PHYSICS

# *Rethinking the arrow of time*

## Citing shortcomings in Eddington's theory, a physicist proposes a new explanation for the existence of "now"

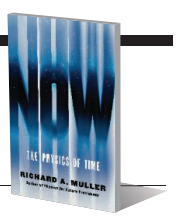
*By* **Lisa Jardine-Wright**

As an astrophysicist and lecturer of relativity and quantum mechanics, I frequently discuss the fundamental principles of Einstein's theories and the interpretations of counterintuitive quantum mechanical properties. However, rarely have I considered the importance or significance of the concept of "now." It is an everyday reality that I simply take for granted. Richard Muller, on the other hand, has given the concept considerable thought. In *Now: The Physics of Time,* Muller successfully introduces and describes most, if not all, of the key elements in an undergraduate physics course, masterfully connecting them with the conceptual thread of "the arrow of time."

When I was a child, I had many questions relating to time: Is it discrete or continuous? What is the smallest measurement of time that we can make? And, as I get older: Is time actually passing faster, or is it just my perception? You may consider such questions to be metaphysical or philosophical, but Muller discusses these and others through the lens of a number of major 20th-century physics discoveries.

With major discoveries come major players. Muller touches on the work and theories of Albert Einstein, Georges Lemaître, Erwin Schrödinger, and Arthur Eddington, to name just a few.

**Now**
**The Physics of Time**
*Richard A. Muller*
Norton, 2016. 364 pp.




There are five parts to the book, and as they progress, Muller's discussion evolves from physics to metaphysics and philosophy. Throughout, he continually reminds the reader that we must not accept theories unless they are testable or falsifiable.

I also infer a second evolution in the book's progression: a gradual transition from accepted theory to speculation. Consider the question, why is it that we remember the past and not the future? I have long considered Eddington's explanation—that the direction of time can be understood through the second law of thermodynamics—to be perfectly acceptable. However, in Muller's view, this explanation is inadequate.

Muller believes that Eddington's entropy explanation of the arrow of time is "deeply flawed" because his theory and subsequent related theories make no predictions but only explain the phenomenon. Muller suggests alternatives such as the "decreasing-entropy" arrow—the theory that we evolve to order rather than disorder on a local level—and the radiation arrow, suggested by the eminent Swiss physicist Walther Ritz, in which radiation drives time forward. He also discusses the possibility that time is an emergent property of our own consciousness (the psychological arrow) and the idea that the parameters of our universe are somehow special, as evidenced by the presence of intelligent life (the anthropic arrow). It is in these sections where Muller touches on aspects of metaphysics and philosophy: the nature of existence, the fact that we are able to ask questions about the universe, and the reason that time must move forward. As yet, there is no definite answer as to why we remember the past and not the future, but Muller suggests that quantum theory or a four-dimensional Big Bang may hold the key.

**"Suppose time stopped. Would you notice? How? Suppose it moved forward in fits and spurts, or at a totally different rate. Could you detect the difference?" asks Richard Muller.**

Along the way, the reader is treated to excellent descriptions of key fundamental concepts in physics, including apparent paradoxes in special relativity, $E = mc^2$, the principle of equivalence, black holes, quantum entanglement, statistical physics, the Big Bang, inflation, and the cosmic microwave background.

The strength of this book lies in Muller's experience as a lecturer and teacher, which has enabled him to describe and explain difficult concepts with simplicity. An example can be found in chapter 3 when he discusses length contraction. To measure a moving bus, he explains, we must measure the front and the back simultaneously. But that, according to Muller, is the catch: "That concept is relative. Simultaneous in one reference frame is not simultaneous in another reference frame. A direct consequence is the fact that the length will be different in different frames."

In his introduction, Muller states that his goal is "to bring together the essential physics, assembling pieces like a jigsaw puzzle until a clear picture of *now* emerges." Has he achieved this goal? The book definitely pre-sents a clear picture of essential physics. The significance of "now" and how time, as well as space, might have been created by the Big Bang is more suggestive than emphatic, in my opinion.

Maybe Muller's theories are right about time. Maybe Eddington's reliance on entropy to understand time is misguided. But one thing is certainly true about *Now*: It provides a concise master class in understanding the essentials of physics. I would recommend it to early-year undergraduate physics majors, who will likely find that it will help to crystallize and catalyze their own conceptual understanding of such fundamental principles. ■

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