scheme is.

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# Biomimetics

## Bioinspired Hierarchical-Structured Surfaces for Green Science and Technology

**Bharat Bhushan**

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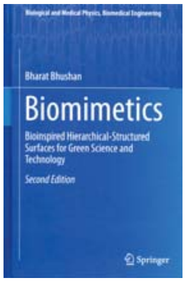

Biological and Medical Physics, Biomedical Engineering
Bharat Bhushan
Biomimetics
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We humans by nature are inquisitive and curious, and it is unsurprising that we want to learn more about the magnificent natural world we live in. When Nature faces problems, it finds incredibly clever solutions, such as the self-cleaning ability of certain leaves, the adhesive properties of gecko feet, and the physical structures that produce the colorful wing scales of butterflies. Nature's inventiveness has inspired scientists to mimic or create synthetic systems that function with the precision and efficiency of natural biological systems, a field called biomimetics or biomimicry. As familiar disciplinary boundaries have become blurred, many physicists have become involved in the field.

Bharat Bhushan's expanded second edition of his book *Biomimetics: Bioinspired Hierarchical-Structured Surfaces for Green Science and Technology* presents researchers and students alike with an extensive array of hierarchical structures that exist in nature, with particular attention to structures with useful wetting properties. The book also deals with other aspects of structured surfaces, such as drag reduction and antifouling to prevent the accumulation of organisms on wetted surfaces of boats and bridges.

Bhushan, an Ohio Eminent Scholar and a Howard D. Winbigler Professor at the Ohio State University, is an expert in tribology and nanotribology as well as in biomimetics. His book, as he makes clear, draws on the work done by his former students, postdoctoral fellows, and visiting scientists at Ohio State. It is meant to serve as a resource for researchers and scientists who want to pursue the exciting field of biomimicry. Bhushan writes that he has two goals in *Biomimetics*: first, to describe surfaces in nature with functions and structures that might be of commercial interest, and second, to analyze and model those examples and suggest methods for fabricating them.

The book's first chapters contain a fairly broad introduction to the wetting of structured surfaces. I found myself wishing, however, for a general discussion of wetting behavior that included flat and cylindrical surfaces. Nonetheless, the wetting of structured surfaces is covered quite nicely and includes extensive citations.

The next few chapters deal with specific examples of structured surfaces, including lotus leaves, rose leaves, and the floating water fern *Salvinia molesta*. The author then covers ways of creating structured surfaces with the desirable properties of those natural exemplars and discusses the wetting characteristics of various fluids on those surfaces. It is rather curious that Bhushan follows his presentation with a chapter that delves into the drag reduction of sharkskin and sharkskin-like structures. That aspect of structured surfaces digresses a bit from the major theme of the book, which is wetting. But the shark chapter is an interesting addition.

Toward the end of the book, the author discusses the adhesive properties of gecko feet, along with the various envi-