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BOOK REVIEW

The Outer Limits of Reason: What Science, Mathematics, and Logic Cannot Tell Us by Noson S. Yanofsky. Cambridge, MA: MIT Press, 2013. 424 pp. $29.95. ISBN 978-0262019354.

Humans seem to be driven by a desire to understand the world they live in, what we call "reality." Jacques Monod, Nobel Laureate and co-discoverer of the gene, considered this desire to be genetic in origin. Perhaps it is the result of neurological development that favored cohesion among groups of hominids that shared a common desire for "understanding." The neuropaleontologist Harry J. Jerison argued that reality itself is a mental construct and that living organisms create their own realities that provide them with just enough information to survive. Indeed, he suggested that the various senses of living organisms sent just enough information to their brains so that they could survive and that additional information was not sent, lest it actually contribute negatively to survival. For example, the frog's eye only sent the frog's brain a target for its tongue if that target was in motion. A stationary insect was not ignored, it literally wasn't there.

Professor Noson S. Yanofsky, in his most fascinating and eminently readable treatise *The Outer Limits of Reason*, tells the story of how humans have developed the faculties and tools of reason with which to describe and understand their reality. Unfortunately for those readers who seek comfort in a belief that these tools and faculties will suffice to bring us complete understanding, Yanofsky reaches a somewhat depressing conclusion. Fortunately, the journey to that conclusion is exciting and thoroughly enjoyable. For Yanofsky, as powerful as these tools of logic, abstract mathematics, physics, and computation are, they are fraught with ambiguities, paradoxes, and ill-defined concepts that hinder their ability to bring understanding. Moreover, what we have already learned about the physical world (our reality) by using these tools indicates that it is a strange place indeed. Quantum mechanics tells us that there is a separation between the observer and the observed ("wholeness"), which leads to a vast array of conundrums. In the quantum mechanical description of things, knowledge of certain pairs of descriptive variables cannot be obtained simultaneously with equal degrees of exactness. Such knowledge is called "complementary," meaning one or the other is to be used depending on the circumstances. In the more familiar "classical" reality, knowledge might be

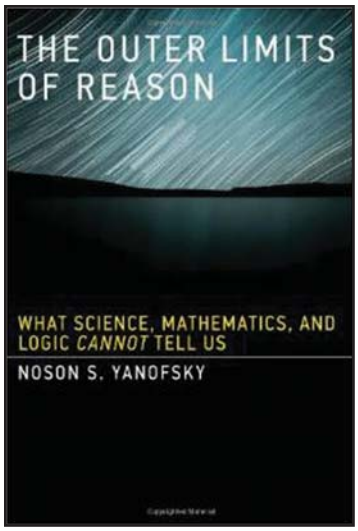
called "supplementary," meaning that each new determination adds to what is already known.

Furthermore, and even more disturbing, is the fact that the very act of observation creates that which is observed, so that one cannot legitimately even talk about a system's measurable characteristics during periods when it is unobserved. Not even Einstein could subscribe to that notion, yet Einstein was apparently wrong. In short, such characteristic variables were not endowed with values (no "hidden variables") prior to their observation. Indeed, Niels Bohr often suggested that quantum mechanics was not a theory of nature, it was a theory of language, what one could say about nature. Perhaps this is our own version of the frog's eye.

Yanofsky also provides us with a brief but complete discussion of Einstein's theory of special relativity. According to this theory, the lengths of moving objects shrink (length contraction) and the elapsed time registered by moving clocks grows larger (time dilation). Moreover, this is no illusion. This is the nature of reality. To Einstein, this was an indication that the much-beloved concepts of length and time duration had no place in a reality in which motion was commonplace. We had come to accept the absolute nature of length and time only because we moved at a snail's pace.

Yanofsky also does a capable job (and a much-needed one) of discussing Thomas Kuhn's seminal book of 1962, *The Structure of Scientific Revolutions*. Although Yanofsky calls this book a treatise in the philosophy of science, Kuhn considered himself a historian of science and would probably have claimed to be motivated by setting straight the historical context of scientific progress. Kuhn describes science as consisting of long periods of normalcy, where new knowledge was systematically acquired according to an existing "paradigm" that defined what tools and methods were acceptable and could be used when adding to existing knowledge, which were infrequently punctuated by anomalies that could not be understood in the current paradigm. When such intractable anomalies arose, a paradigm shift occurred, during which new knowledge was not added incrementally, but instead all pre-existing knowledge underwent a radical shift. Kuhn's thesis is still relevant (and frequently misunderstood and misapplied), so Yanofsky performs a valuable service in discussing it.

One of the many beauties of Yanofsky's book is its admirable completeness. That which Yanofsky states, he proves. He does not tell the reader where to find the necessary explanatory material, he provides it. Even the most arcane mathematical assertions, such as Godel's incompleteness theorem, are proven using the language of logic and abstract mathematics. The reader will be challenged to follow chains of reasoning that are pared down to the limits set forth by Einstein: "as simple as possible, but no



simpler!" The reader is warned that knowledge of the language of abstract mathematics is useful here, although not absolutely necessary.

Yanofsky also deals with philosophical conundrums (what he calls "metascientific-perplexities"), such as Eugene Wigner's question of why mathematics seems so unreasonably capable of framing a description of the natural world. And, indeed, why has the intelligent life required the development of mathematics to come into being in the natural world? Yanofsky does not shy away from these and other teasers that have left great minds following seemingly aimless paths.

He distills these enigmas into three questions:

1: Why is there any structure at all in the universe?
2: Why is the structure that exists capable of sustaining life?
3: Why did this life-sustaining structure generate a creature with enough intelligence to understand the structure?

Yanofsky puts forth several possible "answers" to these questions, ranging from the religious and the mystical to those which generate new types of physical theories (many universes). I believe Yanofsky is at his best when taking us through these answers. He is a fine writer with a sensitivity for all points of view and he does not dismiss any of the various suggestions that have been made. One of Yanofsky's answers involves a deeper discussion of a concept that is dear to my own heart, the concept of "symmetry." In Western thought, symmetry is often associated with beauty, as can be seen in the art of ancient Greece. In Eastern thought, it is often slight deviations from symmetry that are regarded as beautiful, e.g., the "beauty mark." The mathematician Emmy Noether proved that there is a connection between symmetry and certain properties of the physical world, called "conservation laws." Today the artistic connection between symmetry and beauty (as felt by Einstein and Wigner) and the scientific connection between symmetry and conservation laws as shown by Emmy Noether is a dominant aspect of modern physics. Yanofsky does a particularly impressive job with this topic.

Yanofsky's tenth and final chapter is entitled "Beyond Reason." It signals the end of a journey that has been informative and enjoyable. Here, he sums up the various paradoxes of logic and mathematics that can lead the unwary down dangerous roads. He warns us not to abandon reason simply because its language is strewn with pitfalls. Although some may say that to go beyond the limits of reason requires that we switch over to approaches based on imagination and intuition, Yanofsky argues that reason is still the best method for improving humanity's lot in life and should not be abandoned heedlessly. Fortunately, we appear to have an ingrained sense of "beauty, wonder, ethics, and values" that is already "unreasonable" and, perhaps, "irrational," so we should let these guide us as we apply the admittedly imperfect tools of reason. Read the book and judge for yourself.

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Reference

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