Unknowability at the Heart of Science and Mathematics

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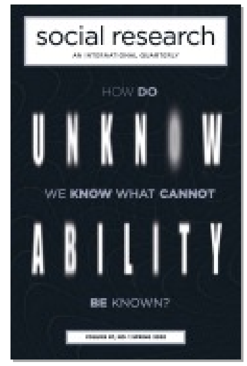

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THE SUCCESS OF THE SCIENTIFIC ENTERPRISE MIGHT SEEM TO SUGGEST that the universe is inherently knowable: that all phenomena can be understood—even predicted—at least in principle and that everything falls on the causal chain linking back to the beginning of time. But such a view of science is naïve. In fact, scientists encounter unanswerable questions and unknowable things.

The concept of unknowability in science has been compared to a painting from 1927 by the German artist Paul Klee called, in translation, *The Limits of Understanding* or *The Limits of Reason*. At the bottom of the canvas is a complicated structure made of linear, mechanical parts; the structure climbs like a ladder. Above the contraption, seemingly on a different plane, is a glowing red sphere floating in space. The ladder doesn't reach. Klee happens to have painted *The Limits of Understanding* just as physicists were discovering quantum mechanics—the strange laws of chance that govern particles at the quantum scale. Quantum mechanics shows that the universe is largely unknowable in a certain sense: except at the exact moment you measure a property of a particle—its location, for instance—there is no answer at all. The particle simply doesn't have a location until you measure it; it has only probabilities of being in various places. The inherent uncertainty and probabilistic nature of our quantum mechanical universe present a fundamental barrier to knowability, a limit to reason.

At the time that unknowability was cropping up in the actual universe, the universe of numbers still appeared solid and comprehensive, something that could be explored without limit. In 1930, three years after Klee painted *The Limits of Understanding*, the great mathematician David Hilbert argued that all mathematical truths could be ascertained by human reasoning. “Our slogan shall stand: ‘We must know; we will know,’” Hilbert declared in a radio address (https://www.maa.org/book/export/html/326610).

But the very next year, the Austrian logician Kurt Gödel showed that we actually won’t; by studying a mathematical relative of the sentence “This sentence is a lie,” Gödel proved the incompleteness theorems. The theorems show that there are no less than an infinite number of mathematical questions that cannot be answered—and true facts that can never be known.

The mathematician, computer scientist, and metabiologist Gregory Chaitin, author of the first paper in this section, discovered one such unknowable truth—the omega number, also known as Chaitin’s constant: a number between 0 and 1 that defines the probability that a random computer program will halt, completing a calculation and providing an answer instead of getting stuck in an infinite loop. Omega is definable, but for reasons related to Gödelian incompleteness, it is unknowable. In his paper, Chaitin explores the concept of unknowability through examples in biology, physics, and mathematics. He then turns to the sociological forces that shape the pursuit of the unknown (as distinct from the unknowable), discussing three fringe scientific theories.

NASA climate scientist Gavin Schmidt deals with another major obstacle to our ability to know things about the world: chaos. When a system is sensitive to every detail, its behavior becomes chaotic—impossible to predict very far in advance. You can never pin down the state of a chaotic system exactly enough at any given time to perfectly project how it will evolve forward into the far future; tiny errors grow and pull the system to an unexpected fate. The archetype of a chaotic system is the weather. Every cloud, gust of wind, and proverbial flap of a butterfly's wings makes a difference, and differences accumulate so that the weather can't be forecast more than a week or so out. Climate—the average of weather—is much more stable and knowable, repeating in a similar pattern year after year. And yet, like the weather, the climate is chaotic; it becomes unpredictable on much longer time scales. Schmidt, who is a leading climate modeler and the director of NASA's Goddard Institute for Space Studies, sees chaos as one of three reasons that the future of climate change is unknowable. Another factor, according to Schmidt, is the inherent imperfection of models in representing the real world. And the third source of unknowability when it comes to the planet's fate is human behavior—what societies will do to curb carbon emissions and mitigate climate change, and how soon.

In his wide-ranging paper, the biologist Stuart Firestein describes unknowability as a source of optimism in science. Best of all is "that deepest of ignorance—the unknown unknown" (117). Before a discovery is made, we never seem to know—and often can't even conceive—what we don't know. In Firestein's view, ignorance compels us forward. He quotes J. B. S. Haldane, who said in 1927—the same year Klee painted *The Limits of Understanding*—"I have no doubt that in reality the future will be vastly more surprising than anything I can imagine.... Not only is the universe queerer than we suppose, it is queerer than we *can* suppose." Firestein further notes that Haldane, who knew nothing of the microbiome, nanoparticles, or the Internet, "was looking forward to being surprised. And this is the optimistic nature of science" (113).