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The Man Who Cracked The Code to Everything ...

... But first it cracked him. The inside story of how Stephen Wolfram went from boy genius to recluse to science renegade.

By Steven Levy

Word had been out that Stephen Wolfram, the onetime enfant terrible of the science world, was working on a book that would Say It All, a paradigm-busting tome that would not only be the definitive account on complexity theory but also the opening gambit in a new way to view the universe. But no one had read it.

Though physically unimposing with a soft, round face and a droll English accent polished at Eton and Oxford, Wolfram had already established himself as a larger-than-life figure in the gossipy world of science. A series of much-discussed reinventions made him sort of the Bob Dylan of physics. He'd been a child genius, and at 21 had been the youngest member of the storied first class of MacArthur genius awards. After laying the groundwork for a brilliant career in particle physics, he'd suddenly switched to the untraditional pursuit of studying complex systems, and, to the establishment's dismay, dared to pioneer the use of computers as a primary research tool. Then he seemed to turn his back on that field. He started a software company to sell Mathematica, a computer language he'd written that did for higher math what the spreadsheet did for business. It made him a rich man. Now he had supposedly returned to science to write a book that would make the biggest splash of all. And, as someone who'd followed his progress since the mid-1980s, I was going to see some of it.

We agreed to meet for dinner in Berkeley. As I drove to the restaurant, rain started coming down in sheets; on the pavement, water ran toward the gutter in twisted, chaotic rivulets - seemingly unfathomable patterns that I would never view in the same way after Stephen Wolfram was done with me. We chatted through dinner, remembering some of our history. And then he handed over

a stack of papers. The type was set and the diagrams were sharp - apparently he was almost at the page-proof stage, with publication pending. I'd known about his work in a former backwater of physics called cellular automata, and as I read the first few paragraphs, it was clear he was using that research as a background to make more profound statements. Very profound statements. As best I could make out in my quick flip through the pages, he seemed to be saying that the key to the universe was computation: The entire cosmos, from quantum particles to the formation of galaxies, was a perpetual runtime flowing from simple rules. Yet despite all our learning, human beings have missed the point of it all, because of the elusive nature of complexity. That is, until Stephen Wolfram came along and uncovered what a few millennia's worth of scientists had somehow failed to comprehend. Whoa.

I wondered if the pages I was holding would actually be a part of history. Or would they be regarded as folly, an act of hubris by a brain-punk who'd been thumbing his nose at the scientific establishment even before he began to shave? I handed it back to him, with the assurance that upon its completion within a few months, I'd get a chance to go through it at my own pace. And so would the world.

That was 10 years ago.

What happened to Stephen Wolfram in the interim has become sort of an urban legend in the scientific community. Not long after our dinner, which occurred in the spring of 1992, he became, in his own words, a "recluse." He moved, with the woman he had recently married (a mathematician), to the Chicago area and started a family. He rarely made the two-hour drive to Wolfram Research, his thriving software company. Instead, he put himself in a kind of voluntary house arrest, single-mindedly devoted to the completion of the book. "He dropped totally out of the scene in every sense of the word," says his friend Terrence Sejnowski, a neuroscientist at the Salk Institute. "He hasn't published a word, he doesn't go to meetings. He's in a self-made isolation center." To maximize his concentration, Wolfram became nocturnal: He worked at night, when the world was asleep, and retired at 8 in the morning.

As the Web emerged and exploded, as dotcoms boomed and busted, as the White House went from Bush to Clinton to Bush, he worked. At some point he had decided that no conventional publisher would provide the attention and exacting standards that his book demanded. (He had no lack of offers.) So he decided to do it himself, using the resources of his software company. It would result in one of the most expensive vanity projects in history. Or as one friend, Gregory Chaitin, an information theorist at IBM, puts it, "He reminds me of the noblemen who worked in science during the 1800s - they did it for the love of it."

Wolfram's days would begin in mid-afternoon. He'd usually do an hour or two of official business, operating a multimillion-dollar company by email and conference call. Early evening hours offered an opportunity for some family time. Then, as the world retired and distractions fell away, he'd enter the professionally soundproofed, wood-lined office on the top floor of his house and immerse himself in the act of remaking science.

He spent hours running thousands of computer simulations and noting the results. Because part of his project involved nailing down the conceptual history of dozens of scientific branches, he'd surf the Web. "One can devour lots of papers in very short amounts of time in the middle of the

night," he would later explain to me. He'd begin with an idea, and start downloading papers. Eventually, "you feel kind of depressed that it's too big a field and you're never going to understand it." But then, "usually in a few days it all starts to kind of crystallize and you realize that there really are only three ideas in this field, and two of them you don't believe. And sometimes at that stage, when I'm checking that I've really got all of the ideas, I find it useful to chat with people. Sometimes you hear about something else. And sometimes you don't."

Wolfram's friends came to know the drill. "You get a call at 2 in the morning," says Sejnowski. "By the morning he knows more than you do." Every two weeks or so, Wolfram would call an outside expert, but usually found these sessions unsatisfying. All too often he'd be disappointed that the alleged master couldn't provide him with the information he needed.

He pressed on, never a day off. "I wanted a straight line from where I started to where I wanted to get to," he says. "I cut off interaction with the outside world - not that it wouldn't have been fun, I personally like it - but those little perturbations would make the thing take longer." On a good night, he'd get a page written, and he'd be a few hundred words closer to finishing. And so it went, night after night, a lone explorer inventing his own brand of science while the world slept.

At various times, it appeared publication was imminent. Those who purchased a collection of his scientific papers, issued in hardback in 1994, saw an image of the cover art for his book, then titled *A Science of Complexity* ("coming soon," the caption said, "sure to become a landmark in the history of modern science"). Over the next few years, Wolfram teased his public by hinting at the contents in occasional interviews. But the publication date kept moving back. Wolfram's friends seriously feared that it would never be completed.

Wolfram predicts an algorithmic key to the universe that can compute quantum physics - or, say, reality TV - in four lines of code.

Early last year, Wolfram told me he was almost finished, this time for real. He promised to send me an early copy, if I would sign a nondisclosure agreement. A few days later, *A New Kind of Science* arrived. My copy (number 26) was broken up into three thick sections. Together they dwarfed a phone book. A sticker on the otherwise blank cover was printed with my name on it. There was a disconcerting warning: "CONFIDENTIAL: Receipt and perusal of this document permitted pursuant to nondisclosure agreement ... If you do not have such an agreement please return this immediately...."

If I thought that the draft I had glimpsed in 1992 was provocative, it was nothing compared with the scope and sheer chutzpah of the finished product. Scheduled to reach stores in May, *A New Kind of Science* will ignite controversy in the scientific world. The self-conscious comparisons with Newton's 1687 *Principia* will undoubtedly earn Wolfram both attention and derision. Some early readers are drawing analogies instead to Galileo - not in terms of scientific achievement, but heresy.

At 1,280 pages, the book pushes the limit of what can be physically bound between two covers. Inside, it recognizes no boundaries, not only ranging through traditional fields of science but venturing into the realms of philosophy, theology, the social sciences, and even extraterrestrial

policy. There are two sections, the larger being a main text of 12 chapters written in everyday English, with almost no equations, in order to reach an audience of nonspecialists. (One of his friends, Carnegie Mellon mathematical logician Dana Scott, complained to Wolfram that *A New Kind of Science* reads like *USA Today*. As if.) Just as important as the text are hundreds of detailed diagrams, the majority of them visual representations of experiments run from Mathematica programs.

The second section is a collection of notes, which includes a piecemeal yet concise history of science through the filter of a didactic middle-aged, MacArthur-winning Jedi mind-warrior. It also contains personal notes, bits of Mathematica code, various mentions of previous work (though bibliographic comments are scrupulously avoided), and an index of 15,000 entries.

To Wolfram, adopting a relatively readable style also meant jettisoning all pretense of humility, a trait that in any case he believes is a waste of time. In a note titled "Clarity and modesty," he admits to having once subscribed to the "common style of understated scientific writing" but concluded that unless he explicitly identified his findings as the earth-shattering concepts he believed them to be, readers wouldn't grasp their significance. Of course, the very nature of his approach - laying his theory out in one Brobdingnagian salvo - is by nature immodest.

By rejecting the standard protocols of scientific publication - the release of findings in a series of refereed, jargon-laden papers with rigorous mathematical proofs - Wolfram is consciously bypassing the establishment, engaging in a form of retail science that aims straight for the people. Wolfram insists that "doing a small piece and telling the world about it" would have taken him three times longer, and besides, "if you give them little pieces, they're not going to come up with grand conclusions."

The book begins with a thunderclap:

"Three centuries ago science was transformed by the dramatic new idea that rules based on mathematical equations could be used to describe the natural world. My purpose in this book is to initiate another such transformation, and to introduce a new kind of science that is based on the much more general types of rules that can be embodied in simple computer programs."

He goes on to explain that by applying a single key observation - that the most complicated behavior imaginable arises from very simple rules - one can view and understand the universe with previously unattainable clarity and insight. The idea of complexity arising from simple rules - and that the universe can best be understood by way of the computation it requires to grind out results from those rules - is at the center of the book. The big idea is that the algorithm is mightier than the equation. "Stephen makes the point that Newton developed calculus before Babbage invented computing - but what if it had been the other way?" says Rocky Kolb, a physicist at the Swiss physics laboratory CERN.

Wolfram is not satisfied with simply explaining and justifying his contentions, but instead makes substantial efforts to apply his insights to dozens of fields. "What's basically happened is that I had this idea of how to use simple programs to understand things about nature, the universe, other stuff," he says. "And you can start looking at questions that have been around forever, and you really get somewhere." He invariably introduces each topic in a similar fashion: Curious to know about _____ [CHOOSE ANY SCIENTIFIC DISCIPLINE] and how his new theories might apply, he

decides to take a look at the history of the field. Amazingly, he concludes, for hundreds of years so-called experts have failed to answer key questions that should have been easily resolved centuries ago. (Wolfram's disappointment in his predecessors is bottomless.) But when Wolfram applies the ideas from *A New Kind of Science*, he begins making progress and expresses the hunch that not long after his ideas are understood, the biggest problems will quickly be resolved, transforming the field.

To list only a few examples: Wolfram finds an exception to the second law of thermodynamics; conjectures why extraterrestrials might be communicating with us in messages we can't perceive; explains seeming randomness in financial markets; defines randomness; elaborates on why the "apparent freedom of human will" is so convincing; reconstructs the foundations of mathematics; devises a new way to perform encryption; insists that Darwinian natural selection is an overrated component in evolution; and, oh, theorizes that there's a "definite ultimate model for the universe." What might this be? The mother of all rules; a single, simple "ultimate rule" that computes everything from quantum physics to reality television.

The climax of the book is the principle of computational equivalence, which may as well be called "Wolfram's law." After hundreds of pages of laying groundwork, presenting case after case of visual examples where simple rules generate counterintuitively complex results, Wolfram concludes that this phenomenon is overwhelmingly commonplace - it's at the base of everything from morphology to traffic jams. Then he goes further, stating that once a system achieves a certain, easily attainable degree of complexity, it's reached the point of maximum complexity, as measured by the computation required to crank out the end result. Everything at that level of complexity - and that means almost everything you can think of, from human thought to rain hitting pavement - is exactly as complex as anything else.

It's an idea that is at once liberating and humbling. Wolfram himself considers it the logical next step from earlier scientific revolutions, each of which disabused humanity of the notion that there is something "special" about our species and its place in the scheme of things. (Copernicus showed we weren't the center of the universe; Darwin proved we were just another product of evolution.) Basically, he's saying that all we hold dear - our minds, if not our souls - is a computational consequence of a simple rule. "It's a very negative conclusion about the human condition," he admits. "You know, consider those gas clouds in the universe that are doing a lot of complicated stuff. What's the difference [computationally] between what they're doing and what we're doing? It's not easy to see."

The principle of computational equivalence also puts limits on science itself, ruling many questions unanswerable because the only way to discover the consequences of many complex processes is to let things proceed naturally. There's no shortcut, since our own computational tools are at best only as powerful as the complicated systems we hope to study.

On the other hand, if the concept is valid, it portends amazing technological developments. "You might think machines can't capture nature because these programs are too simple," Wolfram says. "But the principle of computational equivalence says that's just not true. These programs can do all the stuff that happens in nature." By that reasoning, no barriers exist to prevent machines from thinking as humans do. "I have little doubt," he writes, "that within a matter of a few decades what I have done will have led to some dramatic changes in the foundations of technology - and in our basic ability to take what the universe provides and apply it for our own human purposes."

Only a few people - mainly friends of his in the scientific community - have read the book before its publication. They are vastly impressed, but at this point generally reluctant to endorse all of it; they say people will take decades to absorb everything Wolfram is proposing. Not heard from yet are the voices of the establishment, which undoubtedly will have problems with the unconventional work and its author. "Most scientists will find it difficult to believe that there's a better way to do science," says CERN's Kolb. "It's not the way we've been trained to think."

Probably the toughest criticism will come from those who reject Wolfram's ideas because the evidence for his contentions is based on observing systems contained inside computers. "When it comes to computer experiments," he says, "I can just do them and can know absolutely - definitively - I got the right answer and understand what's going on." Wolfram can argue at length why this is a valid approach. Ultimately, he believes, he and his future followers will generate a wealth of computer-related systems that create phenomena identical to those found in the natural world - and the weight of the evidence will convince all but the most hardened skeptics that his ideas are dead-on. The beginnings of this are rules that seem to produce on a computer the same results as pigmentation patterns on jaguars and seashells, the behavior of financial markets, or the growth of leaves.

For now, the skeptics aren't having it. "Worthless!" says renowned physicist Freeman Dyson, who received an early copy of *A New Kind of Science* and required only a glance before dismissing it. "It's a case of style over substance."

If Wolfram's ideas ultimately are refuted, he will be remembered as one more brilliant guy who went overboard, verging on megalomania. But even if he is wrong, *A New Kind of Science* is an incredible achievement, one that will richly reward adventuresome readers. Of course, if he *is* right, his book indeed belongs to history. Either way, the world is about to reckon with a scientist who's making the biggest leap imaginable: remaking science itself, with only his computer and his brain.

In a sense, *A New Kind of Science* is the result of a journey that began with a computer printout produced by an early Sun workstation on June 1, 1984. Stephen Wolfram, then 25, was already on his second career. Born in 1959 to a father who was both a textile manufacturer and a minor novelist, and a mother who taught philosophy at Oxford, the young Wolfram was clearly a prodigy - and a handful. "I guess I was not a very easy kid," Wolfram told me when we first met in 1984. His baby-sitters would typically leave after a week or so "because I was terrible to them."

At age 10, he decided to become a scientist and began operating in much the same isolated manner that would characterize his later methodology. Almost from the start, he developed an allergy to the establishment. At 12, he won a scholarship to Eton, where he astonished teachers with his brilliance and frustrated them by taking no instruction whatsoever. He made money by doing other kids' math homework. At 14, he became interested in a particle physics problem and wound up writing a paper that was accepted by a prestigious professional journal. He entered Oxford at age 17, but it is an exaggeration to say he attended it - by his account, he went to first-year lectures on his first day and found them "awful." The next two days he dropped in on second- and then third-year lectures, quickly deciding "it was all too horrible - I wasn't going to go to any more lectures." So he worked independently, making no secret of his disdain for the professors he

considered his intellectual inferiors. When he took end-of-year exams, he finished at the top of his class.

Eventually, after publishing 10 papers, he left Oxford for Caltech, which presented him with a PhD in theoretical physics just weeks after he turned 20 and hired him as a faculty member alongside luminaries like Richard Feynman and Murray Gell-Mann. A year later, he won the MacArthur award. He considered the surrounding hubbub an annoyance, and during a network TV interview he conspicuously picked his nose.

At Caltech, he ran into his first serious professional flap. Wolfram had become interested in how computers could help the scientific process; he developed SMP, a computer language that performed tasks like algebra. Because of Caltech's patent rules, an ugly dispute broke out, and Wolfram was forever embittered that he was denied sole ownership of what he considered his creation. He left Caltech for a sinecure at the Institute for Advanced Study, the Princeton, New Jersey-based former home of Albert Einstein. But by that time, he was no longer interested in particle physics. Instead, he began pursuing what he viewed as more creative areas, "things that people would consider crazy." Specifically, he became interested in cellular automata.

At the time, the field of cellular automata, or CAs, oscillated between a science and a computer geek's plaything. CAs themselves are abstract systems that pose a spreadsheetlike universe in which individual cells move from one condition to another - for example, from dark to light - one click at a time, according to what rules have been set for this evolution. These rules determine the color of the cells in the next iteration, depending on the conditions of the current pattern. The word *automata* refers to the nature of the process, in which the patterns on the grid evolve depending not on human intervention but on the rules themselves: Once the initial condition and those rules are set, all a person can do is sit back and watch.

The field was the brainchild of the legendary mathematician John von Neumann, at the suggestion of his friend Stanislaw Ulam. Von Neumann was interested in the idea of artificial life, particularly self-reproduction. His claim - which would be echoed by those who went on to study CAs - was that these systems should not be seen solely as mathematical abstractions but as stripped-down versions of the universe itself, wherein the pageant of cells turned on and off on a checkerboard (or computer screen) could actually stand for the mechanisms in the physical world. One computer scientist, Ed Fredkin, the former head of MIT's famous Project MAC, bent some minds by suggesting that the universe itself was a giant cellular automaton.

Not surprisingly, Wolfram regarded the early work in the field as "just awful" and proceeded to brand the category as his own, somewhat to the dismay of the small CA community, which appreciated the attention Wolfram brought but resented his imperious attitude. ("Wolfram is an absolutely brilliant guy, and he's right about the new kind of science that underlies everything," says Fredkin. "But he can't escape a compulsion to take credit.") Wolfram methodically analyzed sets of rules, developing a classification system that rated the complexity of various CAs - all with the intention of clarifying the way we view complexity in the real world. He did this by studying and numbering all possible rule sets in one-dimensional CAs. These were elementary systems in which the CA grows one line at a time; the state - dark or light - of each cell on the new line is determined by a rule that depends on the conditions on the previous line.

Wolfram also began to build a case that the same mechanisms that determined the outcome of cellular-automata experiments were omnipresent in nature itself. He was often photographed with

seashells whose pigment displayed a pattern that was eerily similar to those produced in his computer printouts of simple CA experiments.

Wolfram was a controversial figure at the Princeton institute in the mid-1980s. Established scientists considered his operation on the third floor of Fuld Hall, where he and his assistants sat in front of workstations and performed digital experiments, as somehow unseemly, not the way serious research should be conducted. "I'm not sure that what he does can be called science," the institute's Dyson told me around that time. "It's more in the nature of mathematical games. He clearly is not a physicist anymore." And Heinz Pagels, the late physicist who headed the New York Academy of Sciences, told me, "The wunderkind has no clothes."

For his part, Wolfram felt he could have used more outrage - it would have meant people were thinking about those ideas and taking them seriously. In Wolfram's mind, studying the results of cellular-automata runs on the computer could unlock deep truths about the universe itself. The proof for him came one fateful day in June 1984 when he printed out the results of a 2-D cellular-automata experiment using Rule 30.

When Wolfram studied the printouts on an airline flight from New York to London, he was thunderstruck. This experiment used the simplest of initial conditions - one darkened cell on the top row. And the process of generating future states was elementary. Yet Rule 30 yielded an eruption of the most complicated, seemingly random output imaginable. (See page 135.) In fact, there seemed no end to it. As Wolfram studied it, he began to realize that there was something profound about how such complexity would arise from a simple program and began to wonder about the implications. Eventually, he would conclude that Rule 30 was not an anomaly but a crucial window onto the way the world operated.

Wolfram's cellular-automata work came to be cited in more than 10,000 papers. He felt, however, that even his enthusiasts were missing the point - that CAs held the key to a vast understanding of the world. Aware that the Institute for Advanced Study was not eager to host his explorations, he left for the University of Illinois at Urbana-Champaign, which gave him his own institute, the Center for Complex Systems Research. But after two years, he left the center - among his many complaints, he says, "the goofiest thing was that I was supposed to be the guy who went out to raise money, while other people got to do science." By then, he had seemingly been diverted by another project - creating a computer language called Mathematica, which took his SMP work at Caltech to a much higher level. He started Wolfram Research and hired top scientists and mathematicians to staff its Champaign headquarters. The software came out in 1988 and was an instant success. By 1995, more than a million people were using it.

Mathematica turned out to be invaluable to Wolfram, allowing him to pursue his real dream of making a mammoth contribution to scientific understanding. On a mundane level, the company brought him the wealth and resources to proceed with his book without having to worry about income or research grants - since Wolfram Research was a private company, with the majority of shares owned by its founder, there was no problem spending millions of dollars on a personal science project. More significantly, the creator of the software turned out to be its most avid consumer. Mathematica was a powerful tool to run the experiments that formed the basis of his "new kind of science." A couple of years after the program was finished, Wolfram gushed to me that "I've been going back and redoing problems, and it's spectacular - things that once took me a week to do now take a half hour." Wolfram had given himself the ammunition to remake science, and in 1991, he withdrew his physical presence from the company to concentrate on the

book. So began his days as a recluse.

On a crisp morning in February this year, I am off to Champaign to sit down with Wolfram for the first time since that night in Berkeley a decade ago. Only a few days before, he absolutely, positively completed *A New Kind of Science*. Still trying to acclimate himself to the weird circumstance of being awake at 9 in the morning, the CEO is making a rare appearance at Wolfram Research, located in an six-story office building not far from the university campus, to review some projects. (The book itself - 50,000 copies - is about to roll off presses at a Canadian printer, the only operation in the western hemisphere that Wolfram judged capable of rendering the high-definition graphics and illustrations. It will cost $12 a copy to print - five or six times that of a conventional book - making its $45 cover price somewhat of a bargain.) What was a mop of unruly hair when we last met is now a balding pate. He wears a tweed jacket, slacks, and sneakers, the picture of a software executive.

For someone with so little patience for human failing, his management style is fairly loose, though clearly his employees are deferential to him. At a Mathematica design review, he flirts with sarcasm - "Why would anyone want to do this?" he says of a proposed feature - but listens to the answer and finally concludes that the proposal is impressive. "I wouldn't have been here for 11 years if he was the terror that people say he is," says marketing exec Jean Buck, who assumes a maternal tolerance toward the quirks of her employer. (She finds it humorous that when she told her boss she'd be busy on Super Bowl Sunday, he asked, "What's that?") The 300 people at Wolfram Research know they are free to act independently, but only in the spirit of their leader. Though during the Internet boom some hoped that Wolfram Research would go public, Theo Gray, a scientist who helped Wolfram form the business, says that was never a possibility. "It wouldn't be Stephen's company then," he says.

Later in the day, I meet with a group who assisted Wolfram on *A New Kind of Science*. There are perhaps a dozen people in the room, and like prisoners shown the open gate after serving a long sentence, everybody is a little stunned that the book is actually finished. There are fact checkers, proofreaders, graphics specialists, PhDs who helped run the computer experiments, the art director, the production manager - a disparate collection who were part scientific staff, part publishing staff. Each day, while Wolfram was sleeping, this contingent would be busily generating graphics, securing permissions, and looking for the perfect photograph of broccoli. (One tells a story of when Wolfram rejected a picture of a panther "because it had a funny expression.") As the book got bigger, there were conflicts over how to handle its complexity. At one point there was actually a debate about whether there should be notes to the notes.

In some ways, *A New Kind of Science* was run like a software project. The work was always to be delivered as a digitally typeset file with all the graphics included: one massive load of bits. So instead of drafts, there were frequent "builds," some of them buggier than others. There were alpha versions and beta versions. Some of the engineers are developing A New Kind of Science Explorer, a PC application with a mini-Mathematica program that allows people to run the experiments in the book and begin to do research projects of their own. Wolfram feels very strongly that "his" kind science is one through which amateurs will unearth major discoveries, and he has been thinking of various ways to assist them.

Suddenly, it occurs to me that someone might be missing in this group. "Who actually edited the

book?" I ask. There is a puzzled silence in the room. An editor? Finally Wolfram says, "No one." Except, of course, the author. Later on, he explains. "I think in terms of 'This is my book and I'm fully responsible for it.'"

After Wolfram's day at his software company, we drive through town to a nondescript steak, chicken, and salad house in Urbana to continue our discussion. I ask him what he thinks the reaction will be to *A New Kind of Science*. He doesn't guess, and in a sense doesn't care. "I think when I started this project I was still very interested in saying, 'What will other people think?' After a while I realized, 'Why am I really doing this? Is it really worth my while to spend 10 years of my life doing something to get other people to say positive things about it?' No, it's not. Absolutely not. And actually, from some very cynical point of view, my opinion of the world at large isn't high enough for me really to be interested in what they have to say."

So when people complain - and they will - that Wolfram's "new kind of science" is built not on proofs but on looking at computer readouts, he'll see their complaints as the howling of dinosaurs. "They'll probably talk derisively about little programs and games," he says. "But it's not really engagement, it's like, 'Let's just hope it goes away.' It's like the print publishers hoping the Web goes away." He prefers to take the long view. He's absolutely confident that his work is sound and is ready to let people absorb it over a period of decades. He believes that in each area he discusses, other researchers will confirm his findings. He thinks that eventually the principle of computational equivalence will be as commonly accepted as gravity. Meanwhile, he says, his main concern is that people actually read the book, and he professes to fear not those who will attack him but bandwagon-riders who will scan a chapter or two and then generate garbage based on their misimpressions.

As the meal progresses, our talk turns to an enigma that is almost certainly a computational equivalent of the mysteries of the universe: Wolfram himself. I point out that in a strange way, this 1,200-page tome with pictures and diagrams of computer experiments and animal skins and seashells and axioms is an extremely personal book. Presented in the guise of science are passionate contentions about religion and free will and the nature of humanity. The discoveries track its author's obsessions. In a sense, *A New Kind of Science* is Stephen Wolfram's autobiography.

"There are definitely elements of expression there," he admits. "I think 10, 15 years ago, I could not have done a decent job. I've seen more of people's lives now. Back then, I would have said, 'I don't care about theology, that's not my thing.' But as I kept looking at the historical context, I started realizing that I actually did care about these things and had something to say about them."

The book also is arguably a rite of passage for him as a man. When I first met Wolfram in 1984, he insouciantly dissed his parents' careers. "I've never read [my father's] novels.... They get good reviews, but they don't sell terribly many copies," he told me. Ironically, *A New Kind of Science* is not just a scientific excursion but also a literary excursion. Like James Joyce, Wolfram believes his ideal reader is one who will devote a lifetime to reading his book, and like Joyce the novelist, Stephen Wolfram (a novelist's son) has produced an encyclopedic world.

If the expression of the book represents his father's craft, the application of his ideas to the riddles of human existence reflects the concerns of his mother, the Oxford philosophy professor, who died in 1993. Back in 1984, he said of her, "I have no idea what she does, and the only

consequence of her being in that profession is that I will never consider doing anything that's labeled philosophy." But *A New Kind of Science* is nothing if not a book on philosophy. One of his friends suggests it should be called *Principia Computatus*. And in another irony not lost on the author, Wolfram's research led him to a textbook on logic written by his mother. "I actually cared about the answers to the questions," he says.

I think back to Wolfram as a brash, trash-talking 25-year-old. Now he's a family man ("Having kids has made him much more of a human being," says a Wolfram Research exec) whose new work, while as iconoclastic as ever, turns out to be a homecoming for him, an outcome that seemed totally unpredictable. Only by nature running its inscrutable computations could the result become apparent.

As dessert is served, I bring up the secret-of-the-universe question. Wolfram's theory that there is a single rule at the heart of everything - a single simple algorithm that, in effect, generates all the rules of physics and everything else - is bound to be one of his most controversial claims, a theory that even some of his close friends in physics aren't buying. Furthermore, Wolfram rubs our faces in the dreary implications of his contention. Not only does a single measly rule account for everything, but if one day we actually see the rule, he predicts, we'll probably find it unimpressive. "One might expect," he writes, "that in the end there would be nothing special about the rule for our universe - just as there has turned out to be nothing special about our position in the solar system or the galaxy."

I have some trouble with this.

"I've got to ask you," I say. "How long do you envision this rule of the universe to be?"

"I'm guessing it's really very short."

"Like how long?"

"I don't know. In Mathematica, for example, perhaps three, four lines of code."

"Four lines of code?"

"That's what I'm guessing. I mean, I don't really know, but I think there's no obvious evidence that it's any longer than that. Now, in a sense, it will be short if Mathematica was a well-designed language. It will be longer if it doesn't happen to be as well-designed, in the sense that that doesn't happen to be the way the universe works. But we're not looking at 25,000 lines of code or something. We're looking at a handful of lines of code."

"So it's not like Windows?"

"No." Wolfram laughs. "It's not like Windows. It's going to be something small, I think. I've certainly wondered. You ask about the theological questions and things. I think there will be a time when one will sort of hold those lines of code in one's hand, and that is the universe. And what does this mean? You know, how do we then feel about things, if this whole thing is just five lines of code or something? And in a sense, that is a very unsatisfying conclusion, that sort of

everything that's going on, everything out there, is all just this five lines of code we're running."

There is a moment of silence between us. In the background are the clatter of dishes and silverware, noises that come from a restaurant in Urbana, Illinois, preparing for closing time. The mundane but complex stuff of equivalent computational processes.

"Well," I say finally, "I guess we'd feel really bad if it wasn't well-written."

Wolfram grins. "Yes, right."

Another pause. "So do you believe we'll find this code in your lifetime?"

"I hope so. Yeah."

"Do you want to find it?"

"Sure. That'd be nice."

"Is that your next thing to do?"

The self-styled Newton of our times smiles, as if to himself. "I'd like to think about that. Yeah."

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Rule 30

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