

‘Limitology’ at the End of the 20th Century

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How is human knowledge possible? To what extent are we allowed to know scientifically about the world and our nature? Such are the fundamental questions of epistemology, particularly the epistemology of the stripe of Kantian ‘Critical Philosophy’. We can slightly modify these epistemological questions into new ones; How is our pursuit of knowledge possible to come to an end? Or, how can we know that we have already arrived at the end-point of the road of scientific inquiry? Or, more crudely, have we not yet entered into the age of “the end of science”? These are the basic questions of an exotic new science called ‘Limitology’.

The term ‘Limitology’ was born in 1994 at a workshop at the Santa Fe Institute titled “The Limits to Scientific Knowledge”. I read about this workshop in the book titled “The End of Science” (2nd ed., New York; Broadway Books, 1997), which is written by John Horgan, a former senior science writer of *Scientific American*. Horgan’s idea is that we are indeed experiencing the end of science, or the ends of all kinds of science. Horgan’s book contends that we now recognize the feeling of exhaustion in every field of intellectual inquiries, from philosophy to neuroscience, or “chaoplexity”. He includes “the end of limitology” itself in his long list of endings. If his own thesis is a piece of limitological estimation, then here is lurking a certain kind of theoretical contradiction, or a flavor of paradox not so rare in many efforts to (meta-scientifically) “demarcate” or (transcendentally) “set limits to” human knowledge.

I do not wish to push this charge of paradoxicality, but only would like to think about the substance of Horgan’s claim. Our scientific inquiry is already at the final stage? If so, is it a welcome situation or a rather lamentable fact? What is the end-product of our long history of scientific inquiry?

I am interested in this topic mainly for two reasons. One is from the viewpoint

of the history of ideas. The philosophy of Charles Sanders Peirce, the founder of American Pragmatism, has been the main subject of my historical study of philosophy. Peirce was an original thinker in many fields of philosophy, and he was perhaps the first person to think seriously about the importance of the idea "the end of science". (Or, Hegel was the first, and Peirce was the second?) He had a vision about the final phase of scientific inquiry. His epistemology identified Truth itself with the end of inquiry. And he insisted that our inquiry would continue indefinitely in the future, but that it is "destined" to converge on the final one, the Truth (Is it a typical contradiction of Limitological claim?)

Peirce started his philosophical career with a piece of essay titled "The Place of Our Age in the History of Civilization", in which, as we shall see below, he sketched his vision of the finale of scientific inquiry. The essay was written in 1863. More than 130 years have passed since then. I would like to assess the validity of Peirce's vision against the background of contemporary limitological estimation.

(We are sometimes told that "the end of science" theme was rather popular among the 19th century physicists. It is often said that Lord Kelvin declared that we had already found all basic physical truths and that by betraying such arrogance he failed completely to predict the future revolutionary course of physics. However, today's historians of science doubt the correctness of this episode. Something very similar to this remark was indeed made by Albert Michelson in 1894, but he was so absorbed in his own optical experiments that he was "oblivious to the violent controversies raging among the theorists at the time". That is, the alleged "Victorian calm in physics" is a myth, says a historian of science⁽¹⁾).

The other reason of my interest in this topic is more temporary and journalistic. I have recently heard about the great fuss of the so-called "Science Wars" and "Sokal's hoax". Alan Sokal, a physicist at New York University, sent a paper on current physics in the style of literary deconstruction to the editors of *Social Text*, an important academic journal for literary and cultural studies. (The title of the paper is "Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity". The paper is citing more than 200 works in the field of natural and human sciences. It is appended with more than 100 academic notes). The editors included the paper in a special issue dedicated to the "science wars" (spring/summer 1996). Simultaneously, Sokal confessed in another journal that his piece was a parody and that he deliberately deformed the theoretical contents in

order to test the intelligence of the editors of such a famous literary journal. He deceptively painted himself as a theorist firmly convinced of the need to hermeneutically transform contemporary physics, but, in fact, by developing a long array of nonsensical analyses of physical theories, he tried to bring the ignorance and arrogance of literary critics in full relief.

When the story broke out, a big controversy arose both on the sides of natural scientists and human scientists, both in America and in France. Sokal then published with a Belgian physicist Jean Bricmont a book titled *Impostures intellectuelles* (Paris; Odile Jacob, 1997), which provoked more controversy. There are so many (more than a hundred thousand, at least) discussions on this topic on the web now all over the world.

This Sokal affair seems to tell many important things about American intellectual life. It is without doubt that Sokal touched on the very delicate problem concerning the ethics of academic publishing. It would take much time for us to understand the real meaning of this affair.

When I heard about this affair for the first time, I felt very curious and embarrassed, and still I am. But I also wondered, if, contrary to the true heart of Sokal himself, our physics is in fact at its dead end, what will be the course of the debate. Sokal trusts his own judgment that only self-complacent literary critics can believe that physics is now in jeopardy, but Horgan reports that the reality is the opposite. According to Horgan, the end of science is not an innocent fancy of literary people, but a gloomy fact grudgingly accepted by scientists themselves. Horgan's view is that contemporary science became nothing but an ironic literary enterprise. If Horgan's claim is right, then, surely, the force of Sokal's criticism dramatically diminishes. (I cannot foretell the fate of literary critics in that case. Should they gladly pass their seats to more elaborate "theories" of natural scientists?)

I do not enter into the debate of Sokal affair in this paper, because I am more anxious than Sokal himself to know that "the end of science" thesis is true or not. At present, the affair has not much prominence in Japan. I read only three papers on this affair appeared in Japanese journals⁽²⁾. But the most informative Sokal website in the world is now open in Japan. So the readers with any interest in this debate may be advised to call up this site (www.math.tohoku.ac.jp/kuroki/Sokal/index.html). Leaving gossipy curiosity aside, I only do an exercise of the history of ideas in this paper, that is, the comparison of Peirce and Horgan.

Peirce wrote the paper "The Place of Our Age" at the age of twenty-four, a year after receiving the degree of M. A. *summa cum laude* in Chemistry from Harvard. He thought that "our scientific age of reason" had been ushered in by the great discoveries in mathematics and physical sciences of the seventeenth century. Those discoveries were followed by the "methodical scepticism" of science and the growth of individual freedom from political and religious absolutism based on power and superstition. Granted that the "materialistic tendency of our age" is one-sided and shortsighted in forgetting the impermanence of material things and the deeper spiritual values of liberty, he also suggested that idealism could receive support from the mastery of physical sciences. Only the union of the material uses of science with the spiritual goals of a religious humanitarianism can approximate the "majestic symphony" played by the sciences in their rendition of the cosmos, said he. "Materialism without idealism is blind, idealism without materialism is void" was his fundamental conviction expressed in this paper.

What is the "majestic symphony" of sciences? For him, it is nothing but the finale of sciences.

When the conclusion of our age comes, and scepticism and materialism have done their perfect work, we shall have a far greater faith than ever before. For then man will see God's wisdom and mercy, not only in every event of his own life, but in that of the gorilla, the lion, the fish, the polyp, the tree, the crystal, the grain of dust, the atom.... So the poet in our days—and the true poet is the true prophet—personifies everything, not rhetorically but in his own feeling. He tells us that he feels an affinity for nature, and loves the stone or the drop of water. But the time is coming when there shall be no more poetry, for that which was poetically divined shall be scientifically known. It is true that the progress of science may die away, but then its essence will have been extracted. This cessation itself will give us time to see that cosmos, that esthetic view of science which Humboldt prematurely conceived. Physics will have made us familiar with the body of all things, and the unity of the body of all; natural history will have shown us the soul of all things in their infinite and amiable idiosyncrasies. Philosophy will have taught us that it is this *all* which constitutes the church. Ah! what a heavenly harmony will be that when all the sciences, one as viol, another as flute, another as trumpet, shall peal forth in that majestic symphony of which the noble organ of astronomy forever sounds the theme⁽³⁾.

"The time is coming when there shall be no more poetry, for that which was poetically divined shall be scientifically known." But then, the "cessation" of

science itself will give us time to see “that esthetic view of science”. All through his life, Peirce was faithful to this vision of the completion of science first cherished in his youth.

His mature theory of “Pragmaticism” was a branch of the “Architecture of Theories”. The basic framework of this grandiose theoretical architecture consisted of three fundamental categories (the Firstness, the Secondness, and the Thirdness) which, he argued to have proved, could be commonly abstracted from phenomenological analysis, formal logic, topological geometry, and physics. On this framework, he thought we could construct a Cosmogonic Philosophy, according to which our universe is governed by the innumerable continuous laws of events, but all laws admit some possibility of chance deviations, and the system of laws is evolving on the principle of love into the final, “most systematic system”.

Furthermore, in his final piece of published paper, Peirce developed “A Neglected Argument for the Reality of God”(1908). It has been neglected by theologians, he argued, because it is in fact not an “argument” for the reality of God, but a “Humble Argumentation” which only suggests that our instinct for guessing and free musement of the universe is the common origin of scientific inquiries (which has three stages) and the emergence of a new idea of God (which is the final stage). In this paper, he left the validity of the argumentation and the nature of God thus argued to exist to the sympathetic appreciation and further elaboration on the side of the readers.

Such was the philosophy of Peirce. He believed in the coming of the final, harmonic systematization of scientific theories. He also believed in the possibility that such a systematization will give us a glimpse of the creator of the “Universe of Experience”. Was he right on these accounts—at least to some extent? Let us jump over one hundred years or so, and look into the contemporary assessment of the balance sheet of scientific knowledge.

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When the first edition of Horgan’s *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age* appeared in 1996, *The Associated Press* called it “an unauthorized biography of science”. It is a biography, because the story of the book is built on the basis of huge amount of interviews with eminent scientists exclusively conducted by Horgan as a writer of *Scientific*

American. The people interviewed include philosophers (Karl Popper, Thomas Kuhn, Paul Feyerabend, Colin McGinn, Nicholas Rescher, among others), physicists (Edward Witten, John Wheeler, David Bohm, Freeman Dyson and others), cosmologists (Stephan Hawking, Roger Penrose), biologists (Richard Dawkins and others), social scientists (Noam Chomsky, Clifford Geertz), chaoplexity theorists (Ilya Prigogine, Mitchell Feigenbaum and others), cognitive scientists (John Eccles, Daniel Dennett, Marvin Minsky, etc. etc.).

But it is an “unauthorized” biography, because all these eminent scientists, although in the personal interviews almost unanimously expressed deep doubt about the value and prospect of their academic field, would certainly, in public, deny vehemently the thesis of the book that science came to an end.

Are they really sceptical about the value and future prospect of their profession? Here are some sample records of conversations;

Rescher, in his 1978 book, *Scientific Progress*, deplored the fact that Stent, Glass, and other prominent scientists seemed to think that science might be approaching a cul-de-sac. Rescher intended to provide “an antidote to this currently pervasive tendency of thought” by demonstrating that science is at least potentially infinite. But the scenario he sketched out over the course of his book was hardly optimistic.... [And] when I telephoned him in 1992, he acknowledged that his analysis had been in most respects a grim one. “We can only investigate nature by interacting with it”, he said. “To do that we must push into regions never investigated before, regions of higher density, lower temperature, or high energy. In all these cases we are pushing fundamental limits, and that requires ever more elaborate and expensive apparatuses. So there is a limit imposed on science by the limits of human resources”.... Rescher, like many other would-be seers, had succumbed to wishful thinking. He admitted that he felt that the end of science would be a tragedy for humanity. If the quest for knowledge ended, what would become of us? What would give our existence meaning? (From Chap. 1, “The End of Progress”)

It was time to launch my big question. Was [Popper's] own falsification concept falsifiable? Popper glared at me. Then his expression softened, and he placed his hand on me. “I don't want to hurt you”, he said quietly, “but it is a silly question”. Peering searchingly into my eyes, he inquired whether one of his critics had persuaded me to ask this question. Yes, I lied. “Exactly”, he said, looking pleased.... Falsification itself is “decidedly unempirical”; it belongs not to science but to philosophy, or “metascience”, and it does not even apply to all of science. Popper was admitting, essentially, that his critic were right: falsification is a mere guideline, a rule of thumb, sometime helpful and sometime not.... I slipped in a final question: Why in his

autobiography did Popper say that he was the happiest philosopher he knew? “Most philosophers are really deeply depressed”, he replied, “because they can’t produce anything worthwhile”.... Popper has always been popular among scientists—and with good reason, since he depicted science as an endless romantic adventure. An editorial in *Nature* once called Popper, quite justly, “the philosopher *for* science”. But Popper’s fellow philosophers have been less kind. His oeuvre, they point out, is rife of contradictions. (Chap. 2, “The End of Philosophy”)

Superstring is the name of an extremely small and extremely hypothetical stringlike particle posited by a popular theory of physics. According to the theory, the wriggling of these strings in a 10-dimensional hyperspace generates all the matter and energy in the universe and even space and time. Many of the world’s leading physicists felt that superstring theory might turn out to be the unified theory they had sought for so long.... Penrose was not among the faithful. “It couldn’t be right”, he told me. “It’s just not the way I’d expect the answer to be “. I began to realize, as Penrose spoke, that to him “the answer” was more than a mere theory of physics, a way of organizing data and predicting events. He was talking about *The Answer*; the secret of life, the solution to the riddle of the universe. Penrose is an admitted Platonist. Scientists do not invent the truth; they discover it. Genuine truths exude a beauty, a self-evident quality that gives them the power of revelation. Superstring theory did not possess these traits, in Penrose’s mind. He conceded that the “suggestion” he set forth in *The Emperor’s New Mind* (Oxford Univ. Press, 1989) —it did not merit the term theory yet, he admitted—was rather ungainly. It might turn out to be wrong, certainly in its details. But he felt sure that it was closer to the truth than was superstring theory. In saying that, I asked, was Penrose implying that one day scientists would find *The Answer* and thus bring their quest to an end?... “I don’t think we are close”, he said slowly, squinting out his office window, “but it does not mean things couldn’t move fast at some stage”. He cogitated some more. “I guess this is rather suggesting there *is* an answer”, he continued, “although perhaps that’s too pessimistic”. This final comment stopped me short. What is so pessimistic, I asked, about a truth seeker thinking that the truth is attainable? “Solving mysteries is a wonderful thing to do”, Penrose replied. “And if they were all solved, somehow, that would be rather boring”. (Introduction, “Searching for *The Answer*”)

In *The Character of Physical Law* (MIT Press, 1967), Richard Feynman, who won a Nobel Prize in 1965 for devising a quantum version of electromagnetism, offered a rather dark prophecy about the future of physics. “We are very lucky to live in an age in which we are still making discoveries. It is like the discovery of America—you only discover it once. The age in which we live is the age in which we are discovering the fundamental laws of nature, and that day will never come again. It is very exciting, it is marvelous, but this excitement will have to go. Of course in the future there will

be other interests. There will be the interest of the connection of one level of phenomena to another—phenomena in biology, and so on.... but there will not be the same thing as we are doing now”... Feynman’s vision was uncanny on target.... I saw the future of physics in 1992 when I attended a symposium at Columbia University in which philosophers and physicists discussed the meaning of quantum mechanics. The symposium demonstrated that more than 60 years after quantum mechanics was invented, its meaning remained, to put it politely, elusive. In the lectures, one could hear the echoes of Wheeler, Bohm, Weinberg, and others. But for the most part each speaker seemed to have arrived at a private understanding of quantum mechanics, couched in idiosyncratic language; no one seemed to understand, let alone agree with, anyone else. The bickering brought to mind what Bohr once said of quantum mechanics: “If you think you understand it, that only shows that you don’t know the first thing about it”. (Chap. 3, “The End of Physics”)

Chomsky’s evolutionary perspective has, if anything, convinced him that we may have only a limited ability to understand nature, human or inhuman. He rejected the notion that evolution shaped the brain into a general-purpose learning and problem-solving machine. Chomsky believes, as Gunter Stent and Colin McGinn do, that innate structure of minds imposes limits on our understanding.... The success of science, Chomsky proposed to me, stems from “a kind of chance convergence of the truth about the world and the structure of our cognitive space. And it *is* a chance convergence because evolution didn’t design us to do this; there’s no pressure on differential reproduction that led to the capacity to solve problems in quantum theory. We had it. It’s just there for the same reason that most other things are there: for some reason that nobody understands”. Modern science has stretched the cognitive capacity of humans to the braking point, according to Chomsky. In the nineteenth century, any well educated person could grasp contemporary physics, but in the twentieth century “you’ve got to be some kind of freak”. That was my opening. Does the increasing difficulty of science, I asked, imply that science might be approaching its limits? Might science, defined as the search for *comprehensible* regularities or patterns in nature, be ending? Abruptly, Chomsky took back everything he had just said. “Science is hard, I would agree with that. But when you talk to young children, they want to understand nature. It’s driven out of them by boring teaching and by an educational system that tells them they’re too stupid to do it”. Suddenly it was the establishment, not our innate nature, that had brought science to its current impasse.... In denying the implication of his own ideas, Chomsky may have been exhibiting just another odd spasm of self-defiance. But I suspect he was really succumbing to wishful thinking. Like so many other scientists, he cannot imagine a world without science. (Chap. 6, “The End of Social Science”)

Dennett granted that neuroscience might never produce a theory of consciousness

that satisfied everyone. “We can’t explain *anything* to everyone’s satisfaction”, he said. After all, many people are dissatisfied with science’s explanation of, say, photosynthesis or biological reproduction. But “the sense of mystery is gone from photosynthesis or reproduction”. Dennett said, “and I think in the end we will have a similar account of consciousness”. [Then] abruptly, Dennett tacked in a completely different direction. “There’s a curious paradox looming” in modern science, he said. “One of the very trends that makes science proceed so rapidly these days is a trend that leads science away from human understanding. When you switch from trying to model things with elegant equations to doing massive computer simulations... you may end up with a model that exquisitely models nature, the phenomena you’re interested in, but you don’t understand the model. That is, you don’t understand it the way you understood models in the old days”. A computer program that accurately modeled the human brain, Dennett noted, might be as inscrutable to us as the brain itself. “Software systems are already at the very edge of human comprehensibility”, he observed. “Even a system like the Internet is absolutely trivial compared to a brain, and yet it’s been patched and built on so much that nobody understand how it works or whether it will go on working. And thus, as you start using software-writing programs and software-debugging programs and code that heals itself, you create new artifacts that have a life of their own..... “. Astonishingly, [despite his appearance as a down-to-earth materialist] Dennett was implying that he, too, had mysterious inclinations. He thought a theory of mind, although it might be highly effective and have great predictive power, was unlikely to be intelligible to mere humans. The only hope humans have of comprehending their own complexity may be to cease being human. (Chap. 7, “The End of Neuroscience”)

So much for the self-critical (and at the same time too often self-justificatory) opinions of famous scientists and philosophers. They are only the typical examples of those of much more numbers of scientists depicted in this book as gripped by some sort of feeling of unease. Now, aren’t these episodes simply attesting the exhaustion and hang-over these scientists are feeling after they have established their fame as eminent scholars? Horgan believes that, to the contrary, their malaise has another, clearer cause. He argues that, if one believes in science, one must accept the possibility, or rather the probability, that the great era of scientific discovery is over. (Here, by science, he means not applied science, but pure science, the primordial human quest to understand the universe and our place in it). Further research may yield no more great revolutions or revelations, but only incremental, diminishing returns.

Reason (1): Science itself, as it advances, 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 a light; quantum mechanics dictates that our knowledge of the microrealm will always be uncertain; chaos theory confirms that even without quantum indeterminacy many phenomena would be impossible to predict; Kurt Gödel's incompleteness theorem denies us the possibility of constructing a complete, consistent mathematical description of reality. And evolutionary biology keeps reminding us that we are animals, designed by natural selection not for discovering deep truths of nature, but for breeding. In short, as physicist Freeman Dyson said, "Since we know that laws of physics are mathematical, and we know that mathematics is an inconsistent system, it is a sort of plausible that physics will be inconsistent".

Reason (2): As Feynman put aptly, "You only discover America once". We have already experienced the age of great discoveries; Darwin's evolutionary theory, Freud's psychoanalysis, relativity theory, and quantum mechanics. Many physicists are still struggling to construct a synthetic theory of relativity and quantum mechanics, that is, quantum gravity theory. But any solution for that theory like superstring model is super-hypothetical and hyper-incomprehensible. And the questions left unanswered after those great discoveries are too speculative ones to admit any solid answers and confirmations. How, exactly, was the universe created? Could our universe be just one of infinite number of universes? Could quarks and electrons be composed of still smaller particles, ad infinitum? First of all, what does quantum mechanics really mean? And, how, exactly, did life begin on earth? All these questions, though whose answers are eagerly pursued by today's scientists and enthusiastically chased by popular science journal readers, may never be definitely answered given the limits of human intelligence and resources.

But, of course, scientists are still doing their research, and we are applauding new Nobelists in physics and chemistry every year. If the age of great scientific discoveries is already over, and if there are left only questions unresolvable in reasonably definite and confirmable ways, then, what are these scientists doing? According to Horgan, they are basically taking one of the following two options open to them;

Track (1): Some scientists, like Hawking, are "strong" in the manner just analogous to Harold Bloom's "strong poets". While strong poets engage in an Oedipal struggle to define themselves in relation to old masters like Shakespeare or Dante, strong scientists are pursuing science in a speculative, postmodern mode which could be called "ironic science". Their common strategy is to point to all

shortcomings of current scientific knowledge, to all the questions left unanswered like those mentioned above. Those questions may never be definitely answered. Hence strong scientists offer only points of view, opinions, which are, at best, interesting, which provoke further comment. But the opinions do not converge on the truth. They cannot achieve empirically verifiable surprises that force scientists to make substantial revisions in their basic description of reality. Ironic science cannot achieve the traditional scientific goal of transcending the truth we already have. But at its best, it can, like great art or literary criticism, induce wonder in us; it keeps us in awe before the mystery of the universe.

Track (2): Other scientists, like Dennett or Dyson, are advancing the possibility that one day we humans will create intelligent machines that can transcend our puny knowledge. According to its most fantastic (or phantasmic?) scenario, machines transform the entire cosmos into a vast, unified, information-processing network. All matter becomes mind. An all-powerful computer would try to answer *The Question*: Why is there something rather than nothing? And in its effort to find *The Answer*, the universal mind itself may discover the ultimate limits of knowledge. This proposal is not science, of course, but wishful thinking. But it is not the type of wishful thinking Rescher and Chomsky succumbed. Rather it is scientifically dressed theology. This scientific theology starts from the assumption that a super-super-intelligent computer can somehow make up a universe-wide information network, and then it equates this network with God. Dyson muses, “What will mind chooses to do when it informs and controls the universe? I do not make any clear distinction between mind and God. God is what mind becomes when it passed beyond the scale of our comprehension. God may be considered to be either a world soul or a collection of world souls. We are the chief inlets of God on this planet at the present stage of his development. We may later grow with his predecessor, or we may be left behind”.

Thus, science has ended. It has outgrown the ideal of the pursuit of truth and is now endeavoring to transform itself into two different styles of intellectual activity, that is, irony and theology. But then, which style of thinking should we welcome as a successor of science? As for Horgan himself, he sides with the option of scientific theology. He confesses that the experience of “After Babel” situation in the scientific world naturally led him to the following conviction. That is, “Science”, not particular scientists but scientific knowledge itself, is realizing that its lust for final knowledge and unification has brought it to the brink of eternal nothingness, and that it dies, everything dies; being itself will vanish. Its

terrified recognition of its own plight will compel it to flee from itself. Therefore, "creation" stems, with all its pain and beauty and multiplicity. Therefore, our human, Oedipal, ironical struggle to cope with the mystery of the universe continues.

He asked Dyson for the name of any philosopher who could help him articulate this vague theological view, and Dyson advised him to consult Charles Hartshorne, a famous philosopher and process theologian. Horgan telephoned Hartshorne and asked him if this idea had any significance or coherence. Hartshorne answered that the idea was the most coherent one and that it was called "Socinianism". The Socinians believed that God changed, learned, and evolved through time, just as we humans do. God knows all of the corners of the universe in its minute details exactly, its past and present, but, with all his omniscience, he cannot know its future course in principle. Hartshorne has spent his very long life arguing that the only theology consistent with the modern science is Socinianism, and he finally found an ardent supporter in a young science writer. Science is getting close to its limits, and the truth of Socinianism is becoming clearer.

4

The End of Science was a bestseller. There appeared many reviews praising its entertaining and thought-provoking story. As a reading, it is surely full of fun, for we are provided with many exclusive portrayals of the private lives and opinions of eminent scientists and scholars. However, there were very few reviewers who agreed to the conclusion of the book that science came to an end or nearly so. (The exceptional case of David Lindley's review in *IEEE Spectrum* is not surprising, because Lindley himself wrote *The End of Physics* (New York; Basic Books, 1993) in order to say that physics and cosmology may well have reached dead ends). The reason of this general dismissal is not difficult to understand. We can think of a variety of criticisms against Horgan's thesis.

Criticism (1): We are fed up with too many "The End of *X*". The most famous one is Francis Fukuyama's *The End of History and The Last Man* (New York; Free Press, 1992). But we have also Bill McKibben's *The End of Nature* (New York; Anchor Books), or Gianni Vattimo's *The End of Modernity* (London; Polity Press, 1988). All these the-end-of-something-big books are the products of fin-de-siècle (or millennium) sensationalism. They show a kind of narcissism for insisting that ours is a special era.

Criticism (2): “The end of science” slogan is antiscience. The book has implications that discourage young people from pursuing studies in science. If, as Horgan says, the age of great scientific discovery is over, there is no point in trying to accomplish, see, experience anything new.

(Possible answer) These complaints are natural, but they are external criticisms; they do touch neither on the concrete situation of today’s science nor on Horgan’s reasoning which lead to his conclusion. They could be question-begging, if his conclusion were true. We need more specific reason to doubt it.

Criticism (3): The conclusion of the book is a mere conjecture. Nobody knows about tomorrow, let alone the future course of science. It is unscientific and contradictory to say that science has come to its limits.

(Possible answer) Certainly it is a conjecture, but, as Popper emphasized, conjecture is an essential component of scientific inquiry. Popper constructed his own falsification principle on a logical analysis and some historical analyses of science. He “meta-scientifically” painted science as “unended quest”. Horgan relies on different historical data of science, and depicts it as being caught in impasse. The pictures are different, but the method is equal.

Criticism (4): Horgan’s historiography of contemporary science depends, in part, on the principle of “diminishing returns”, which he borrowed from modern standard economic theory. Some “complexity” theorists in economics are seriously doubting the validity of this principle⁽⁴⁾. Therefore, his limitological estimation that natural and social sciences are coming to dead-ends is nonsense. It is his historiography itself which outlived its usefulness.

(Possible answer) Perhaps this challenge is well worth considering. “The end of science” slogan and “chaoplexity” theories share the convictions that our standard understanding of scientific inquiry is obsolete and that the perpetual increase of the degree of scientific predictability is a myth. They only part from each other about the blueprint of future science. While Horgan believes that contemporary science is getting closer and closer to literary enterprise or theology, chaoplexity theorists are arguing that “chaos” or “complexity” is not a smart literary metaphor but a symbol of the new frontier of scientific inquiry. According to them, we are just beginning to discover the vast terrain of “non-linear” phenomenal variations by means of a decidedly “non-reductionist” method, i. e., “simulation”. However, at the present stage at least, the believers in the possibility of higher-order synthesis of sciences from the chaoplexity viewpoint is a minority. Only time will tell which is right, Horgan or Chaoplexity—.

Thus, it may be safe to say this. "The end of science" argument is not flawless, but it seems to be not completely refuted either. So, let us suppose here, for the argument's sake, that this is a plausible picture of the current status of human scientific knowledge. And let us recall now the philosophy of Charles Peirce and the question I posed at the beginning of this paper. Peirce believed in the final, harmonic systematization of sciences. He also believed in the emergence of new theological consciousness as a result of such a systematization. After one hundred years or so, have these beliefs turned out to be true or not?

The answer is simple. If Horgan's survey is correct, then Peirce's philosophy is half refuted, half vindicated. Peirce was wrong in thinking that the finale of science is a majestic harmony. Science ended not because it completed an "Architecture of Theories", but because it recognized its own deep inconsistency and incomprehensibility. But Peirce was right in guessing that the end of science would be a beginning of new theology. At least the author of *The End of Science* is sympathetic toward Hartshorne's Socinianism. And Hartshorne's philosophy is in reality a development of Peirce's Cosmogonic Philosophy. Therefore, Peirce's position is partially vindicated.

Peirce's philosophy is widely considered to be original but enigmatic. It is a mixture of many creative ideas and numerous impenetrable speculations. Now, his philosophy seems to be half justified. He turned out to be too optimistic about the future of science, but his view of "after science" was on target. Only he could not think of the possibility of Gödel's incompleteness theorem. Perhaps Peircians like me should be very happy about this result? Regrettably, I do not think so. Exactly speaking, Peirce is not even half vindicated. For it is a curious result indeed.

Peirce-Hartshorne theology is a theoretical consequence of the project of systematic cosmogony. Horgan's theology is that of the impossibility of such a cosmogony. Surely here is something really amiss. We should think about three possibilities. (1) Peirce-Hartshorne argument for a new theology is mistaken. (2) Horgan's argument for that is mistaken. (3) Both arguments are mistaken. If (3) is the case, then, their common theology may be mistaken too, because from contradictory premisses anything can be inferred.

As is easily noticed, it is a typical "antinomy" situation. Hence, finally, we cannot but add one more complaint on the list of criticisms of Horgan.

Criticism (5): The argument for the end of science runs a risk of being trapped in an antinomy. It argues that even if we could surpass our intellectual boundaries of comprehensibility and become super-humanly clever, still our omniscience

would under the spell of formal incompleteness. But we do not really know the exact relationship of human comprehensibility and formal incompleteness. Therefore, we cannot understand the nature of super-human intelligence and the assumption of ever learning, ever evolving God is an “illusion of reason”. It means that our Limitology has not yet fully established the formal constraints of human understanding to draw any conclusion. We should rather better start again from that bottom of Critical Philosophy.

Notes

(1) Stephen Brush, “Romance in Six Figures”, *Physics Today*, Jan. 1969. Cf. also Lawrence Badash, “The Completeness of Nineteenth-Century Science”, *Isis*, vol. 1972, and Thomas Kuhn, *Black-Body Theory and The Quantum Discontinuity*, Oxford; Clarendon Press, 1978.

(2) After I wrote this paper, *Revue de la pensee d'aujourd'hui* (Tokyo, in Japanese) published a special issue on this affair (Nov. 1998).

(3) *Writings of Charles S. Peirce: A Chronological Edition*, vol. 1, Bloomington; Indiana University Press, 1981, p. 125.

(4) Yoshinori Shiozawa, *Economics of Complex Systems* (in Japanese), Tokyo; Seisansei-shuppan, 1997.