The Cellular Automaton and the Cosmic Tapestry

Kathleen Duffy

Abstract

The 2002 best seller, *A New Kind of Science* by Stephen Wolfram, has caused a stir within the scientific community. In its more than 1000 pages, Wolfram presents the fruit of his efforts to model all of the facets of nature, including the universe itself, with simple programs. The goal of this project is to gain insight into the origin and nature of complexity, a behavior that has only recently achieved widespread interest within the scientific community. Wolfram's preliminary results show that the behavior of spacetime can indeed be modeled with programs called cellular automata and causal networks in which the fundamental reality is the interconnection between network nodes.

Some seventy-five years ago, Jesuit paleontologist, Pierre Teilhard de Chardin (1881-1955), in his book, *The Human Phenomenon*, proposed a new way of modeling the universe. In order to portray the cosmos as a whole and "to organize the tangle of appearances" (Teilhard, *The Human Phenomenon* 95), he constructed and explored a metaphor that I call "the cosmic tapestry" (Duffy 1-12). This metaphor also focuses on interconnections within the evolutionary cosmos.

In this paper, I provide a short introduction to Teilhard's cosmic tapestry and to Wolfram's new science. I then suggest parallels between these two views of the universe, noting particularly the common theme of interconnection.

Biography

Kathleen Duffy, SSJ received her PhD in Physics from Drexel University. Currently, she is Professor of Physics at Chestnut Hill College. Formerly, she taught physics at Drexel University, Bryn Mawr College, Ateneo de Manila University and University of the Philippines. She has published research in atomic and molecular physics and in chaos theory in journals such as Physics Review Letters, Journal of Chemical Physics and Chemical Physics Letters, as well as Philippine journals and bulletins. She is presently a member of the Board of Directors of the METANEXUS Institute for Religion and Science and Cosmos and Creation. Her current research interest is in the synthetic work of Teilhard de Chardin and its relationship to modern developments in science. She has published some of her work in this field in Teilhard Studies.

Introduction

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Some seventy-five years ago, Jesuit paleontologist, Pierre Teilhard de Chardin (1881-1955), in his book, *The Human Phenomenon*, proposed a new way of modeling the universe. In order to portray the cosmos as a whole and "to organize the tangle of appearances" (Teilhard, *The Human Phenomenon* 95), he constructed and explored a metaphor that I call "the cosmic tapestry" (Duffy 1-12). This metaphor also focuses on interconnections within the evolutionary cosmos.

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The Cosmic Tapestry

At the beginning of *The Human Phenomenon*, Teilhard states that in this study he is seeking to discover an experimental law of recurrence that expresses the successive appearance in the course of time of the elements of the universe (Teilhard, *The Human Phenomenon* 1). These elements, he notes, appear with increasing complexity; first inorganic matter: atoms, molecules, polymers; then life: single cells, tissue, organs, plants and animals including the human; and finally, thought. His concern is that without a sense of the whole spacetime history of the cosmos, with its amazing transitions from matter to life to mind, it is difficult to understand the full import of the evolutionary paradigm and its potential for motivating action for the future.

In order to view the whole of the cosmos with all of its complexity, Teilhard suggests plotting the positions of the elementary particles, the simplest forms of matter, present at the beginning of time on a spacetime plot. Initially, these particles are represented by dots randomly scattered throughout space. However, as time proceeds and the particles begin to interact with one another, the curves that represent their positions resemble threads and tend to weave more complex entities so that eventually the plot resembles a four-dimensional, though unfinished, tapestry. Successive three-dimensional cross sections of this tapestry at specific times in cosmic history reveal a universe of increasing complexity. Teilhard's tapestry image illustrates the tendency of the cosmos toward union since everything that is formed requires the knitting together of threads.

Just as the quanta of matter present at the beginning are weaving our present experience of the material world, so Teilhard conjectures that at the beginning there were quanta of spirit that are responsible for weaving the various manifestations of psyche in our world. This means that, to some degree, all matter is psychic and that the psychic component experiences a movement toward complexity similar to that in the physical domain. Teilhard captures the symmetry of this double movement in a law that he calls the law of complexity-consciousness (*The Human Phenomenon* 216). This law states that the complexification of matter and spirit are intimately connected. In fact, it is impossible for spirit to become more complex without a physical matrix of increasing complexity to support it. Teilhard's law of complexity-consciousness describes the complexification that goes on within the cosmos and points the way to its future development in thought. Teilhard finds that once the evolutionary cosmos is looked at in the correct way, as a whole, this complementary weaving process becomes obvious.

And how is the weaving accomplished? Why this thrust toward greater complexity? And, especially, what does the appearance of mind tell us about the universe? Teilhard certainly agrees that the laws of science embedded within the cosmos are responsible for the weaving of matter. But the trend within the spiritual layer of the tapestry toward more highly developed states of mind leads Teilhard to conjecture that the cosmos is being allured by a Person toward a final unified state, an Omega Point. From his Christian tradition, he identifies this Person with the Person of Christ. The tapestry threads of matter respond to the laws of physics but the tapestry threads of spirit respond to the Cosmic Christ.

Cellular Automata and Causal Networks

Stephen Wolfram, the developer of computer language, *Mathematica*, is also attempting to model the universe. In his recent best-seller, Wolfram claims that by using various forms of computer programs, such as cellular automata and causal networks, he has been able to reproduce the characteristic behavior of many physical systems.

Equipped with results in the form of computer-generated output from countless experiments, he demonstrates rather clearly that complexity should be included in the list of the possible normal behaviors of a physical system. In fact, he finds that even systems that obey simple rules can produce complex behavior. This discovery becomes the basis for what he has termed a new kind of science. Wolfram claims that the new science is powerful enough to encompass the results of traditional science and, as a byproduct, to provide more physical insight into known phenomena. In particular, he is able to suggest ways to model the known universe in a manner consistent with the laws of physics. He does this by means of simple programs such as cellular automata and causal networks in which it is ultimately interconnection between nodes that is the fundamental reality.

In its simplest form, a cellular automaton consists of an initial line of squares colored either black or white (known as the initial conditions) plus a set of rules that determine the colors of the cells in subsequent lines. These rules usually rely on local information such as the color of the cell itself and that of its closest neighbors. A typical rule might read: if a particular cell and its two neighbors are white, color the cell at that position on the next line black; otherwise color it white. After several iterations of the specified set of rules, a pattern begins to appear that can be characterized as one of the following: “repetition, nesting, randomness [or] localized structures” (Wolfram 106).

A second general call of programs that Wolfram utilizes in his new science is the network. A network system is a collection of nodes and connections between nodes with rules that specify how these connections change from step to step. The nodes in the network represent events while, in a causal network, the connections between the nodes represent the causal relations between events (Wolfram 490). The layout of the network system is inconsequential since it is the ways in which the nodes are connected that specify the properties of the system (Wolfram 193).

Wolfram finds that no matter what the system, whether it is a cellular automaton or a natural physical system, the kinds of behavior that surface are universal. Although the appearance of complex behavior requires that the underlying rules are mildly complex, once this threshold is passed, making the rules more complex does not increase the complexity of its behavior. (Wolfram 105-106).

Wolfram states boldly that “our universe is just a simple program” (Wolfram 434). Starting from an initial state and responding to the set of rules embedded within, the universe evolves as if it were a giant computer updating its state at each moment of time. Wolfram takes his conjecture seriously and explores the types of programs that could possibly exhibit the behavior that we see in the cosmos. He constructs a model of spacetime from a combination of an automaton which updates the system in time and a causal network that describes relationships in space (Wolfram 475, 508). In fact, with a variety of cellular automata and causal networks, Wolfram is able to model not only spacetime but also gravity, relativity, and elementary particles and to fulfill the prescriptions of physical laws such as the conservation of energy, the Second Law of Thermodynamics, and quantum mechanics.

The Parallels

Although their approaches to the study of nature’s complexity differ radically, Wolfram and Teilhard share some common ground. For instance both note the limitations of traditional science. They find scientists in some sense blinded by their preconceptions about the way nature behaves. Both feel that there is more to be seen and that deeper seeing depends on the model used to describe the universe. Wolfram notes how traditional methods of science have missed complex behavior because they focus too narrowly on simple systems that can be solved with traditional methods (Wolfram 21). Until recently, few new approaches have been suggested. Teilhard, on the other hand, claims that by looking at nature in its parts rather than taking the cosmic process as a whole into account, scientists have generally ignored the psychic aspects of nature.

Both scientists are clear that one must look at the whole of the phenomenon and not simply its parts. Wolfram says, for instance, that "universality is . . . quite crucial in finding general ways to characterize and understand the complexity we see in natural systems" (Wolfram 643). Teilhard insists on studying the "whole of the phenomenon" (Teilhard, *The Human Phenomenon* 1).

Wolfram and Teilhard both sense that there is a deep organizational rule or set of rules at work within the fabric of the cosmos. Teilhard discovers one such rule, the law of complexity-consciousness (Teilhard, *The Human Phenomenon* 216), which he summarizes in these words: "To be more is to be more united" (Teilhard, *The Human Phenomenon* 3). This rule sums up the ideals that the cosmos strives for as it continues to grope its way toward the Omega Point. Since the continuing evolution depends on the action of free agents, Teilhard is open to the surprise of its unfolding but believes that in the end it will culminate in Omega. Wolfram is also looking for simple rules. He is trying to understand the basic mechanism involved in the formation of patterns from snowflakes to turbulent fluids (Wolfram 17) and finally to the universe itself. These rules are difficult to find even though cellular automata are deterministic; that is, the rules to be followed at each step are clearly spelled out. More often than not, it becomes impossible to decipher these rules from the pattern that is generated (Wolfram 31). Besides, he claims that the Principle of Computational Equivalence shows that it will be impossible to find this simple rule for the universe as a whole or to know the ultimate outcome of the evolutionary project. This principle, he says,

> encapsulates both the ultimate power and the ultimate weakness of science. For it implies that all the wonders of our universe can in effect be captured by simple rules, yet it shows that there can be no way to know all the consequences of these rules, except in effect just to watch and see how they unfold. (Wolfram 846)

Each of these scientists uses a simple metaphor to elucidate his understanding of the cosmic becoming. Wolfram seeks to describe ongoing development of the universe using a simple program that he claims is capable of producing much of the complexity that is presently being found in science, particularly in physics and biology (Wolfram 434). This is a non-traditional model, an abstract representation for the physical effects that operate within the universe. Teilhard also uses a non-traditional model for the evolutionary process. His cosmic tapestry serves as both a mathematical model and a metaphor for evolution which he calls "a light illuminating all facts" (Teilhard, *The Human Phenomenon* 152). This metaphor has the added advantage of being able to model not only physical but also spiritual or psychic effects.

Both scientists note the difficulty of being embedded within the universe that they are trying to study. For Wolfram the difficulty has more to do with the way we perceive time and how he must adjust his computer program to allow time to flow in a way that is consistent with causality (Wolfram 487, 490). Teilhard finds that, because the human species is both at the center of perspective and at the center of construction of the universe (Teilhard, *The Human Phenomenon* 4), it is difficult to plumb the complex tangle of threads in which we are embedded. He finds that he needs a guiding thread, a thread that turns out to be related to the nervous system (Teilhard, *The Human Phenomenon* 93), a thread whose evolution provides a concrete connection between the material and spiritual layers of the tapestry.

Over the last couple of decades, complexity scientists like Wolfram have been able to show rather clearly that "local rules generate global order" (Lewin 38). Both Wolfram and Teilhard consider interactions that are local, involving only nearest neighbors, but whose effects somehow spread throughout the system and affect the system as a whole. Rules for cellular automata usually involve only nearest neighbors but their effects do not remain local. Teilhard also notes the importance of interactions with nearest neighbors. “We have gradually come to understand that no elemental thread in the universe is wholly independent in its growth of its neighboring threads” (Teilhard, *The Future of Man* 87). In fact, the vibration of a single tapestry thread affects the whole fabric. Teilhard’s law of complexity-consciousness acts locally but with global consequences.

There are also major differences between the two models. Obviously, Wolfram is using a quantitative approach while Teilhard’s is qualitative. Furthermore, in order to model spacetime using cellular automata and causal networks, Wolfram needs to divide both space and time into discrete steps. Teilhard’s cosmic tapestry, on the other hand, depicts space and time as continuous. However, both Teilhard and Wolfram stress the importance of connectivity: Wolfram by way of his causal networks that focus on causal relationships between nodes and Teilhard by way of his law of union, “to be more is to be more united with more” (Teilhard, *Science and Christ* 45).

Another obvious difference between the two approaches is their starting points. Wolfram begins with simple rules to show that complex behavior can be generated from simple rules (Wolfram 466). Yet, although he has been able to generate behavior characteristic of much of the behavior known to physics, he is far from discovering the simple rules and initial conditions that characterize the universe as a whole, a fact that he claims is impossible.

On the other hand, Teilhard starts with the complexity he sees, the patterns that have formed through the eons of evolutionary activity. Tracing the advance of psychism and physical structure, he intuits the simple underlying rule at work in the cosmos responsible for the order we experience in the cosmos.

Conclusion

Both scientists are attentive to and trying to understand the order of the cosmic unfolding. Wolfram is looking for a simple rule to generate this order; Teilhard claims he has found it. Teilhard sees the human as the peak of evolution; Wolfram regards the human as merely another computation equivalent to others in the universe. In fact, Wolfram reduces all processes, whether natural or produced by human effort, to computations (Wolfram 715). And yet they both scientists agree that basic to the cosmic program is the deep connectivity and interdependence among all of its apparently discrete elements.

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