CHEMICAL REACTION **BY STEVE HERMAN**

A New Kind of (Cosmetic) Science, Part I

Stephen Wolfram's recent book, *A New Kind of Science* (NKS), challenges the very foundations of traditional science. Does it have implications for the industry?

The mathematician, carried along on his flood of symbols, dealing apparently with purely formal truths, may still reach results of endless importance for our descriptions of the physical universe.
—Karl Pearson

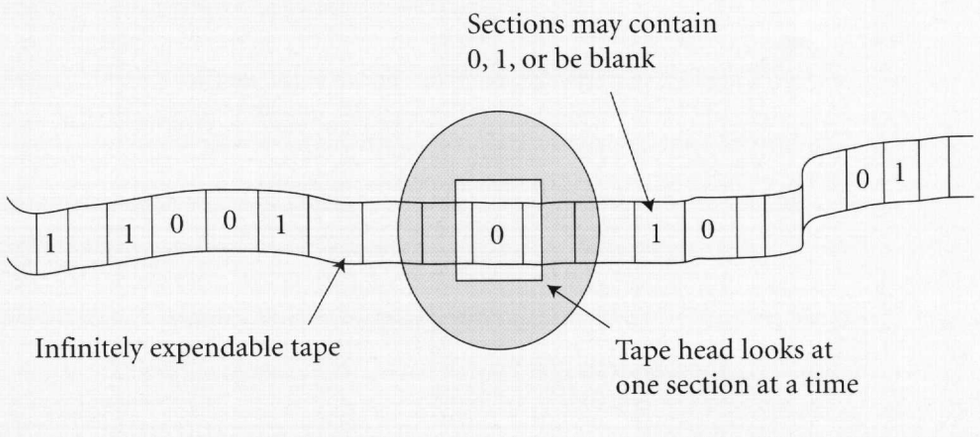
HOW SCIENTIFIC is cosmetic science? Most professionals on the technical side of the industry know some chemistry and biology and may have a basic working knowledge of colloidal behavior. Alas, having grounding in conventional science can result in a feeling of befuddlement when a revolutionary theory comes along that overturns conventional wisdom. Stephen Wolfram's recent book, *A New Kind of Science* (NKS),[1] challenges the very foundations of traditional science and many other fields as well.

Much about Wolfram is controversial, but one point is beyond dispute: he is a very smart man. Proof is easily provided; a doctorate in physics from Caltech at the age of 20 and a MacArthur Foundation "genius" fellowship at 21 says enough for his intelligence. He recently completed a 20-year effort, the last half as a virtual recluse (although he kept running his company and maintained scientific and industrial contacts), to recast the way science is done at the most basic level. Wolfram has moved away from mathematical equations as the basic tool of science and replaced them with computer computations. Information, rather than matter and energy, becomes the fundamental essence of his new reality. It is not a paradigm shift likely to endear him to a large group with a stake in the "Old Science."

It will take time for NKS to be judged by experts in the fields it touches. Early estimates range from calling him the new Newton to fairly critical views—and everything in between. His egocentric approach to presenting the ideas in his book, his lack of modesty—even the fact that he has made a lot of money with his ideas—tends to polarize opinion. Whether NKS ultimately is considered totally right, totally wrong or somewhere in between, it demands every intelligent scientist's attention, and only time will tell where in the spectrum his work ultimately falls.

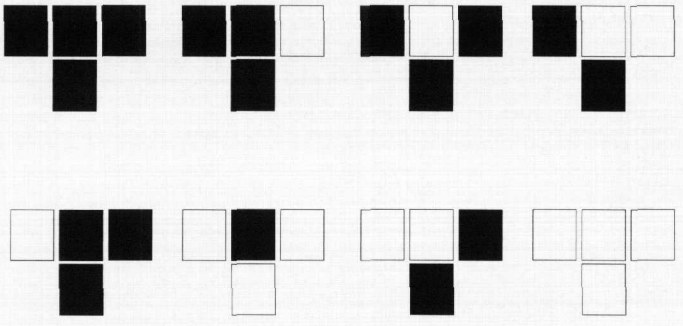
Computer technology has expanded incredibly on both the hardware and software sides over the past decade, but the essential concepts of computing were established in the '30s. To understand computational logic, one can skip the gigabytes and video cards of today and focus on the principles of the Turing Machine. Alan Turing created—in his mind—a computing machine consisting of an infinitely long tape and a finite register of memory. Instructions can be written on

FIGURE 1. THE COMPONENTS OF A TURING MACHINE

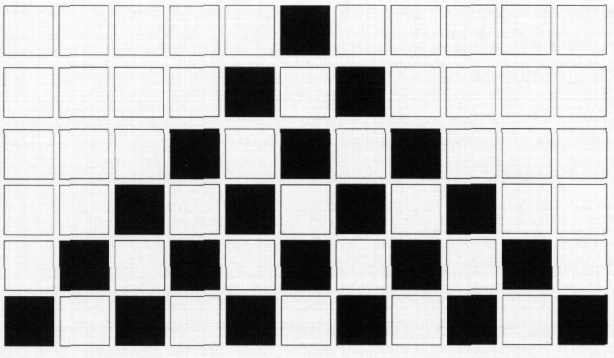


How scientific is cosmetic science?

FIGURE 2. CELLULAR AUTOMATON
Wolfram's presentation of cellular automaton for a simple repeating pattern.



Cellular automaton rule 250.



Rule 250 pattern.

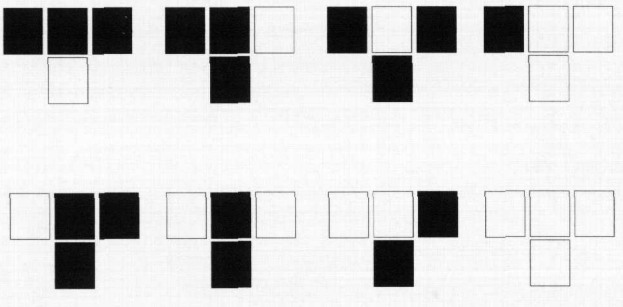
the tape, and a processor carries out a few essential operations. Figure 1 shows its components.

All the Turing machine's manipulations are of digital information, and operations are performed in sequence. Turing began applying his principles to electrical computers in the early '50s, but his untimely death (eating a cyanide-laced apple) at the age of 41 brought his scientific contributions to a tragic halt.[2]

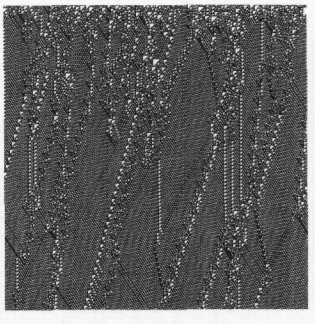
Now that there is a basic computer, a program is needed: Mathematica. According to Wolfram's Web site, "The visionary concept of Mathematica was to create once and for all a single system that could handle all the various aspects of technical computing in a coherent and unified way. The key intellectual advance that made this possible was the invention of a new kind of symbolic computer language that could for the first time manipulate the very wide range of objects involved in technical computing using only a fairly small number of basic primitives.[3]

Wolfram has been successful marketing Mathematica to a variety of scientific, academic and governmental users. Mathematica also provided the software tools to explore Wofram's obsession with finding a new foundation for scientific reasoning. His vision centered on the final ingredient of the New Science, cellular automata. A one-dimensional cellular automaton consists of two things: a row of cells and a

FIGURE 3. RULE 110
The proof—if it is indeed proof—relies on comparing regions of the rule 110 pattern with cyclic tag systems.



Cellular automaton rule 110.



Rule 110 pattern.

set of rules. There are also two-dimensional cellular automata, which use rectangular grids of cells, and systems with colored cells, but this discussion will be restricted to basic one-dimensional black-and-white representations, which can generate high levels of complexity.

A cellular automaton (CA) is an array of identically programmed automata, or "cells," that interact with one another. Each of the cells can be in one of several states, depending on the automaton. In a three-state automaton, the states might be black, red and blue. Wolfram restricts his examples to black and white. The epiphany triggering NKS was that astonishingly complex patterns are created by simple rules for CA.

Mathematicians John von Neumann and Stanislaw Ulam first developed the CA concept in the '60s, and Wolfram's first papers on the subject go back to 1982. Wolfram's early work helped change the direction of work on CA for the past 20 years. Thus, much of the basic information has been available for half a century, and primarily NKS has fleshed out the ideas, created many computer printouts, targeted the presentation to a general audience and promoted the book aggressively.

Figure 2 shows Wolfram's presentation of CA for a simple repeating pattern. There are 256 possible patterns, which can be seen by taking the eight top patterns of three blocks as fixed and generating every combination for the bottom square (2 x 2 x 2 x 2 x 2 x 2 x 2 x 2 gives 256 variations).

Special claims are made for rule 110 (Figure 3), which can act as a "universal computer," essentially equivalent to a Universal Turing Machine. The proof—if it is indeed proof—relies on comparing regions of the rule 110 pattern with cyclic tag systems, which operate in steps by removing the first element of a sequence and adding new elements at the end of the sequence.

The logic becomes challenging. Fortunately, it is possible to play a game based on CA and enjoy some properties of these systems. The Game of Life[4] was originated by John Conway to create as simple a "universe" as possible that was capable of computation. The system consists of a rectangular grid where each square could be in one of two states—on or off. He thought of them as cells, alive and dead. The rules of the system are very simple: a cell survives if it has two or three living neighbors. A new cell is created on a "dead" square if it has exactly three living neighbors. The game can be hypnotic. It also achieved some fame when it was featured in a 1970 Scientific American column.[5]

When the Game of Life wears out its welcome, sit back and watch the young Stephen Wolfram's favorite movie, 2001: A Space Odyssey. The HA HAL 9000 computer is very much like the ultimate CA pattern, and it represents one vision of what can happen when computers can think. GCI

Editor's Note:

This is part one of a two-part series that discusses Stephen Wolfram's book, *A New Kind of Science*. Part II will apply the scientific theory to the industry, particularly to the sense of smell and fragrances.

Acknowledgement

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References

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A cellular automaton is an array of identically programmed automata, or "cells," that interact with one another.