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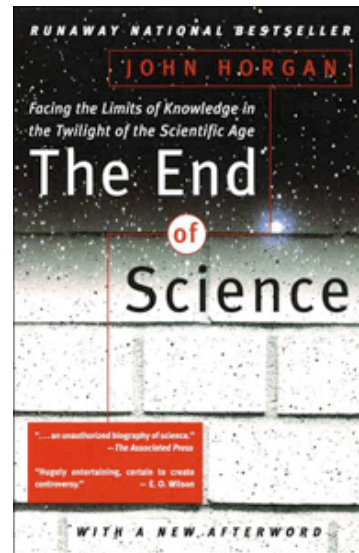
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## Looking Back at the End of Science

*More than a decade after its original publication, does the prophecy of a controversial book still ring true?* **By John Horgan**

March 1, 2008



When I began writing about science twenty-six years ago, I believed in what Vannevar Bush, founder of the National Science Foundation, called "the endless frontier" of science. I started questioning that myth in the late 1980s, when physicists like Stephen Hawking declared they were on the verge of a "final theory" that would solve all their field's outstanding mysteries.

That astonishing claim provoked me to wonder whether not just physics but science as a whole might end. After years of reading and talking to scientists about this topic, I concluded that the era of great scientific discovery might already be over, in the following sense: Scientists will never again achieve insights into nature as profound as the atomic theory of matter, quantum mechanics, relativity, the big bang, evolution by natural selection, and DNA-based genetics. Scientists will extend, refine, and apply this knowledge, but there will be no more great revolutions or revelations.

That was the basic message of *The End of Science*, published in 1996. The science establishment was not amused. My book was denounced by dozens of Nobel laureates, the White House science advisor, the heads of the Human Genome Project, the British minister of science, and the editors of *Nature*, *Science*, and *Scientific American*, where I was working at the time.

### **What Nineteenth-century Physicists Really Thought**

Most critics merely indulged in chest-thumping declarations of faith in scientific progress, but some have offered reasonable objections. By far the most common is some variation of, "Oh come on, that's what physicists thought at the end of the nineteenth century." Actually, most physicists then were wrestling with profound questions, such as whether atoms really exist. The historian of science Stephen Brush has called the alleged Victorian calm in physics "a myth."

Moreover, even if some scientists wrongly predicted science was ending in the past, why does that mean all future predictions must be wrong? Science itself tells us that there are limits to knowledge. Relativity theory prohibits travel or communication faster than light. Quantum mechanics and chaos theory constrain the precision with which we can make predictions. Evolutionary biology reminds us that we are animals, shaped by natural selection not for discovering deep truths of nature but for breeding.

The greatest barrier to future progress in science is its past success. Postmodern philosophers hate this comparison, but scientific discovery resembles the exploration of the Earth. We are now unlikely to discover something truly astonishing like the lost continent of Atlantis or dinosaurs on a secluded island. In the same way, scientists are unlikely to discover anything surpassing natural selection, quantum mechanics, or the big bang.

### **Unanswerable Questions and Ironic Science**

Another common objection to my argument is that science still poses many profound questions. True, but some of these questions may be unanswerable. The big bang theory 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.

Scientists's attempts to solve these mysteries often take the form of what I call ironic science, unconfirmable speculation that resembles philosophy or theology rather than genuine science. My favorite example of ironic science is string theory, which for more than twenty years has been the leading contender for a unified theory of physics.

Unfortunately, strings are so small that you'd need an accelerator one thousand light years around to detect them. String theory also comes in so many versions that it can accommodate virtually any data. Critics call this the Alice's Restaurant problem. That's a reference to the Arlo Guthrie verse: "You can get anything you want at Alice's Restaurant." But of course a theory that predicts everything really predicts

nothing.

### **Taking on Chaoplexity**

The physicist and Nobel laureate Robert Laughlin grants that we might have reached "the end of reductionism," which identifies the basic particles and forces underpinning the physical realm. Nevertheless, he insists that scientists can discover profound new laws by investigating complex, emergent phenomena, which cannot be understood in terms of their individual components.

Laughlin is merely recycling rhetoric from the fields of chaos and complexity, which are so similar that I lump them under a single term, chaoplexity. Chaoplexologists argue that advances in computation and mathematics will soon make fields like economics, ecology, and climatology as rigorous and predictive as nuclear physics.

The chaoplexologists have failed to deliver on any of their promises. One reason is the notorious butterfly effect. To predict the course of a chaotic system, such as a climate, ecology, or economy, you must determine its initial conditions with infinite precision, which is of course impossible. The butterfly effect limits both prediction and explanation, and it suggests that many of chaoplexologists' grand goals cannot be achieved.

### **What about Applied Science?**

The physicist Michio Kaku wrote recently that "the foundations of science are largely over" because we have discovered the basic laws ruling physical reality. But Kaku insists that we can manipulate these laws to create an endless supply of new technologies, medicines, and other applications. In other words, pure science might be over, but applied science is just beginning. Kaku compares science to chess. We've just learned the rules, and now we're going to become grand masters.

Applied science obviously has much further to go, and it's hard to know precisely where it might end. That's why *The End of Science* focused on pure science. But I doubt the predictions of techno-optimists like Ray Kurzweil that advances in genetics, nanotech, and other fields will soon make us immortal. I'd have more confidence that scientists could solve senescence if they'd had more success with cancer.

After Richard Nixon declared a "war on cancer" in 1971, cancer mortality rates actually rose for two decades before declining slightly over the past fifteen years, mostly because of a decline in smoking. I hope someday researchers will find a cure that renders cancer as obsolete as smallpox. But given

the record of cancer research so far, isn't it a bit premature to talk about immortality?

### **Brain Science Is Just Beginning!**

The British biologist Lewis Wolpert once told me that my argument is "absolute rubbish." He was particularly upset by a chapter entitled "The End of Neuroscience." Neuroscience, he declared, is "just beginning!"

Actually, neuroscience has deep roots. Galvani showed two centuries ago that nerves emit and respond to electric current, and a century ago Golgi, Cajal, and others began unraveling the structure and function of neurons. The claim that neuroscience is "just beginning" reflects not the field's actual age but its output.

Although neuroscientists have acquired increasingly powerful tools for probing and modeling the brain, they have failed to produce a compelling theory of the mind. Nor have researchers winnowed out pre-existing theories. Theories of the mind never really die. They just go in and out of fashion. Some prominent neuroscientists, such as the Nobel laureates Eric Kandel and Gerald Edelman, still think the best theory of the mind is Freudian psychoanalysis.

Our best hope for a breakthrough is to crack the neural code, the set of rules or algorithms that transforms electrical pulses emitted by brain cells into perceptions, memories, and decisions. But recent research suggests that each brain may operate according to many different neural codes, which keep changing in response to new experiences. Some leading neuroscientists, such as Christof Koch, worry that the neural code might be too complex to fully decipher.

### **Will the End of Science Be Self-fulfilling?**

Some critics worry that my predictions might become self-fulfilling by discouraging young people from becoming scientists. To be honest, I worry about this problem too, especially now that I teach at a science-oriented school. I tell my students that, even if I'm right that the era of profound discoveries has ended, there is still much meaningful work to do, especially in applied science.

They can develop better treatments for AIDS or cancer or schizophrenia. They can invent cleaner, cheaper sources of energy, or devise computer models that give us a better understanding of global warming. They can even help us understand why we fight wars and how we can avoid them. I also urge my students to question all big, ambitious theories, including mine. The only way to find out how far science can go is to keep pushing against its limits.

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