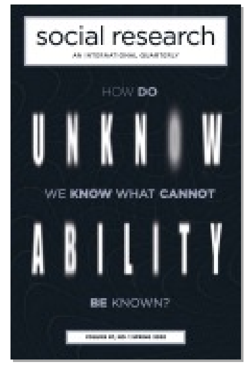
Unknowability in Mathematics, Biology, and Physics

Gregory J. Chaitin



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THERE ARE THREE FIELDS IN MATHEMATICS THAT DEAL WITH UNKNOWABILITY; in chronological order, they are probability theory, metamathematics, and algorithmic information theory. The theory of probabilities began in a series of letters between Pascal and Fermat. One of the first books in this field is *A Philosophical Essay on Probabilities* by Pierre-Simon Laplace, published in 1814, which is still very much worth reading.

The theory of probability is about indeterminate events, but it is not about mathematical facts, which are always black or white, not grey, and which are necessary, not contingent, truths. However, the field of *meta*mathematics is actually about unknowability within mathematics itself—and a fascinating piece of intellectual history associated with the names David Hilbert, Kurt Gödel, and Alan Turing. These three gentlemen are mentioned elsewhere in this volume, so I will not dwell on them.

The newest mathematical field dealing with unknowability is algorithmic information theory. The star of this theory is a real number, the halting probability Omega, which is defined as the probability that a self-contained computer program chosen at random will eventually halt. If all programs halted, the halting probability would be one. If no program halted, the halting probability would be zero. And since some programs eventually halt and others don't, Omega is actually between zero and one.

Omega has a rather straightforward mathematical definition, and it is a single, well-defined real number. Yet its numerical value is maximally unknowable. The base-two bits of the numerical value of the halting probability Omega provide a perfect simulation within pure mathematics of independent tosses of a fair coin. Whether an individual bit is a zero or a one is, to God or to an infinite mind, a single, well-determined individual mathematical truth, but to us down here, it appears maximally unknowable and very much like the result of independent tosses of a fair coin.

Hilbert had hoped that there would be a theory of everything for pure mathematics, but Omega shows that pure math is more like biology, the domain of the irreducibly complex, than it is like fundamental physics, where there is still hope of finding a small set of simple equations that determine the universe.

So that brings us to biology, a very messy, complicated field. I have a wife and a child, so I love messy biology, but from a mathematical point of view, biology looks rather intractable, rather opaque. Will we ever be able to prove mathematically that life must evolve? Does Darwin's theory provably account for the spectacular biological creativity that led to human beings, to you and me? Can one prove that random mutations and natural selection are enough to account for the richness and diversity of our biosphere?

There is a highly developed field called systems biology that deals with computer simulations of complex biological systems, but there are very few mathematical proofs in biology. What can be done about this? Well, in a remarkable 1948 lecture published in 1951 and remarkably forgotten, *The General and Logical Theory of Automata,* John von Neumann identified the fundamental mathematical idea hidden in biology. That's the idea of software, which accounts both for the plasticity of computer technology and its overwhelming success, and for the plasticity of the biosphere with its spectacular diversity of forms. To put it bluntly, nature invented software millennia before humanity did. Biology deals with extremely ancient software. "Evo-devo," or evolutionary developmental biology, is a kind of software archeology.

The new field I call "metabiology" recognizes the impossibility of a fundamental mathematical theory dealing with the effect of random mutations on natural software, on DNA, so instead it proposes studying the effect of random mutations on artificial software, on computer programs. That, in fact, turns out to be tractable mathematically, and it is probably as close as one can get to a theoretical biology as deeply impregnated with mathematics as theoretical physics already is.

When I was a visiting professor at the Federal University of Rio de Janeiro, I sketched out these ideas, and they were published in a little book in English (Chaitin 2012) that has also appeared in Chinese, Japanese, Italian, and Spanish. Teaching this material in Rio helped me organize my thoughts and write the book, and for a while we even had a small metabiology research group that included my wife, Virginia, who studied metabiology's epistemological foundations and implications; and Felipe Abrahão, who did his PhD on extending the mathematical framework. After my visiting professorship expired, there was a hiatus, but I am now happy to say that these ideas have been taken up by Hector Zenil and his collaborators in Europe. Some of their work on metabiology was covered in an excellent article in *Quanta* magazine, "Mathematical Simplicity May Drive Evolution's Speed" (Cepelewicz 2018). So perhaps the mathematical unknowability of biology is decreasing slightly.

NOW I WOULD LIKE TO TURN TO PHYSICS. THE END OF MARCH 2019 MARKED the thirtieth anniversary of a notorious 1989 press conference at the University of Utah, announcing a discovery by Martin Fleischmann, an extremely distinguished electrochemist, and his younger colleague Stanley Pons. They claimed they had an electrochemical cell that was generating so much excess energy, so much heat, that the source had to be nuclear energy—it was far too big to be chemical in origin.

For a month or so there were media frenzies and many replication attempts. The cover of *Time* magazine proclaimed that nuclear fusion had been achieved in a test tube. But this quickly turned into a fiasco. The final verdict was that the two scientists were incompetent or worse. They resigned their professorships and fled the country. Fleischmann returned to England, and Pons fled to France, resigning his American citizenship. Just mentioning "cold fusion" can destroy a scientist's career. It is an unmentionable topic and has been so for three decades—in most of the world. But strangely enough, there are places where people think differently.

In Japan there is now a national project to counter global warming using a technology based on a much more sophisticated version of Pons and Fleischmann's discovery. Remember, the Japanese have no petroleum, and the Fukushima nuclear accident was a catastrophe. There is also tremendous political and economic backing for what they wisely refer to as the "new hydrogen energy" rather than "cold fusion." A press release in English and strangely invisible outside Japan, in fact, recently announced a collaboration between Mitsubishi, a Japanese foundation called Clean Planet, and Tohoku University, where there is even a university department devoted to developing this new hydrogen energy source. I think the fact that what is unmentionable in much of the world is a national imperative in Japan is a fascinating example of the sociology of science.

Finally, I would like to look at Randell Mills's work on "hydrinos" and dark matter, the mysterious 90 percent of the mass of the universe that no one can see or identify. It is a curious fact that the solar corona is much, much hotter than the surface of the sun. What can the source of all this energy be? According to Mills, who has his own private research institute, the energy in the corona is released when atomic hydrogen turns into what he calls hydrinos, a more compact form of hydrogen than is allowed by conventional quantum mechanics. The electron in a hydrino atom is closer to the proton than was normally thought possible because it forms what Mills calls an "orbisphere," that is, some kind of a surface, not a point. Mills says that hydrinos are the dark matter, and he has some intriguing experiments in which he claims to have created a piece of the solar corona in his laboratory. According to Mills, the brilliant spectrum the device emits in the deep UV is similar to the deep UV part of the spectrum of the solar corona.

What, then, are we to make of "new hydrogen energy" and "hydrinos"? Whether or not they eventually save humanity from global warming, whatever the final verdict, there is no doubt in my mind that they constitute fascinating chapters in the history of ideas and in the sociology of science.

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