A Christian Appraisal of Stephen Wolfram's *A New Kind of Science*

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Abstract: Wolfram exposes some ideas about informatics that relate to Christian scholarship: Does Wolfram's definition of free will permit God to have free will? Will human souls resurrected to a new body—as described by St. Paul and Aquinas —be like software that is moved to new hardware? Jesus' incarnation as in-form-ation in the Aristotelian sense.

"Computers are useless. They can only give answers."
—Pablo Picasso [Grim 1]

1. Informatics offers the latest metaphor of mind.

Before I begin speaking, let me say thanks to my student Shawn Horine who provided the slides.

Computer Science is not just a discipline. It is a metaphor that has pervaded all of society. It has invaded our persons. It's not the first. Fourteenth century clocks gave rise to a clockwork image. We say, "What makes her tick?" Nineteenth century steam engines gave rise to a thermodynamic image. We say, "He's just letting off steam." The computer age has given rise to the information processing image. We say, "I'll get his input on that." Or, "I'm processing that."

Metaphors for thinking come from all parts of our body. Our digestive system: "She's ruminating on that." Or, "I haven't had time to digest that." Our reproductive organs. "That was a seminal idea." Or, "How did he conceive of that idea?" Our blood pump. "My heart goes out to you." Even when thinking is located in our brain, it is regarded as done by what psychologists like William James in 1860 called a homunculus or "little man." The homunculus sees— so we have "in-sight" using eyes that point inward. He teaches—so we have "in-tuition."

In our lifetime, metaphors for thinking have shifted from parts of the body to computing machines—from the Biology Department to the Computer Science Department. Computer Science is not about computers any more than Astronomy is about telescopes or Biology is about microscopes. [Wolfram 42, but originally Edsger Dijkstra for the first half] But if the computer is merely the tool of Computer Science, what is Computer Science?

In most countries of the world, Computer Science is called Informatics to emphasize that it is about information in general. The Dewey Decimal system classifies Informatics as 001—the most general category. Cornell University classifies Computing and Information Sciences as a Dean's level university-wide unit across all schools. Informatics is too pervasive to house within a single school. Computer scientists at MIT seriously regard computers as a form of artificial life.

Ellen Ullman in a Harper's Magazine article cautions us not that computers can be defined as artificial life, but that they open the door to "the redefinition of life itself as artificial." Cognitive Psychology is already a branch of Computer Science. Now Biology is fast becoming a branch. DNA is just "code," as though it were a computer code. [Ullman 63] Two of my students have worked on artificial life in recent years: Lisa Croft Strite solved a graph theory problem using ant colony optimization. [Strite] Keith Wagner entered a soccer team in a worldwide softbot soccer team competition—Robo Cup. Keith's program allows his team to learn from the play of other teams. His team players do not come with a ready-made idea of what winning at soccer is. But they learn even as they play by interacting with other teams and with their teammates. Computer scientists expect to get intelligence, even consciousness, out of this "emergent behavior." [Ullman 64] Ullman calls this fantasy a "flight from introspection." [66] She doesn't notice that "introspection" is itself a metaphor!

2. Aristotle anticipated the definition of software in his definition of soul.

The idea of information goes back to Aristotle. In Figure 1 defines soul according to Aristotle at the left column, and in the middle column defines software.

Soul: Body :: Software: Hardware		
Soul	**Software**	**Hardware or Body (meatware)**
Ideas (Dawkins' memes?)	Programs	
Immortal because abstract	Immortal because abstract	Mortal (rusts)
Aristotelian form (*morphe*) of a person	Aristotelian form of a computational system	Aristotelian substance (*schema*)
Formal cause, among Aristotle's four kinds of cause	Formal cause, among Aristotle's four kinds of cause	Material cause (matter) and efficient cause (opening/closing of circuits)
Needs body to be animated	Needs hardware (or meatware) to run	
Agent intellect (acquires concepts)	Executable code and temporary data	Short-term memory areas of brain; RAM, processors
Receptive intellect (retains and uses concepts)	Permanent data	Long-term memory areas of brain; ROM, disks

Table 1 Comparing Soul and Software [cf. Barrow & Tipler 680]

According to Aristotle, to be "informed" is to have new forms added to our receptive intellect. Theologian Thomas Aquinas agreed. For Aristotle and for Aquinas, our souls can't exist apart from our bodies, just as software has to run on some hardware. But what of the resurrection? In I Corinthians 15, St. Paul teaches that our bodies will be resurrected as glorified bodies. Using cannibalism as a test case, Aquinas argued that our glorified bodies do not have to share anything in common with our physical bodies. We might add, except the ability to "run the software."

St. Paul describes Jesus' incarnation in these words: "Jesus although in the *morphe*—the form—of God, took on the form of a servant." [Phil. 2:6-7] Jesus is the ultimate information, God's in-form-ation as a human.

Stephen Wolfram offers a much more radical metaphor in his new book, *A New Kind of Science*. Not that our souls are software, but that everything is software. Is Wolfram proposing that we live in some kind of a noumenal world like the Matrix in the film by the Wachowski brothers? *Apparently* so—all puns intended.

3. Digital computers offer powerful metaphors for all processes, human or natural.

What is so powerful about Computer Science that leads Wolfram to this kind of hyperbole? **First, computers are powerful because they offer fine-grained models of the world.** Every academic field model the world. After all, a model is just a precise metaphor. In Computer Science, a computer models human thinking; a robot models human behavior. But there is something very special about the modeling that Computer Science does.

> The protean nature of the computer is such that it can act like a machine or like a language to be shaped and exploited. It is a medium that can dynamically simulate the details of any other medium, including media that cannot exist physically. It is not a tool, although it can act like many tools. *It is the first meta-medium,* and as such it has degrees of freedom for representation and expression never before encountered and as yet barely investigated.
>
> —Alan Kay [as quoted in Wolff, emph. mine]

David Gelernter—Yale University Computer Scientist—explains. Imagine a computer model of the world that is this precise: When Professor Greg Crow here at Pt. Loma Nazarene University goes to the Internet on his office computer to get a map of San Diego, not only is the intersection of Lomaland Drive and Catalina Boulevard on the map, but so is his office on the map, and in his office so is his computer—right there on the map!—, and on the computer screen on that map is the model of the computer on which he is seeing this whole scene. [Gelernter] You've seen a similar model on your Windows desktop. The "My Computer" icon is a part of your desktop representing all of the computer..

Computers offer "mirror worlds," to use Gelernter's term [Gelernter]. (You've read about Gelernter in the news. Gelernter's powerful vision of technology so angered mathematician Theodore Kaczynski that Kaczynski mailed him a bomb that exploded in his face. Kaczynski is the Unabomber.)

Second, computers are powerful because they use abstraction to organize complexity. Abstraction is systematically forgetting details. Abstraction is certainly not unique to Computer Science. Think of business systems, biological systems, kinship systems, or even plumbing systems. A corporation is an abstract person; a painting is an abstract visual scene. My supermarket bonus card is an abstraction of my identity— as viewed by Giant Food Corporation.

Forgetting details allows us to focus on what is really important, but it raises an important question: What reality underlies the details? Forget the dots of a photograph so that you can focus on the photograph. But now you can't admit a photograph as evidence in some courts, because a computer can alter it in ways that escape detection.

Third, computers are powerful because they are capable of self-reference. Allowing a computing machine to refer to itself, like the "My Computer" icon does in the Windows operating system was the key insight of John Von Neumann in the 1940s that led to the computer revolution: A computer can operate on the very computer programs that instruct it how to operate! It's as though a genie offered you three wishes, and you were smart enough to make your first wish, "Tell me what I should wish for." Computer scientists think that iteration and recursion as interchangeable. They are not. Recursion requires one additional feature of a system that iteration does not have: self-reference. Self-reference in turn requires the ability to assign names things, which is to say, requires abstraction.

Other fields besides informatics have examples of self-reference. Psychologists caution us not to be stressed about being stressed. Humorists may depends on self-reference, as when a cartoon character says, "I'm not a man, I'm a cartoon character." Linguists study self-referring sentences. For example, I began this presentation with an impossible sentence. I said, "Before I begin speaking let me say...."

4. *A New Kind of Science* claims that simple programs can account for all processes.

In May 2002, Stephen Wolfram's published a controversial book, *A New Kind of Science,* on the foundations of Computer Science. It ranked 425th at Amazon.com in mid-October. It sold 120,000 copies by November. Considering that it is a 1200 page scientific tome with 900 pages of hard text and 300 pages of harder yet small-type footnotes, that's an amazing number of copies.

It has been reviewed by hundreds of reviewers, although only one other reviewer seems to have read all of it, footnotes included. I have taken a year to read it, and the 300 pages of footnotes have required my remembering everything about mathematical logic that I learned in graduate school.

It's not the first time that a potentially revolutionary scientific treatise was brought directly to the public instead of through peer-reviewed channels. Darwin's *Origin of the Species* is another important example. Wolfram reclused himself for 10 years to write the book. Not a humble man, he considers his work to be as revolutionary as Darwin's.

Wolfram sets out to answer the most logical objection to Darwin. How is it that life illustrates such complexity, and yet it apparently began in such simplicity?

Wolfram rejects the intelligent design hypothesis, which accounts for complexity coming out by assuming complexity going in, or by complexity guiding along the way. Wolfram shows instead that simple systems illustrate great complexity.

To paraphrase *A New Kind of Science* [545], not any computer programs, but very simple computer programs, are adequate to explain many phenomena for which we knew only complicated explanations before. In 1981, Edward Fredkin of MIT proposed his "Digital Philosophy," in which he argued that the whole universe can be described by a computer program. Wolfram carries digital philosophy one step further. He argues that the computer program can be a simple cellular automaton—a sort of spreadsheet whose interface consists only of colored cells.

To do this, Wolfram must meet my colleague Dr. Robin Collins's objection to all proposals like Fredkin's. Fredkin required a notion of absolute space and time. This contradicts known empirical facts about the collapse of a quantum wave function. [Collins] To meet Collins's objection, Wolfram uses a causal network in place of absolute space and time—although he doesn't explain his causal network further, since all his examples are large-scale enough that events have to be physically near each other for one to cause the other. Wolfram's model sounds strangely like the Merovingian's comment in *The Matrix Reloaded:* "Causality is the only real."

Back in the realm of space and time, Wolfram has some beautiful results. For example, he demonstrates a very simple computer program to generate turbulent fluid flow, which (until Wolfram's work) was regarded as requiring randomness. [380] There is still no deterministic mathematical equation for turbulent flow as there is for smooth flow. But a cellular automation with simple initial conditions can generate turbulence.

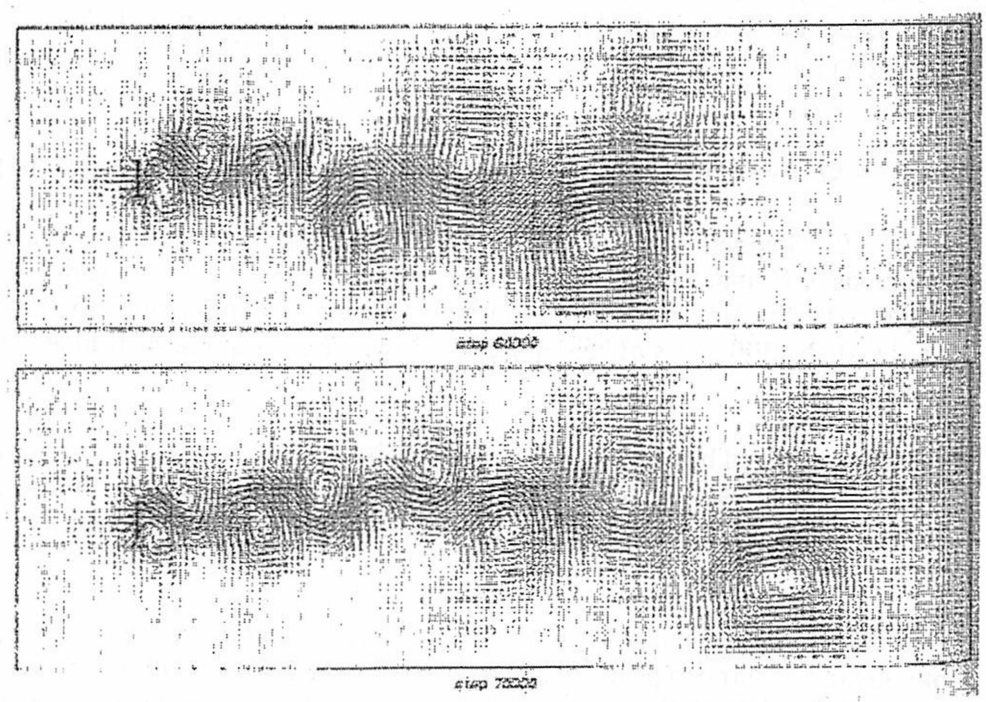

Figure 1 Cellular automaton generating turbulence [Wolfram 380]

Using examples such as this, Wolfram argues that cellular automata are more powerful than mathematical equations. Computer Science has Library of Congress classification QA, as a mathematical science; I think that Wolfram would put it back in Dewey's Decimal classification 001.64, as a general science.

Wolfram's view of computation can be summarized by Table 2.

	Not organized	Organized
Complex	Statistics 1650 Graunt	Computer Science 1938 Turing
Simple		Mathematics 500 BC Thales the science of patterns

Table 2 Computer Science studies organized complexity

You are surprised to learn that Mathematics is simple according to Wolfram! Let me offer two pieces of supporting evidence, even though I'm not a convert to Wolfram's New Science. First, noise is not music; clapping is not music. To be music sound must be both organized and complex. Computational models have done a better job of synthesizing music than mathematical models have. See Table 3.

	Not organized	Organized
Complex	Noise	Music
Simple		Clapping, sine wave, violin single note

Table 3 Music represents organized complexity

Second, every computer program can be thought of as a proof that its input results in its output. So contrast the Windows XP computer operating system with its 50 million lines of computer code [Lemos]—over a million pages—with the largest mathematical proof ever produced, the 2000 pages of Alfred North Whitehead and Bertrand Russell's *Principia Mathematica*. Computer programs are the most complicated intellectual structures humanity has ever created. See Table 4.

	Not organized	Organized
Complex		Windows XP 1 million pages
Simple		Principia Mathematica 2000 pages

Table 4 Software: more complicated than Mathematics

Wolfram proposes a **Principle of Computational Equivalence,** which regards as axiomatic that every process whether natural or human "can be *viewed as* a computation." [Emph. mine] Although Wolfram does not say so, he implies the stronger statement that all processes *are* computations. How is it then that we cannot use this axiom to predict the future? Wolfram argues that there is also in effect a **Principle of Computational Irreducibility:** For all the computational structures that he studies (computer programs, mathematics, DNA, and quantum physics) one can always find a problem for which the number of steps to solve it—that is, to generate a given output—can not be shortened.

For example, there are computer programs to predict the weather. They do a very good job for tomorrow morning, better than chance for Monday, and pretty bad for next Thursday. But Wolfram's principle of computational irreducibility implies that to do a perfect job, the computer program would have to take as long to run as the weather takes to happen.

Such a principle of computational irreducibility can't be proven because it's a statement about proof, not a statement to be proved. But there are some solved problems which point in the direction of his principle. Wolfram cites this one example: Some short mathematical theorems are known always to have long proofs. [779]

Wolfram uses the fact that some computational processes cannot be shortened to explain free will, no less! [750] I'll summarize his definition of free will:

> **We believe ourselves to have free will in exactly those situations in which there is no shorter way to discover the outcome of our behaviors than to play out the behaviors and observe the outcome.**

In that sense, Wolfram claims that the weather "has a mind of its own" too. On this definition, a theist would have to say that if God has free will, it is because He cannot predict the detailed unfolding of the outcome of His own behavior.

Wolfram uses as his definition of random numbers the classical definition of Kolmogorov in 1965 refined by IBM scholar Gregory Chaitin in 1975: A number sequence is random "if the smallest algorithm capable of specifying it to a computer has about the same number of bits of information as the series itself." [Chaitin] Then a number is random if its digits are a random sequence of digits. Chaitin's random numbers pass all of the usual statistical tests of randomness. They are uniformly distributed and they have no long runs, and they pass other tests proposed by Knuth, such as a serial correlation test, collision test, and chi squared test. [Knuth] Wolfram's new claim is that determinism can produce true randomness. More precisely, the cellular automaton that he calls "Rule 30" pictured in

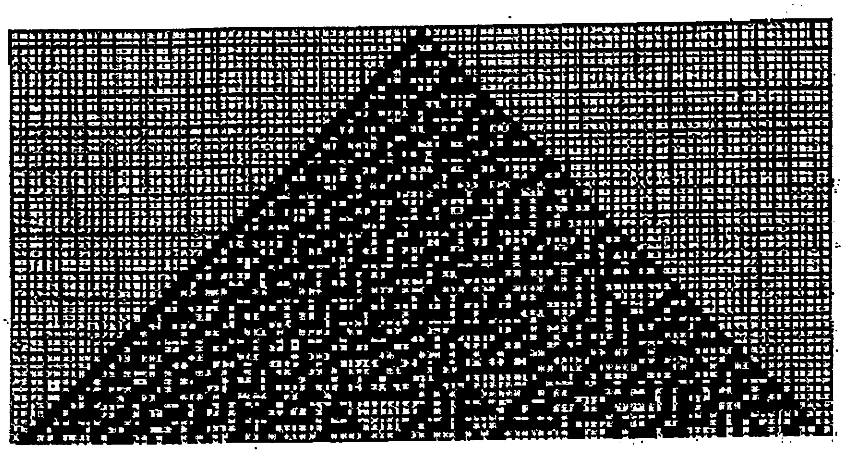

Figure 2 Rule 30 [Wolfram 1084]

Figure 2 satisfies all known statistical tests for randomness. [1084]

Wolfram believes without proof that Rule 30 is incompressible. Like predicting the weather, we must play out the sequence to see the outcome; there is no shorter way of discovering the outcome. But he believes this on the strength of examples like turbulence in fluids [380] where he models with cellular automata things heretofore thought to be random.

We will never be able to prove that all random processes can be modeled by cellular automata, but Wolfram's book is a call for us to research how many processes can be so modeled.

5. Wolfram's work deserves a Christian appraisal.

a. Wolfram is at least a methodological naturalist.

Wolfram's approach is absolutely naturalistic, but Christians for hundreds of years have argued that methodological naturalism is an appropriate way to do science, so this aspect of his work is not per se in opposition to Christian teaching. That is, we can use reason and experiment without appeal to tradition and verbal revelation. Scripture supports this strategy. St. Paul in Romans claims that we can come to know about God by using reason and experience.

b. Some Christian theologians argue for the openness of God.

What does Wolfram's definition of free will say about God's free will? I drew the corollary above that if God has free will, it is because He cannot predict the detailed unfolding of the outcome of His own behavior. Wolfram is no theist, but if he were, he would side with Christian theologians who argue for what they call the "openness of God." [Pinnock] Take the Book of Isaiah for example. Half of the time, Isaiah supports God's foreknowledge; the other half of the time, Isaiah supports God's changing His mind in response to our obedience. Thus again Wolfram's work is not per se in opposition to Christian teaching.

c. Some Christian theologians argue that determinism can produce true randomness.

Wolfram argues that deterministic computations can produce true randomness. It's easy to prove that there are random numbers because a Cantor diagonalization process shows that there are irrational decimals whose digits are not even computable, since there are only countably many computable functions. But so little is known about even well-known irrationals like π or of $\sqrt{2}$. We don't even know whether the digits pass the first statistical test for randomness: Are their digits uniformly distributed when written in any base? [Preuss] Even if their digits succeed in passing the uniform distribution test, then there are over a dozen other tests we might ask about, and nothing to keep mathematicians from suggesting other tests that we haven't thought about yet, perhaps involving higher and higher moments—higher-order skewness tests.

Christian theologians are divided on the question of whether God determines everything, including seeming random processes. If anything, Wolfram's proposing that randomness can arise from deterministic processes is a good model for free will existing in a universe in which

God determines everything. Again, Wolfram's work is not per se in opposition to Christian teaching.

d. Christians should not automatically be put off by Wolfram's prideful tone.

Many reviewers [Clark 2003] have criticized Wolfram because of the tone of his work, which at many places is self-serving and filled with an exaggerated sense of self-importance. That tone is definitely there, but it is not an unadulterated hubris. It is instead a hurtful sense that others did not regard his contributions in the early 1980s as nearly important as he thinks they should have been regarded. Christians who use gentle words will be more attractive to Wolfram than those who excoriate him.

6. Wolfram's reductionism fails in the end.

Instead of regarding space-time as fundamental, quantum physics today regards causal networks as fundamental. Experimental data about action-at-a-distance matches this assumption better than, say, the deterministic hidden variables posited by Einstein and Bohn. Wolfram devotes a mere passing mention to causal networks so as to remain consistent with experiments that test quantum mechanics. Wolfram hasn't thought through the implications of causal networks for his thesis that computation underlies all processes. What would a cellular automaton look like in a causal network? What indeed is the topology of such a network? We are left to guess.

Physicist Sir Roger Penrose flounders on the dilemma of reductionism as well. He refers to "three mysteries" [Penrose 414–415]: The first mystery is that the mathematical can describe the physical; the second mystery is that the physical can embody the mental; the third mystery is that the mental can comprehend the mathematical. Wolfram fails to carry out his program of reductionism; at least Penrose admits that reductionism cannot possibly explain all that is.

Physicist Frank Tipler in his book, *The Physics of Immortality,* considered the universe as a computational system obeying the physical laws of quantum mechanics. Those laws, Tipler argues, allow him to prove as a theorem (!) that "humans probably have free will, [and] that we shall have resurrected life in a heaven that is the home of the ultimate cause of the very existence of the universe itself." [Tipler xi] Tipler starting with a reasonable set of axioms about the laws of physics has arrived at a theological position reminiscent of Catholic theologian Pierre Teilhard de Chardin. De Chardin views Jesus Christ as the "Omega Point" of history. Tipler is not so specific, although Tipler has in mind an omega point in which information plays the central role. That is about as close as one can come using only Physics to the Christ who was in-form-ed.

Maybe someday Stephen Wolfram will find that his study of information will lead him to God as it did for Frank Tipler.

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