Statement of Dr. Stephen Wolfram
Founder & CEO, Wolfram Research, Inc.
and author of *A New Kind of Science*

before the

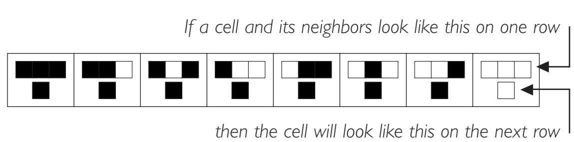
Subcommittee on Science, Technology, and Space
Committee on Commerce, Science, and Transportation
United States Senate

September 4, 2003

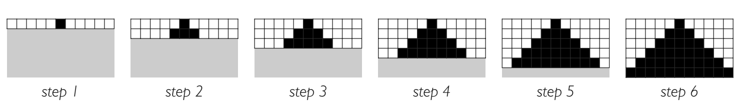
Thank you for inviting me here today.

Nearly four centuries ago, Galileo turned a telescope to the sky for the first time. What he saw changed forever our view of the universe—and ultimately launched much of modern science. I have had the privilege of beginning to explore another new world, made visible not by telescopes but by computers. And in that world I have made some most surprising discoveries—that have led me to a new kind of science.

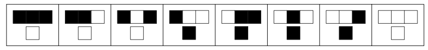
The computer revolution has been fueled by our ability to have computers run specific programs built for particular tasks. But what if we were to explore the world of all possible programs? What would we find out there? Here is a representation of a very simple program for coloring squares down a page.

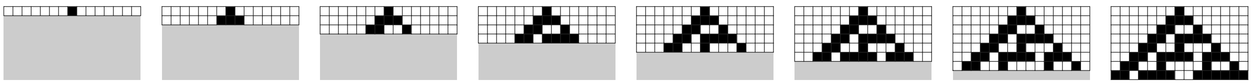


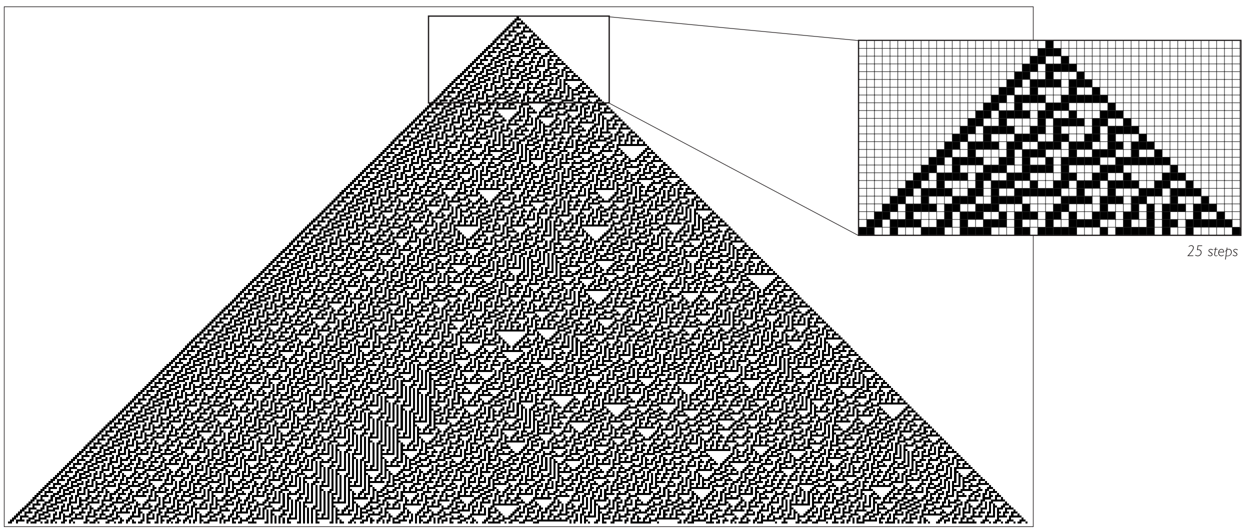
This is what happens if we run the program.



The simple program makes a simple pattern.

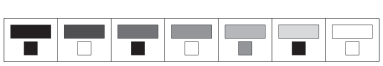
But here is a program I call rule 30.  Again it's a very simple program. But now look at what it does (▼). That little program makes all of this. It's amazing. And I think it's also profoundly important. Because I think it finally shows us the essential secret that nature uses to make so much complexity.

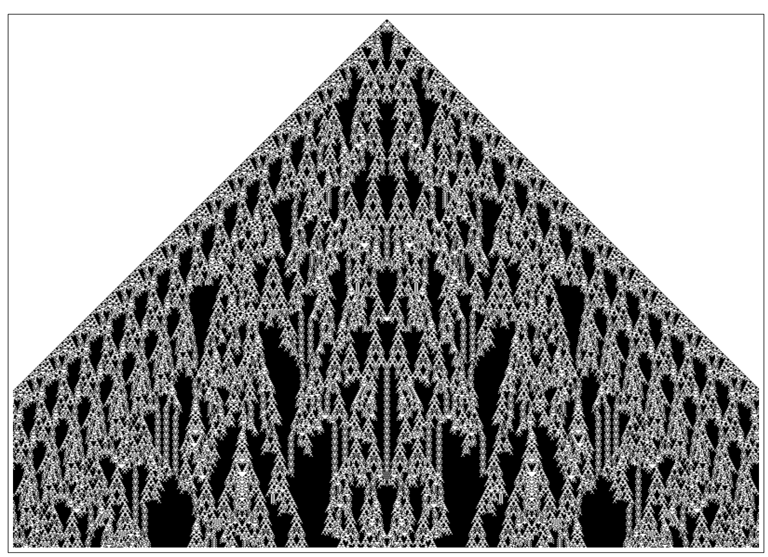




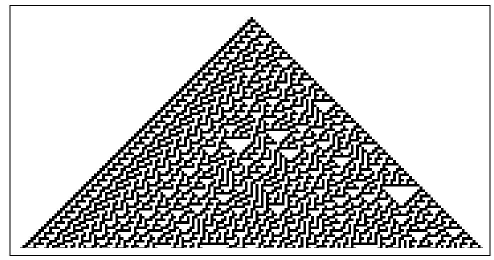
For three hundred years the exact sciences have been built on mathematical equations. And they have made—and continue to make—great progress on many fronts. But in the face of significant complexity, they have consistently gotten stuck. And I believe the reason is a fundamental one. And that to go further one needs a new kind of science, whose foundation is programs, not just mathematics.

At the core of this new kind of science is an exploration of the abstract world of simple programs. But from this, there come applications, both immediate and profoundly far-reaching. If in the past we had been faced with something like this (▶) we would never expect to understand it. But now we have discovered that it can just come from this (▼) very simple program.



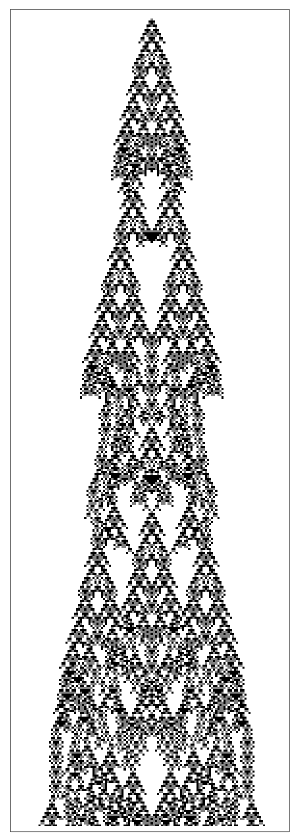


In nature, we find many elaborate patterns—like the ones on this mollusc shell (▸). Which we now see can be explained by very simple programs. And for example throughout biology, complexity can come from simple programs. Which then finally begins to give us the possibility of a true theoretical biology.



Today we know the genome. But now we must work out how it operates—and I think simple programs are key. Fifty years ago we found the basic mechanism for heredity; perhaps now simple programs can show us basic mechanisms for processes like aging.

Traditional mathematical science has had its greatest success in physics. But still we do not have an ultimate theory of physics. And indeed our theories always just seem to get more complicated. But one of the suggestions of my work is that at the very lowest level—below even space and time—there may just be a simple program. A program, which, if run long enough, would actually reproduce in precise detail everything in our universe.

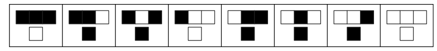


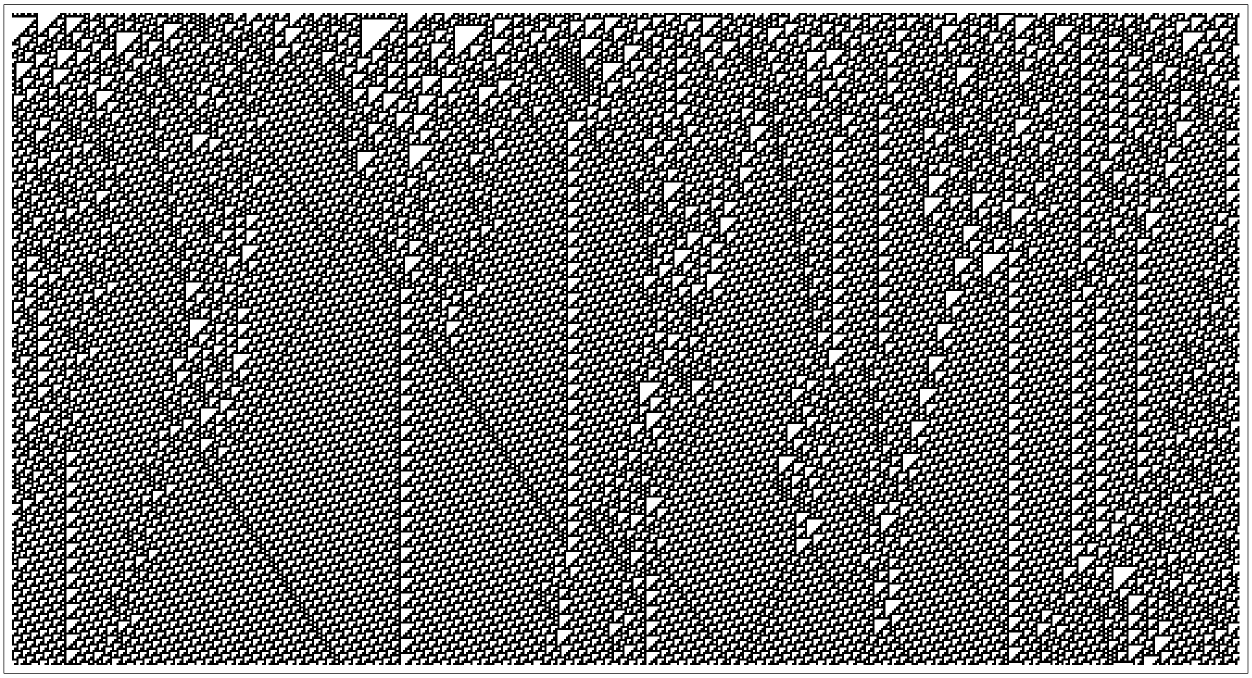
Finding that program would be a dramatic moment for science. But from the progress I have made, I am hopeful that it may not be too far away.

There are also many more everyday issues to which simple programs bring new models and perspectives—not only in physics and biology, but also for example in earth and social sciences. Simple programs also seem uniquely suited to analyzing many critical systems that involve large numbers of interconnected parts.

Having captured phenomena scientifically, one can start to harness them for technology. So now we can begin to create technology built not on concepts like wheels or waves, but on processes like this (▸). And as we explore the vast world of simple programs, we can systematically mine it for technology. Finding new and unexpected programs that can be used for encryption, or pattern recognition, or decentralized control. Perhaps even finding programs that manipulate information more like humans. And indeed creating a whole new generation of technology—from which new industries can grow.

One of my surprising discoveries—embodied in what I call the Principle of Computational Equivalence—is that powerful computation is fundamentally common. It doesn't take a sophisticated CPU chip to be

able to do computation. Simple programs do it. Like this one. 
Or like many of the ones in nature.



This has many deep implications for what can and cannot be done in science. But it also immediately suggests that we can use much simpler elements to make computers. Which for example points to a new approach to nanotechnology.

Over the past year, my book has stimulated great activity in many scientific and technical communities. As well, of course, as some of the turbulence one should expect in any potential paradigm shift.

In moving forward, education is key—and there is no lack of enthusiastic students. Institutional structures will take time to develop. But it has been exciting to see how quickly teaching of some of the core ideas has begun even at the high school level.

One day the study of the computational world will no doubt be an established science, like physics, or chemistry, or mathematics. But today the exploration of the computational world still stands before us as a great frontier. With the potential not only to unlock some of the deepest questions in science, but also to define a whole new direction for technology.

Thank you. I just tried to cover twenty-five years of work in five minutes. I'd be happy to expand on anything.

Further Information

Book: Stephen Wolfram, *A New Kind of Science* (Wolfram Media, 2002)

Website: www.wolframscience.com

About Stephen Wolfram

Stephen Wolfram was born in London and educated at Eton, Oxford, and Caltech. He received his Ph.D. in theoretical physics in 1979 at the age of 20, and in 1981 was recognized with a MacArthur award.

In the early 1980s he made a series of discoveries about systems known as cellular automata, which have yielded many new insights in physics, mathematics, computer science, biology and other fields.

In 1986 he founded Wolfram Research, Inc. and began the creation of *Mathematica*, now the world's leading software system for scientific and technical computing.

With *Mathematica* as his tool, Wolfram spent the 1990s pursuing an ambitious program of basic science, culminating in the 2002 release of his 1200-page book *A New Kind of Science*. An immediate bestseller, the book has been widely hailed as initiating a paradigm shift of historic importance in science.

In addition to leading his company and creating innovative technology, Wolfram is now developing a series of research and educational initiatives in the science he has created.