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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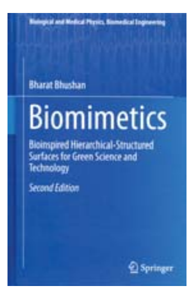

We humans by nature are inquisitive and curious, and it is unsurprising that we want to learn more about the magnificent natural world we live in. When Nature faces problems, it finds incredibly clever solutions, such as the self-cleaning ability of certain leaves, the adhesive properties of gecko feet, 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 environmental conditions that might affect a gecko's ability to adhere to a surface. However, a rather curious omission is the defense mechanism of the beetle *Hemisphaerota cyanea*, discovered by Thomas Eisner and Daniel Aneshansley in 2000: To achieve a secure footing and make it nearly impossible for its predators to dislodge it, the beetle makes use of capillary forces, generated by an oil dispatched through a large number of adhesive bristles. The book's final chapters deal with structural coloration. Chapter 14 focuses on nacre, or mother-of-pearl. Chapter 15, which deals with the ways structure affects surface coloration, uses the wing scales of butterflies and the exoskeletons of beetles as its key examples.

In general, the book is a nice introduction to biomimetics. Its many references will aid researchers who want to learn more about the field, though it is a bit disappointing to see that some key original references are not cited. But regardless of its minor limitations, *Biomimetics* is a well-written compendium that will serve a need in the ever-growing field of biomimicry.

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Astronomy in the Ancient World

Early and Modern Views on Celestial Events

Alexus McLeod

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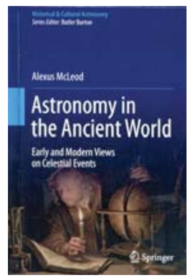

Alexus McLeod's new book, *Astronomy in the Ancient World: Early and Modern Views on Celestial Events*, without a doubt represents a noble intent. Astronomy is often considered the "first exact science" in Western scientific thought. McLeod informs readers up front that he is seeking a much more inclusive history of astronomy. Accordingly, the 234-page book, broken up into an introduction and four parts with two chapters each, aims to cover non-Western astronomies around the globe. McLeod includes celestial traditions of Mesoamerica, Native North America, China, and India alongside an abridged treatment of early European astronomy.

The strength of the book is part 2, which deals with China. The material is well organized, and McLeod successfully places Chinese astronomical activity in its cultural context. The opening material analyzes the development of the armillary sphere and its utility for Chinese sky watching. That serves as a solid introduction, and McLeod follows it by using historical records to demonstrate connections between celestial events and the political and cosmological contexts that rendered them meaningful to historical observers. For example, McLeod reviews the three major Han-era cosmological theories—*gai tian*, *hun tian*, and *xuan ye*—as cosmological concepts and as inspirations for political organization. His descriptions are insightful and well developed.

The rest of the book, unfortunately, is of distinctly lower quality. The part on India has a promising concept: It seeks to place the monumental astronomical instruments patronized by 18th-century Indian ruler Jai Singh II in a broader cultural and political context. Some of the material is interesting—for example, McLeod effectively relates Singh's astronomical pursuits to his interest in traditional religious rituals—but the overall treatment wanders tremendously. A rushed section on "Islamic Thought and Astronomy, and Its Influence on India," for instance, contains several redundant paragraphs, which suggests a lack of authorial attention.

Furthermore, the book's intended audience is unclear. I often found myself wondering whether it was written as a textbook for a high school class. At one point, McLeod writes, "One easy way to think of this is to think of it in terms of a Cartesian coordinate system, on a flat surface—one of the kind you've likely seen in school. In such a coordinate system any point is located by an x and y position. To determine the location of any given point, we have to determine where it is along each axis." The assumption that readers will need a Cartesian plane explained feels out of step with much of the rest of the book.

The ambiguity of the intended audience, though, is not the only trouble. It is clear that neither the reviewers nor the editors paid sufficient attention to the production of the book. Numerous typographical errors appear throughout the text; a mistake like "Pleades star cluster" should not have made it into print once, much less twice. Even the material on China does not escape editorial problems. There are consistent typographical errors and one footnote (on page 87) that reads simply as "[6]Dubs . . ." with no corresponding reference in the bibliography.

Had I not agreed to review the entire book, I never would have made it past the first part, which covers Mesoamerican astronomy, my own area of research. No Mesoamerican record exists of the supernova of AD 1054, but McLeod devotes an entire passage to "1054 for the Maya: Some Speculations." If his intent is to raise greater awareness of non-Western astronomies, his efforts would have been better served by getting right what is known, rather than offering unsupported hypotheses that he himself refers to as "wildly speculative." Overall,