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BOOK REVIEW

Until the End of Time: Mind, Matter, and Our Search for Meaning in an Evolving Universe by Brian Greene. Knopf, 2020. 448 pp. $26.99. ISBN 978-1524731670.

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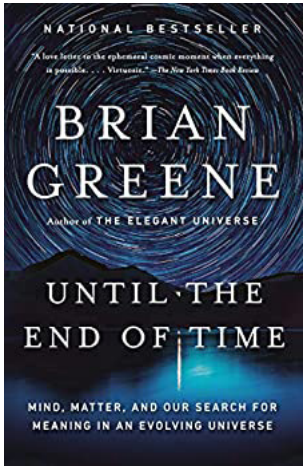
Brian Greene's *Until the End of Time: Mind, Matter, and Our Search for Meaning in an Evolving Universe*, as the title suggests, is an ambitious work. Greene takes the reader on a vast tour which begins with the birth of the universe and ends with its (likely) dissolution. The staggering timescale that Greene considers here is perhaps unique among science books aimed at a wide audience. And Greene uses the backdrop of the universe's emergence and demise as an effective platform to explore human meaning in a relatively wide range of inquiry. These subjects include consciousness, religion, language, and the arts. It appears significant for Greene that these, as important as they are, all play out in a relatively brief time in the context of the evolution and demise of the universe. At the end of the day, Greene submits that life is likely ephemeral. He provides a quote from Nabokov that characterizes human life as a "brief crack of light between two eternities of darkness" (p. 13).

Greene excels in describing the history of our understanding of our universe's origins, both the theoretical frameworks (which emerged in large part from Einstein's theory of general relativity) and empirical confirmations detected by scientists. According to Einstein's equations, gravity under some conditions might be repulsive, rather than always attractive (as we might think). So as Greene describes, under the right conditions, large clumpy objects such as stars and planets, can drive



things apart. But this aspect of Einstein's framework didn't get much attention until observations revealed that the universe was expanding. Eventually, inflationary theory posited a region of space could be filled with a particular kind of substance (which Greene calls "cosmic fuel") that under the right conditions might be repulsive. Greene walks us through the historical development of a theory of how an astronomically small region might erupt "almost instantaneously stretching to as large as the observable universe, if not larger" (p. 48). However, more impressive perhaps is when this developing theory incorporated quantum mechanics. The resulting prediction involved a distinct pattern of temperature variations across space, a sort of cosmological footprint. And Greene notes that telescopic observations beginning in the early 1990s confirmed the predicted pattern.

How did such a low entropy state as the universe's origin even exist? Greene acknowledges this mystery is likely beyond us, as we are much better acquainted with processes that expand entropy. And Greene is quite adept at vividly describing how the "entropic two-step" leads to the birth of stars. We might imagine the big bang as a colossal explosion of gas and particles evenly spreading out throughout the universe. However, here Greene vividly describes the crucial role of how gravity acts to bring matter together. As he explains, in portions of the universe where energy and particles expand, leading to areas of low energy, gravity leads the central core of these portions to compress. Greene walks us through how this process amplifies and grows stronger, leading to the stars that populate our universe.

Perhaps the singular key in unraveling much of the universe's unfolding and as well its ultimate fate, according to Greene, is the concept of entropy. And Greene is indeed adept at guiding the reader through its subtleties and implications. In the early chapters, Greene fully describes the concept to readers, as well as the history of understanding it. As most readers already know, the entropy of the

universe, according to the second law of thermodynamics, expands over time. Thus, higher quality or relatively ordered states of energy must decline with time. However, perhaps the most important concept here is what Greene calls the "entropic two-step." This is where a process that appears to lower entropy (increase order and raise the quality of energy) is in apparent violation of the second law. However, as Greene explains, such increases in order must come at the expense of raising the level of entropy overall. For example, in order for a biological cell to ingest the nutrients to grow and thrive, it must expel heat into the environment. This leads to one of Greene's key points: that "the dual forces of entropy and evolution are well-matched partners in the trek of the emergence of life" (p. 7).

However, as his book's title suggests, Greene's subject matter is considerably broader than cosmology. In the middle chapters, Greene considers possible explanations for consciousness, how life evolved, the nature of our stories, the roots of our sacred beliefs, and the instinct toward creativity. Perhaps the strongest challenge for a materialist such as Greene is the problem of consciousness. Greene seems to recognize this difficult problem and acknowledges that we likely have a long way to go in explaining it in materialistic terms. Here, Greene does a good job of framing the problem:

> How can a collection of mindless, thoughtless, emotionless particles come together and yield inner sensations of color or sound, of elation or wonder, of confusion or surprise? Particles can have mass, electric charge, and a handful of other similar features . . . but all these qualities seem completely disconnected from anything remotely like subjective experience. How then does a whirl of particles inside a head—which is all that a brain is—create impressions, sensations, and feelings? (p. 125)

Although a committed materialist, Greene presents a relatively wide range of different views to the problem and acknowledges the positions of fairly prominent non-materialist philosophers such as Thomas Nagel and David Chalmers. He also has a clear discussion of the knowledge problem, which concerns a brilliant but color-blind neuroscientist named Mary. In the thought experiment, which helps flesh out the hard problem, Mary understands all there is to seeing,

but she has never experienced the color red. When Mary is given the ability to see color, the question arises how this new knowledge can be reconciled with physicalism.

Greene, however, does arguably put his thumb on the scale to suggest that consciousness will ultimately be explained in materialistic terms. Toward this end, he presents in a favorable light a theory of consciousness developed by neuroscientist Michael Graziano. As Greene clearly explains, Graziano's theory posits that our brain somehow creates very simple mental schemas from attending to the world around us. These mental schemas filter out unnecessary information involving the firings of the brain's neurons and other information processing. And Graziano claims that out of these sorts of simple schema we create something of a simplified schema for our own attention, as well as those of other people and animals we suppose have minds. Thus, Graziano's theory suggests our notion of consciousness emerges from such simplified schemas. While Greene does an excellent job of summarizing Graziano's framework, he fails to consider the more critical questions that critics of materialism might raise. Most importantly, how does such a functionalist approach, which might be characterized in terms similar to a sophisticated robot, generate the "something it is like to be" quality that conscious beings possess? How do the inherently subjective feelings of conscious beings emerge from collections of simplified schemas generated by processes that might be completely described in terms of a sophisticated computer? In my reading, Graziano (2016) characterizes the qualia of consciousness as intuitions that lead us astray about the nature of our experience. But should we characterize the pain of a small child or animal as an "intuition?" Graziano's explanation appears to be close to Daniel Dennett's (1991) rather dismissive take on the reality of subjective qualia.

Such bias comes up again when Greene considers the problem of free will. Here, Greene counsels that no matter what our experience, in the laws of nature (whether classical or quantum mechanical), the world is governed by mathematical laws that leave no room for true free will. However, his arguments on the degree quantum mechanics constrains free will can be questioned. Near the end of his book, he summarizes his position this way:

> Because reality is quantum mechanical, the pronouncements of the laws are probabilistic, but even so the probabilities are rigidly determined by mathematics. Particles and fields do what they do without concern for meaning or value or significance. Even when their indifferent mathematical progression yields life, physical laws maintain complete control. Life has no capacity to intercede or overrule or influence the laws.

But this is not quite right on two counts. First, as Greene has acknowledged earlier, we have no answer to the quantum measurement problem. That is, currently we lack a satisfactory solution for most physicists that explains how quantum superpositions (in quantum experiments) transition into actual experimental outcomes. However, physicist Henry Stapp (2017) argues that the "collapse of the wave function" results from the "choice" of nature in response to the choosing of the experimenter. Thus, Stapp explicitly incorporates a notion of free will in his interpretation of quantum mechanics. Now while few physicists currently embrace this interpretation, we might note that bringing free will into the picture—something we seem to have direct acquaintance with—is arguably more plausible than Everett's "many worlds" style and other interpretations that clash strongly with our direct experience and that (so far) we have no evidence for.

The other problem is with Greene's claim that "the probabilities are rigidly determined by mathematics." Actually, any sort of mathematical equation that determines the Born probabilities within the wave function does not (yet) exist. My reading of the literature suggests that these probabilities emerge holistically as a result of the physical configuration of the experimental setup. And what can we say concerning quantum behavior outside of the lab? Very little. Many might imagine that quantum behavior is negligible outside of the laboratory, and until recently this has been the conventional thinking. However, the growing field of quantum biology has revealed quantum nature in various biological processes. Perhaps one day we might even find quantum links within the brain.

At this point, I'd like to isolate what appears (to me anyway) some fundamental guiding principles that arguably limits some of Greene's thinking. These fundamental principles are: 1) materialism

(or physicalism), 2) reductionism, and 3) the sort of scientism that seeks only explanations that can be expressed in mathematical terms. Thus, when he considers topics such as consciousness, free will, and meaning, he falls back to these guiding principles. When he is considering, for example, whether consciousness might be linked with quantum mechanics, he notes that he hasn't seen the math that might support this, and this fuels his skepticism against the view that the two might be linked. But Greene appears to treat these principles as indispensable axioms, rather than metaphysical assumptions that might be of questionable use in some areas of inquiry.

If we carry into our inquiry a bedrock assumption that everything must be governed by mathematical laws, how can we avoid concluding that free will must be illusory? In such cases, the answer appears to be determined by our assumption rather than the processes of the world we seek to understand. Of course, such assumptions have arguably served science (especially classical science) very well. But what about areas, such as quantum mechanics and consciousness, where significant gaps persist in our understanding? Must we maintain a tight grip on such assumptions, even in the presence of persistent mysteries?

Recently, the philosopher Goff (2019) has argued that science, through Galileo's influence, has developed in ways that, while successful for investigating the physical world, might actually handicap us in areas such as consciousness. That is, Goff notes that Galileo specifically argued for greater focus on the quantitative features of the world, which could be expressed in mathematical language, in order to facilitate scientific understanding of the material world, but arguably at the expense of the world's more qualitative aspects. Given this bit of history in science, we can legitimately question whether fundamental assumptions that have served cosmologists well will continue to serve us in such problem areas as consciousness and free will.

Of course, to be fair, there is nevertheless much in this book to admire and value. Greene's views are an excellent presentation of mainstream science. And his clear exposition on a wide range of scientific research, as well as his ability to discuss respectfully and sympathetically views quite opposed to his own, make this book a worthwhile investment.

But how does Greene fit the search for meaning within such a

materialistic framework? Greene spends quite a bit of time discussing the origin of our stories, sacred beliefs, various kinds of art, and these (as you might expect) are considered within a framework heavily influenced by modern theories of evolution. And Greene does a good job presenting the question and debate on how to reconcile the artistic impulse with evolution (which is oriented around fitness for survival). Ultimately Greene gives weight to explanations that link abilities or dispositions of questionable survival value (such as creating music or poetry) with abilities that are valuable in that sense (pattern seeking or the ability to imagine what others might be thinking). Thus, adaptions that help us survive through better pattern recognition, so the thinking goes, might also give us an appreciation of poetry for free. While Greene does explore alternatives, he seems to favor this class of explanations. Thus, Greene appears to be sympathetic to Steven Pinker's assessment that music and the language arts "amount to nutritionally bankrupt desserts served up to pattern-obsessed human brains" (p. 227).

Greene suggests that this class of explanation may help us understand the origin of religion or sacred beliefs as well. Adaptions in our brain that improved pattern recognition as well as our ability to imagine cognitive abilities in others, might have also led humans to ascribe intelligence to some sort of god or aspects of nature. And the religious institutions that emerged may have facilitated cooperation across groups of individuals, as well as altruistic behavior. While Greene is no believer, he does acknowledge the evolutionary value that religious institutions have likely provided in human history. Another advantage religion arguably bestowed (again possibly resulting from adaptions in pattern recognition) was providing a sense of order or meaning as a buttress against the angst if not fear around our mortality. But Greene has little to say on the role religion arguably played in foundation for ethics and morality, not to mention any serious consideration of connecting with a transcendent reality. That said, Greene does acknowledge how in his personal life, after the death of his father, connecting with his Jewish tradition and practices helped bring some measure of peace.

In the book's closing chapters, Greene turns toward the far future and walks us through various speculative scenarios on the universe's ending. In another five billion years, Greene suggests that the sun

will deplete its supply of hydrogen, which through fusion supplies the energy of our solar system. As a result, the decline in energy pressure will give gravity the upper hand, leading to our sun imploding. But this in turn leads to a sharp increase in pressure and pressure in a relatively thin layer of hydrogen. As a result, another round of hydrogen fusion produces an intense outward push. The sun expands and consumes the inner planets, most likely including our own.

Greene also considers the possibility in the future of other stars venturing close to our own solar system. Due to the gravitational pull from a wayward star, Earth might be flung from its orbit around the sun. In this scenario, the Earth's temperature would plummet and the upper layers of the world's oceans would freeze. But Greene considers that some life might indeed survive deep in the Earth's interior, warmed by the nuclear fission at its core. He speculates that life on the ocean floor might carry on for billions of years as if nothing had happened. In addition, Greene considers that in billions of years the universe will expand at faster rates, where the fabric of space itself is stretched faster than the speed of light. In this case, from any vantage point in the universe, there are fewer stars, as the light cannot travel fast enough to keep up with the extension of space.

However, even as Greene describes various ways the universe might end, he also weaves into his discussion discoveries or breakthroughs in cosmology. His discussion of the expansion of space itself includes recent explorations into *dark energy*, responsible for pushing galaxies apart. Greene also summarizes the development of theories on gravity waves, which originated from Einstein's theory of relativity, and were recently confirmed through observations at the Laser Interferometer Gravitational Wave Observatory, in order to explore their role in nudging the Earth off its orbit (assuming the Earth is still in orbit) and into the sun. Another fascinating journey Greene provides concerns our theoretical understanding of black holes, primarily due to Steven Hawking, that these enigmatic bodies radiate particles. Eventually, Greene argues, time will claim even black holes in the universe as their radiation leads them to waste away.

In the end, the universe, just as our own lives, must come to an end. And according to Greene, attempts to find some sort of deeper or inherent meaning, beyond pure constructions, is unsupported by

science, and therefore likely leads us in the wrong direction. My own view, based on empirical research in parapsychology (which likely does not interest Greene) as well as persistent gaps in our understanding of consciousness, is quite different. Too many questions in these areas remain unanswered to warrant such a confident dismissal of meaning in some deeper, intrinsic sense. But Greene's book presents an admirable and wide-ranging look at how our vast universe unfolded and how it might likely end.

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