THE UNKNOWN AND THE UNKNOWABLE

JOSEPH F. TRAUB

Columbia University
Department of Computer Science

and

Santa Fe Institute
External Faculty

Technical Report# CUCS-014-97

[1]In 1931 a logician named Kurt Godel announced a result that astonished the scientific world. Godel said that there are statements about arithmetic that can never be proved or disproved. This impossibility result is about elementary arithmetic, not some arcane corner of mathematics. To the educated lay person, Godel's undecidability theorem may be the single most widely-known mathematical result of the 20th century. It certainly limits what mathematics can do. Does it limit what we can ever know about the world around us; that is, does it limit science?

I'll discuss the unknown and the unknowable in science, raising more questions than I will answer. I will also talk about two topics which have been much in the news in 1996, and which might erroneously be confused with my topic.

These are, first, the book by John Horgan, called **The End of Science**, and second, the great hoax played on the editors of "Science Wars" in the journal *Social Text*, which may have come to your attention a few months ago in *The New York Times*.

My primary theme is the unknown and the unknowable, and I began by mentioning Godel's theorem. This is just one of numerous impossibility results established in the last 60 years stating what cannot be done. Another famous negative result, due to the British genius, Alan Turing, states that you cannot tell in advance if a certain abstraction of a digital computer called a Turing machine will ever halt with the correct answer. Now, what all these impossibility results have in common is that they are about the manipulation of symbols, that is, they are about mathematics.

What does this have to do with science? Science is about understanding the universe and everything in it. Examples of scientific questions are:

- How do children acquire language?
- Will there be major global changes due to human activities, and what will be the effects on earth's ocean levels, and on agriculture and biodiversity?

[1]This talk was presented to the Century Association, New York City, on October 3, 1996.

Note that there are, a priori, no mathematical models that accompany these questions. Science uses mathematics, but it is also very different from mathematics. Can we up the ante from mathematics and prove impossibility results in science? That is, can we establish the unknowable in science?

Ralph Gomory, the President of the Alfred P. Sloan Foundation, proposes a tripartite division of science: the known, the unknown, and the unknowable. The known is taught in the schools and universities and is exhibited in the science museums. But scientists are excited by the unknown. Parenthetically, artists go to art museums to learn; scientists do not go to science museums because those museums act as if it's all known and preordained. That may be changing; exemplars are the Exploratorium in San Francisco and the American Museum of Natural History.

Gomory's tripartite division proposes three distinct areas: the known, the unknown which may someday become known, and the unknowable, which will never be known. The unknown and the unknowable form the boundary of science. Here are examples of questions for which the answers are today unknown.

- How do physical processes in the brain give rise to subjective experience? That is, explain consciousness.
- Can the healthy, active lives of humans be significantly prolonged by, say, a factor of two or three?
- How did life originate on earth?
- Will the universe expand forever, or will it collapse?
- Can we develop a grand unified theory of the fundamental physical laws?
- Why do fundamental constants, such as the speed of light, have their particular values?
- Is there life elsewhere in the universe? Is it intelligent?
- How do children acquire language?

For which of these are the answers unknowable? We cannot prove scientific unknowability. That can only be done in mathematics. This is sometimes not understood, even by professionals. I expressed my interest in the unknowable to a very senior European scientist. He immediately responded that this had been, of course, settled by Godel's theorem. Not so; Godel's theorem limits the power of mathematics and does not establish that certain scientific questions are unanswerable.

What are some of the reasons why a scientific question might be unanswerable? I'll limit myself to just three here.

- Insufficient data has survived. That can be a problem in ur-linguistics, archaeology, and history.
- Contingent events, sometimes called frozen accidents, may limit our ability to explain certain phenomena. (On the other hand, as Stephen Jay Gould eloquently argues, historical explanations in science can be as convincing as those arising from general theories.)
- Resources, such as energy, may simply not be available in our part of the universe to discriminate among contesting theories about the universe.

Of course we must be very careful in stating that something is impossible or unknowable. You're all familiar with some of the notorious announcements concerning impossibility, such as, there cannot be a heavier-than-air flying machine.

The unknowable has long been the province of philosophy and epistemology, with questions raised by giants such as Immanuel Kant and Ludwig Wittgenstein. My goal is to move the distinction between the unknown and the unknowable from philosophy to science.

What is the basis for my belief that we might succeed?

- The Zeitgeist seems right for tackling such questions.
- We have had great success in establishing impossibility results in mathematics and theoretical computer science. Although these ideas cannot be directly applied to science, I'm hopeful that the modes of thought might be transferable.
- Very recent workshops have brought together leading physicists, economists, cognitive scientists, biologists, computer scientists, and mathematicians who have strong interests in defining the unknowable in their own fields.

As advertised earlier, I will now move to two topics much in the news in 1996 which might seem part of my theme of the unknown and the unknowable.

The first is a book called **The End of Science**, authored by John Horgan. John sent me the manuscript last fall for my comments. I suggested some minor technical corrections and told him I totally disagreed with his thesis that science had made such extraordinary progress that its golden age was over and only mopping up was left. Incidentally, the manuscript was titled "The Ends of Science", which is an ambiguous and far more interesting title. Apparently the publisher changed that to **The End of Science**, hoping to derive some advantage from the success of books titled "The End of You Name It", starting with Francis Fukuyama's foolish **The End of History**.

John writes very well indeed; he is a senior writer for *Scientific American*, and his book features juicy anecdotes about many scientists who are household names. However, I never would have predicted the amount of media attention that the book has actually received.

Its message is basically pessimistic. Here is an excerpt from a column in *The New York Times*: "In a series of interviews with some of today’s leading scientists, Mr. Horgan finds an atmosphere of anxiety and melancholy, and a tendency for them to engage in fantastical speculation without much acknowledgment that ’the great era of scientific discovery is over.’"

Those are not the emotions of the scientists that I know. The ones with whom I’m in touch are vitally excited by their work. There’s more to be done than ever, and we can’t wait to get on with it.

I’m not saying that there aren’t difficulties. Funding for research has leveled off and will probably decrease. Universities don’t have tenure positions available for young scientists. The emphasis in some of the leading corporate laboratories has shifted away from basic research. The Federal laboratories are in turmoil due to budget cuts and re-direction. But such difficulties are to be expected after the period of unparalleled growth which followed the Second World War. Horgan is claiming it’s all over because the fundamental discoveries have been made.

Earlier I gave a very partial list of big scientific questions. Let me remind you of a couple of items from that list:

- How do physical processes in the brain give rise to subjective experience? That is, explain consciousness.
- Is there life elsewhere in the universe? Is it intelligent?
- Will the universe expand forever or will it collapse?

I don’t find John Horgan’s thesis, that all the important discoveries are behind us, very compelling. Furthermore, each major advance leads to important new questions. Reports of the death of science have been greatly exaggerated. Indeed, I believe they’re just plain wrong.

Another way in which science has been in the news this year is because of the "Science Wars" special issue of a journal called *Social Text.* This journal is published by people who believe that science is culture-based, and that it follows arbitrary rules, like baseball. In the spring a front-page article in *The New York Times* reported that an NYU physicist, Alan Sokal, had published a send-up of the kinds of papers to be found in *Social Text*. The paper, called

"Towards a Transformative Hermeneutics of Quantum Gravity", was a parody of the journal's stultifying, buzzword-laden style. Here's just one sentence from Sokal's article: "In quantum gravity, as we shall see, the space-time manifold ceases to exist as an objective physical reality; geometry becomes relational and contextual; and the foundational conceptual categories of prior science--among them, existence itself--become problematized and relativized." The editors of *Social Text* were unable to detect that this was a hoax.

A flurry of letters to the *Times* and hot electronic postings on the Internet showed artists joining with scientists in laughing at the way in which the editors of *Social Text* had been taken.

Of course there were replies from scholars like Stanley Fish, Andrew Ross, and Stanley Aronowitz, who are part of the editorial collective that runs *Social Text*. It was a posting by Andrew Ross, the co-editor of Social Text, and director of the American Studies Program at NYU, which is relevant to my concerns tonight. I'll limit myself to quoting two questions that he raises:

"Should non-scientists have some say in the professional scientific community?"

"Should non-experts have anything to say about scientific methodology and epistemology?"

He obviously feels the answer to both questions is Yes.

I believe this is a very dangerous direction. There are well-known public examples of what can happen when political values dictate the results of scientific research. Instances include the Nazi racial investigations; the Soviet geneticist Lysenko, who, backed by Stalin, insisted on the Lamarckian inheritance of acquired traits; and today, in our country, the insistence of certain fundamentalist Christians on teaching "creation science."

These examples are known to most of you. I want to give two personal examples. My closest scientific collaborator is Henryk Wozniakowski, who holds professorships at Columbia and the University of Warsaw. When he was choosing what to study in the Communist Poland of the 60s, he was leaning towards economics. His father warned him that he would not enjoy freedom of inquiry if he were a professor of economics in Poland, so he chose mathematics instead.

The second example is from China. In the late spring of 1989, my wife and I were visiting

China as guests of the Chinese Academy of Sciences. We arrived in Tiananmen Square on June 3, but that’s a story for another day. At a banquet hosted by the Mathematics Department at Hangzhou University, I was introduced to a professor whose only job was secretary of the Communist Party for the department. My hosts seemed to take such a position as standard operating procedure.

These are extreme examples, but they illustrate the dangers of nonspecialists inserting political values into scientific methodology. I’m sure that the editors of Social Text do not desire such consequences. But a word of warning. The editors view themselves as "progressives" or "leftists". You can be sure that if they attempt to shape science according to their values, the right will try to do the same. I believe that the country will be the worse for such interference.

There are many non-scientific pressures that play a role in shaping science. One example is congressional lobbying by defense contractors, both during and after the Cold War. This lobbying influences appropriations which affects research funding.

Certainly, lobbying influences what research gets funded and therefore what science gets done. What I find particularly invidious about critics who believe that science rests solely on a cultural base, and that its rules are arbitrary, is that they want to exert control over the results of science research, which I regard as far more dangerous.

I see the study of the unknowable as an enrichment of science. What kind of results will be obtained? Nobody yet knows, which is what makes it so interesting.