The End of Science
by John Horgan
McGill University, January 21, 1997

I'm delighted to be here at McGill tonight. I've been rather fond of Canada lately, because it has given my book The End of Science such a warm reception. Last summer my book made the McClean's bestseller list for a couple of weeks. And Canadian reviewers have given me some hearty pats on the back. But even those who praised the book usually took pains to point out that they did not agree with its central premise. A review in the Toronto Globe and Mail last summer ended with this line: "What higher praise can you give to a book than to say that you loved it, even though you thought it was totally wrong?"

Just this month another Canadian reviewer suggested that I concocted this end-of-science schtick as a way to package a lot of material about famous scientists I'd gathered over the years. Let me assure you that's not so. Anyone who doubts my sincerity can ask my wife or friends or colleagues at Scientific American about my true intentions. They will tell you horror stories about having to endure years of interminable harangues from me on the limits of science.

Now it's your turn. What I'd like to do tonight is summarize my end-of-science argument and then rebut, one by one, the most common counter-arguments. If I'm successful, none of you will have any questions for me at the end of my speech, because you'll all find my thesis so convincing. But since that's never happened before, I'll try to leave plenty of time for questions.

My claim is that science is a bounded enterprise, limited by social, economic, physical and cognitive factors. Science is being threatened, literally, in some cases, by technophobes like the Unabomber, by animal-rights activists, by creationists and other religious fundamentalists, by post-modern philosophers and, most important of all, by stingy politicians.

Also, as science advances, it keeps imposing limits on its own power. Einstein's theory of special relativity prohibits the transmission of matter or even information at speeds faster than that of light. Quantum mechanics dictates that our knowledge of the microrealm will always be slightly blurred. Chaos theory confirms that even without quantum indeterminacy many phenomena would be impossible to predict. And evolutionary biology keeps reminding us that we are animals, designed by natural selection not for discovering deep truths of nature but for breeding.

All these limits are important. But in my view, by far the greatest barrier to future progress in science--and especially pure science--is its past success. Researchers have already created a map of physical reality, ranging from the

Sometime during the next few hundred million years, single-celled organisms emerged on the earth. Prodded by natural selection, these microbes evolved into an amazingly diverse array of more complex creatures, including Homo sapiens.

I believe that this map of reality that scientists have constructed, and this narrative of creation, from the big bang through the present, is essentially true. It will thus be as viable 100 or even 1,000 years from now as it is today. I also believe that, given how far science has already come, and given the limits constraining further research, science will be hard-pressed to make any truly profound additions to the knowledge it has already generated. Further research may yield no more great revelations or revolutions but only incremental returns.

The vast majority of scientists are content to fill in details of the great paradigms laid down by their predecessors or to apply that knowledge for practical purposes. They try to show how a new high-temperature superconductor can be understood in quantum terms, or how a mutation in a particular stretch of DNA triggers breast cancer. These are certainly worthy goals.

But some scientists are much too ambitious and creative to settle for filling in details or developing practical applications. They want to transcend the received wisdom, to precipitate revolutions in knowledge analogous to those triggered by Darwin's theory of evolution or by quantum mechanics.

For the most part these over-reachers have only one option: to pursue science in a speculative, non-empirical mode that I call ironic science. Ironic science resembles literature or philosophy or theology in that it offers points of view, opinions, which are, at best, "interesting," which provoke further comment. But it does not converge on the truth.

One of the most spectacular examples of ironic science is superstring theory, which for more than a decade has been the leading contender for a unified theory of physics. Often called a "theory of everything," it posits that all the matter and energy in the universe and even space and time stem from infinitesimal, string-like particles wriggling in a hyperspace consisting of 10 (or more) dimensions. Unfortunately, the microrealm that superstrings allegedly inhabit is completely inaccessible to human experimenters. A superstring is supposedly as small in comparison to a proton as a proton is in comparison to the solar system. Probing this realm directly would require an accelerator 1,000 light years around. Our entire solar system is only one light day around. It is this problem that led the Nobel laureate Sheldon Glashow to compare superstring theorists to "medieval theologians." How many superstrings can dance on the head of a pin?

There are many other examples of ironic science that you have probably heard of, in part because science journalists like myself enjoy writing about them so much. Cosmology, for example, has given rise to all kinds of theories involving parallel universes, which are supposedly connected to our universe by aneurisms in spacetime called wormholes. In biology, we have the Gaia hypothesis of Lynn Margulis and James Lovelock, which suggests that all organisms somehow cooperate to ensure their self-perpetuation. Then there are the anti-Darwinian ideas of Brian Goodwin and Stuart Kauffman, who think life stems not primarily from natural selection but from some mysterious "laws of complexity" that they have glimpsed in their computer simulations.

answers to such questions may be fascinating, or have enormous practical value, but they merely extend the prevailing paradigm rather than yielding profound new insights into nature

Other questions are profound but unanswerable. The big bang theory, for example, poses a very obvious and deep question: Why did the big bang happen in the first place, and what, if anything, preceded it? The answer is that we don't know, and we will never know, because the origin of the universe is too distant from us in space and time. That is an absolute limit of science, one forced on us by our physical limitations. There are lots of other unanswerable questions. Are there other dimensions in space and time in addition to our own? Are there other universes?

Then there is a whole class of what I call inevitability questions. Just how inevitable was the universe, or the laws of physics, or life, or life intelligent enough to wonder how inevitable it was? Underlying all these questions is the biggest question of all: Why is there something rather than nothing? None of these inevitability questions are answerable. You can't determine the probability of the universe or of life on earth when you have only one universe and one history of life to contemplate. Statistics require more than one data point. So, again, it is true that answers always raise new questions. But that does not mean that science will never end. It only means that science can never answer all possible questions, it can never quench our curiosity, it can never be complete.

Unanswerable questions, by the way, are what give rise to superstring theory, Gaia, psychoanalysis and other example of ironic science, as well as all of philosophy.

3. What About Life on Mars?

The day the life on Mars story broke last August, I walked into my office at Scientific American, and several colleagues immediately came up to me with big smirks and said, "So, what does Mr. No More Big Discoveries say now?" It took me a while to come up with a response, but here it is:

The discovery of extraterrestrial life would represent one of the most thrilling find and biology in general. But would it mean that science is suddenly liberated from all the limits that I have described? Hardly. If we find life on Mars, we will know that life arose in this solar system, and perhaps not even more than once. It may be that life originated on Mars and then spread to the earth, or vice versa.

More importantly, we will be just as ignorant about whether life exists elsewhere in the universe, and we will still be facing huge obstacles to answering that question. Let's say that engineers come up with a space transport method that boosts the velocity of spaceships by a factor of more than 10, to one million miles an hour. That spaceship would still require 3,000 years to reach the nearest star, Alpha Centauri.

Now it's possible that one of these days the radio receivers employed in our Search for Extraterrestrial Intelligence program, called SETI, will pick up electromagnetic signals--the alien equivalent of Seinfeld--coming from another star. But it's worth noting that most of the SETI proponents are physicists, who have an extremely deterministic view of reality. Physicists think that the existence of a highly technological civilization here on earth makes the existence of similar civilizations elsewhere highly probable.

The real experts on life, biologists, find this view ludicrous, because they know how much contingency--just plain luck--is involved in evolution. Stephen Jay Gould, the Harvard paleontologist, has said that if the great experiment of life were re-run a million times oest(-)Tj0.00h(el)3 4 ((elt[r)6 (u)4 (n a m)4 (il)3 (l)3 (io)]TJ4.91 0)3 (l)3 (r)6 (

rests on the firm foundation of quantum mechanics, and modern genetics, far from undermining the fundamental paradigm of Darwinian evolution, has bolstered it.

If you view atoms and elements and the double helix and viruses and stars and galaxies as inventions, projections of our culture, which future cultures may replace with other convenient illusions, then you are unlikely to agree with me that science is finite. If science is as ephemeral as art, of course it can continue forever. But if you think that science is a process of discovery rather than merely of invention, if you believe that science is capable of achieving genuine truth, then you must take seriously the possibility that all the great, genuine paradigm shifts are behind us.

5. The Chaoplexity Gambit

Many modern scientists--including, no doubt, some right here at McGill--hope that advances in computers and mathematics will enable them to transcend their current knowledge and create a powerful new science. This is the faith that sustains the trendy fields of chaos and complexity. In my book I lump chaos and complexity together under a single term, chaoplexity, because after reading dozens of books about chaos and complexity and talking to scores of people in both fields, I realized that there is no significant difference between them. Also, I just wanted to irritate the chaoplexologists.

Chaoplexologists have argued that with more powerful computers and mathematics they can answer age-old questions about the inevitability, or lack thereof, of life, or even of the entire universe. They can find new laws of nature analogous to gravity or the second law of thermodynamics. They can make economics and other social sciences as rigorous as physics. They can find a cure for AIDS. These are all claims that have been made by researchers at the Santa Fe Institute, which is a leading center of chaoplexity.

These claims stem from an overly optimistic interpretation of certain developments in computer science. Over the past few decades, researchers have found that various simple rules, when followed by a computer, can generate patterns that appear to vary randomly as a function of time or scale. Let's call this illusory randomness "pseudo-noise." A paradigmatic example of a pseudo-noisy system is the mother of all fractals, the Mandelbrot set, which is an icon of the chaoplexity movement.

The fields of both chaos and complexity have held out the hope that much of the noise that seems to pervade nature is actually pseudo-noise, the result of some underlying, deterministic algorithm. But the noise that makes it so difficult to predict earthquakes, the stock market, the weather and other phenomena is not apparent but very real. This kind of noisiness will never be reduced to any simple set of rules, in my view.

Of course, faster computers and advanced mathematical techniques will improve our ability to predict certain complicated phenomena. Popular impressions notwithstanding, weather forecasting has become more accurate over the last few decades, in part because of improvements in computer modeling. But an even more important factor is improvements in data-gathering--notably satellite imaging.

But neuroscience will not deliver what so many philosophers and scientists he pointed out. But the best thing about making immortality the primary goal of science, Sapolsky said, is that it is almost certainly unattainable, so scientists can keep getting funds for more research forever.

8. The End of Science is an unprovable and therefore ironic hypothesis

I admit that, as a journalist, I'm overly fond of playing gotcha games. In my book, for example, I describe an interview with the great philosopher Karl Popper, who argued that scientists can never prove a theory is true; they can only falsify it, or prove it is false. Naturally I had to ask Popper, Is your falsifiability hypothesis falsifiable? Popper was 90 then, but still intellectually armed and very dangerous. He put his hand on my hand, looked deep into my eyes, and said, very gently, "I don't want to hurt you, but it is a silly question."

Given my style of journalism, I guess it's only fair that some critics have tried galaxies or even other universes. We are not going to become infinitely wise or immortal through genetic engineering. We are not going to discover the mind of God, as the British physicist Stephen Hawking once put it. We are not going to know why there is something rather than nothing. We'll be stuck in a permanent state of wonder before the mystery of existence--which may not be such a terrible thing. After all, our sense of wonder is the wellspring not only of science but also of art, and literature, and philosophy, and religion.

Some interviewers have asked me: If science ends, what will happen to humanity? What will be our fate? The honest answer is: How the hell should I know? But let me offer a couple of prophecies from people I interviewed for my book.

One is Gunther Stent, one of the pioneers of modern genetics. Almost 30 years ago Stent wrote a brilliant booke is (o)3 (3 (u)4 (r(h)4 (il2 (.n2.9 (t e)-10 (o)3tl)-7 (e o)3 (f)5 (p expansion of the universe, something that spawns a whole new era in pure science and proves me wrong. But I also sincerely believe th