

Wigner's Gift Horse

Is nature completely mathematical?



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Conference Idea: Is nature completely mathematical?

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Mathematicians develop abstract theories with beauty and simplicity in mind. Scientists, on the other hand, work to explain the world in all its messiness and complexity. Yet remarkably, time after time, scientific explanations of messy, complex phenomena have taken the form of beautiful, simple mathematical equations.

Referring to this persistent coincidence, mid-century physicist Eugene Wigner noted the “unreasonable effectiveness” of math in explaining nature, calling mathematics a “miracle” and “a wonderful gift which we neither understand nor deserve.”



PAUL DAVIES
Arizona State University

But today, scientists can't resist the urge to look this gift horse in the mouth and wonder just how far the miracle – if miracle it be – will extend.

Is nature *completely* mathematical?

Uncertainty, Unknowability and Inevitably, Gödel

Scientists are far from agreement, but the question of how mathematical the fundamental nature of the universe is has proven fertile for the development of new ideas.

Paul Davies, a physicist at Arizona State University, says that the mathematical structure of the universe is surprising and demands an explanation – but is probably not at the root of everything, particularly mental events. “Could it be the case that my feeling happy or seeing the color red will never be amenable to a mathematical description? It's hard to see how mathematics is even relevant,” he says.

Further, some things are intrinsically unknowable, Davies argues. Quantum uncertainty – the inability to exactly identify both the position and velocity of any body – is one source of this unknowability. Davies also suspects that the universe itself, like a computer, doesn't give exact answers, instead

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- Stephen Wolfram

rounding its results to some small extent. These “rounding errors” again limit the precision with which we can make predictions, even in theory.

A third source of unknowability is Kurt Gödel's Incompleteness Theorem, which shows that no finite number of mathematical axioms can capture all elements of reality; in particular, true mathematical statements will always exist that can't be proven. Mathematician and computer scientist Alan Turing later extended Gödel's result to show that there are numbers that no computer could ever calculate. We'll never know what any of these numbers are – after all, if we knew an incalculable number's value, we'd be

able to calculate it – but we know they exist, teeming just out of sight in an unseen dark side of mathematics.

Janna Levin, a cosmologist at Barnard College, has been trying to figure out if Gödel and Turing's conclusions have implications for physics. If the uncomputable numbers never appear in physics, then they don't pose a problem for physicists. “But is it possible for any observable – the expansion rate of the universe, say – to ever assume a value that is one of the uncomputable numbers?” Levin wonders.



JANNA LEVIN
Barnard College

Nevertheless, Levin believes that nature is completely mathematical, even if important physical properties turn out to be incomputable. “Nothing about that ever breaks the relationship between nature and mathematics,” she says. After all, the expansion rate of the universe would still be a number, even if we couldn't calculate it precisely. “I believe that every physical process can be described by mathematical laws, even if they're probabilistic or involve branches of math that are quite counterintuitive.”

If Not Math, Then Code?

Cosmologist and computer scientist Stephen Wolfram takes another view. He says that Gödel's result suggests that mathematics isn't the right framework to understand the physical world at all. "It's amazing that [Gödel's] discovery didn't make people a bit freaked out about using equations to describe nature," he says. "I have to say, I think that the very notion that equations are a good approach to describing the natural world is a little bizarre."



STEPHEN WOLFRAM
Wolfram Research

The successes of mathematics so far do little to persuade Wolfram that mathematics is best framework for science. "Eugene Wigner, the guy who talked about the unreasonable effectiveness of mathematics? I think he just got muddled," Wolfram says. "He said, 'Look, math is really really successful for doing

physics.' What he mistook is that physics bit off those portions of nature that its methods allowed it to describe. But physics hasn't really successfully captured other things, like fluids for example. The science we have is influenced by what we can describe with mathematics."

Wolfram argues that the way to unlock the rest of science is to give up on mathematics and look for explanations analogous to computer code. Very simple computer programs can produce remarkably complex behavior that mimics phenomena science has had difficulty modeling, like the motion of fluids, for example. So studying the behavior of these programs may provide scientists with new insights about these phenomena.

Indeed, Wolfram thinks the universe itself may be generated by a computer program simple enough to be expressed in a few lines of code. "If the laws are simple enough, if we look in the right way we'll find them," he says. "If they're not, it will be tougher. The history of physics makes one pessimistic that we could ever end physics. I don't share that pessimism."

It All Goes Back To Plato

Max Tegmark, a cosmologist at the Massachusetts Institute of Technology, shares Wolfram's hope that we can know the ultimate laws of physics. But unlike Wolfram, Tegmark senses that those laws will be mathematical. That's because Tegmark thinks that math doesn't just *describe* nature, it *is* nature.

Tegmark believes in an extreme form of Platonism, the idea that mathematical objects exist in a sort of universe of their own. Imagine that, Tegmark says, "there's this museum in this Platonic math space that has these mathematical

objects that exists outside of space and time," Tegmark says. "What I'm saying is that their existence is exactly the same as a physical existence, and our universe is one of these guys in the museum."

Tegmark admits that his theory sounds strange at first, but he argues that the theory's very strangeness may be further evidence that he's right. "If a fundamental theory doesn't sound far out, it's almost certainly wrong," he says. He has also found that his theory generates testable predictions, so someday, he may have solid, scientific backing for his "counter-intuitive, disturbing" hypothesis.



MAX TEGMARK
MIT

If he's right, then Tegmark's simple mathematical theory would be the ultimate expression of Wigner's miracle. If not, then Wigner's muddled gift horse lives another day – to bite away some more at the laws of physics.



SOLID Kepler's nested depiction of the five platonic solids, which he thought was a good model for the orbits of the five then-known planets.