

of mathematics when applied to physical problems. Rather, he is arguing that the physical universe is itself an aspect of mathematics. I'm far from certain how one would construct a convincing argument for such a claim, but in my opinion, *Our Mathematical Universe* doesn't pull it off.

The main problem, I believe, is that the book's argument is circular. Tegmark assumes that mathematical objects defined by mathematical axioms—for instance, the real numbers and Lebesgue measure—are part of physical reality. Given that the abstract notions of real numbers and measure have the same status as, say, observations of the spectral lines of sodium, it is not too surprising to end up thinking that the universe is part of mathematics.

On occasion, Tegmark's assertion of the physical reality of mathematical constructs leads to difficulties. One example comes up in his discussion of the many-worlds interpretation of quantum mechanics. In that picture, observations that would give a random yes or no result in the usual Copenhagen interpretation instead give rise to two worlds, one having yes as the result and one having no.

The worrisome argument involves mathematician Émile Borel's notion of normal numbers—numbers that in some rigorous sense could be regarded as random. Borel proved that except for a set of “zero size” (zero Lebesgue measure for the experts), all real numbers are normal. Tegmark invokes that theorem to explain why we never encounter a world in which yes or no experiments that are supposed to give random-seeming results actually give results that look nonrandom. He mentions none of the rigorous mathematics involved in Borel's demonstration, but instead dramatically exclaims that Borel confronted mathematicians “with a theorem at the heart of classical mathematics that could be reinterpreted in terms of probabilities even though the theorem itself never mentioned probabilities at all.” In fact, the word *probabilités* is in the title of Borel's paper.

In any case, the real issue is that Tegmark regards the theorem as a result about physics. That's problematic because although the normal numbers make up almost everything, almost none of them are known explicitly. Never mind that you can only run a finite number of experiments; given an infinite string of random-seeming physical results expressed as a binary sequence of 1 (yes) and 0 (no), you can't

determine if it actually represents a normal number, as the Borel theorem would predict.

But perhaps the most important question about Tegmark's claim is, Does it matter, except perhaps to those interested in metaphysics? Most of his assertions can't be tested, and whether you accept them as true or not seems to make no difference to the future development of physics.

Francis Sullivan

*Institute for Defense Analyses
Bowie, Maryland*

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