The Last Magic

Review of *The Applicability of Mathematics as a Philosophical Problem* by Mark Steiner (Harvard University Press, 1999)

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If mathematics is about finding solutions to well-defined problems, then philosophy is about finding problems in what previously we thought were well-settled solutions. Mark Steiner's *The Applicability of Mathematics As a Philosophical Problem* mirrors both sides of this statement, admitting that mathematics is the key to solving problems in the physical sciences, but also asserting that this very applicability of mathematics to physics constitutes a problem.

What sort of problem? According to Steiner, the reigning "ideology" or "background belief" for the natural sciences is naturalism. Typically naturalism is identified with the view that nature constitutes a closed system of causes that is devoid of miracle, teleology, or any mindlike superintendence. An immediate consequence of naturalism is that it leaves humanity with no privileged place in the scheme of things. It's this aspect of naturalism that Steiner stresses. Naturalism gives us no reason to think that investigations into nature should be, as Steiner puts it, "user-friendly" to human idiosyncrasies. And yet they are.

Steiner's point of departure is Eugene Wigner's often reprinted article "The Unreasonable Effectiveness of Mathematics in the Natural Sciences." Wigner concludes that article with a striking aphorism: "The appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve." Throughout the article Wigner refers to the "miracle" and "mystery" of mathematics in solving the problems of physics. Yet although Wigner leaves the reader with a sense of wonder, he does not indicate how this sense of wonder translates into a problem that demands resolution. Enter the philosopher Mark Steiner.

Steiner's project is to take Wigner's pretheoretic wonder at the applicability of mathematics to physics and translate it into a philosophical problem for naturalism. The applicability of mathematics to physics is not a problem for a mind-first Platonic world-view or a math-first Pythagorean world-view or a Logos-first theistic world-view. It is, however, a problem for a nature-first impersonal world-view. According to Steiner, naturalists are in no position to expect that, much less act as though, mathematics should assist in the discovery of physical insights. That naturalists do counts against their naturalism.

It is important to understand that Steiner is not simply appealing to the success of mathematics in resolving the problems of physics. It is not the isolated successes of mathematics as applied to problems in the physical sciences that for Steiner constitutes a philosophical problem (after all, there are many instances where mathematics has failed to be successfully applied to problems in physics). The problem, rather, is the global success of mathematics as a research strategy for facilitating discovery in the physical sciences.

This is a subtle point, and one impossible to convey without actual case studies from mathematics and physics. Indeed, much of Steiner's book consists of such case studies. Consider, for in stance, the physicist Paul Dirac's discovery of the positron and antiparticles more generally. The positron is a particle just like an electron, only with a positive charge. Yet when Dirac proposed the positron, there was no experimental

evidence for it. Indeed, there was no reason even to expect its existence. Why, then, did Dirac propose such a particle?

Dirac was at the time trying to understand the Klein-Gordon field equation and the energy levels it assigned to certain quantum systems. He wanted to extend this equation relativistically to the electron, but he found that the only way to do so was by factoring it. Unfortunately, the equation resisted factoring over the real and complex numbers. Dirac therefore "brute-forced" the factorization by introducing higher dimensional "number-like" objects (the property where these objects differed from ordinary numbers was commutativity of multiplication).

The factoring worked and gave Dirac the relativistic solution he wanted for the electron. But because the "number-like" objects he introduced also had a higher dimension than the ordinary numbers, Dirac's solution to the Klein-Gordon equation also yielded extra solutions--solutions corresponding to the extra dimensions of his "number-like" objects. One of the solutions suggested a positively charged particle that in every other way was identical to the electron. What started as a mathematical trick designed to factor an equation and yield insight into the electron therefore yielded an entirely new particle and, indeed, an entirely new type of matter--antimatter, the discovery of which fundamentally altered our understanding of the physical universe.

Dirac's mathematical manipulations and physical speculations would have remained just that except for two facts: (1) In 1932 Carl Anderson experimentally confirmed the existence of the positron. (2) In the nineteenth century mathematicians had already constructed the "number-like" objects that Dirac needed to factor the Klein-Gordon equation. They are known today collectively as the Clifford algebra, and Dirac had to reinvent it to get a relativistic equation for the electron.

Where is the philosophical problem for naturalism in examples like this (and Steiner makes clear that such examples are wide spread throughout mathematics in its application to physics)? The problem is that mathematics is a thoroughly human enterprise. Nature may condition us to see patterns that are readily perceived--that, as it were, ride on the surface structure of nature. At the same time, nature should be indifferent to human idiosyncrasies. Thus, the problem for naturalism posed by Dirac's reinvention of the Clifford algebra and subsequent discovery of antimatter is that it occurred entirely through the manipulation of humanly constructed notations, and with attention not to physical reality but to human convenience.

Equations that are factorable are much easier for us to deal with than those that are not. Factorability, however, has no physical significance. A world indifferent to us has no stake in rendering itself intelligible to us by making the equations that describe it factorable through some mathematical device (like the Clifford algebra). And yet precisely such idiosyncratic manipulations of humanly constructed notations result in genuine and previously unsuspected physical insights.

There really is a problem here for naturalism. As Steiner notes, in every other area where human constructions are manipulated according to human convenience, naturalism expects and indeed confirms no profound insight into the structure of the world. The rules of chess, for instance, do not yield insight into the structure of the atom. The study of palindromes (sentences that read the same backward as forward; e.g., "Madam, I'm Adam") tells us nothing about the first three minutes after the Big Bang.

Indeed, the claim that human constructions manipulated according to human convenience supply insights into reality belongs to what traditionally has been called magic--the view that what humans do in the purely human world (i.e., the microcosm) mirrors the deep structure of the world at large (i.e., the macrocosm). Naturalism has no place for magic. And yet the applicability of mathematics to physics is magic. Ac cording to Steiner, mathematics is the last redoubt of magic, but one that stands se cure and is in no danger of naturalistic debunking. This is a user-friendly world where we humans are the users, and where the tool of discovery that renders the natural world friendly is mathematics.

In place of naturalism, Steiner therefore opts for an anthropocentrism which affirms that humans do have a privileged place in the scheme of things. Steiner's anthropocentrism falls short of a full-blown metaphysical position like Judeo-Christian theism, Platonism, or Pythagoreanism. But it stands sharply against the widely held evolutionary view that humans are mere accidents of natural history.

The Applicability of Mathematics As a Philosophical Problem is a technical contribution to analytic philosophy that presupposes not just a background in philosophy but also extensive exposure to mathematics and physics. Readers without the relevant technical background should be prepared to find no more than 20 percent of the book intelligible. Even so, Steiner's challenge to naturalism is accessible, powerful, and well worth pondering.