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strong poet: the appetite of the reading public for scientific “revolutions.”
As empirical science ossifies, journalists such as myself, who feed society’s
hunger, will come under more pressure to tout theories that supposedly
transcend quantum mechanics or the big bang theory or natural selection.
Journalists are, after all, largely responsible for the popular impression that
fields such as chaos and complexity represent genuinely new sciences
superior to the stodgy old reductionist methods of Newton, Einstein, and
Darwin. Journalists, myself included, have also helped Roger Penrose’s
ideas about consciousness win an audience much larger than they deserve
given their poor standing among professional neuroscientists.

I do not mean to imply that ironic science has no value. Far from it. At its
best ironic science, like great art or philosophy or, yes, literary criticism,
duces wonder in us; it keeps us in awe before the mystery of the universe.
But it cannot achieve its goal of transcending the truth we already have.
And it certainly cannot give us—in fact, it protects us from—The Answer,
a truth so potent that it quenches our curiosity once and for all time. After
all, science itself decrees that we humans must always be content with
partial truths.

Through most of this book, I will examine science as it is practiced
today, by humans. (Chapter 2 takes up philosophy.) In the final two
chapters I will consider the possibility—advanced by a surprising number
of scientists and philosophers—that one day we humans will create intel-
ligent machines that can transcend our puny knowledge. In my favorite
version of this scenario, machines transform the entire cosmos into a vast,
unified, information-processing network. All matter becomes mind. The
proposal is not science, of course, but wishful thinking. It nonetheless
raises some interesting questions, questions normally left to theologians.
What would an all-powerful cosmic computer do? What would it think
about? I can imagine only one possibility. It would try to answer The
Question, the one that lurks behind all other questions, like an actor
playing all the parts of a play: Why is there something rather than nothing?
In its effort to find The Answer to The Question, the universal mind may
discover the ultimate limits of knowledge.

In 1989, just a month after my meeting with Roger Penrose in
Syracuse, Gustavus Adolphus College in Minnesota held a sympo-
sium with the provocative but misleading title, “The End of Science?” The
meeting’s premise was that belief in science—rather than science itself—
was coming to an end. As one organizer put it, “There is an increasing
feeling that science as a unified, universal, objective endeavor is over.”
Most of the speakers were philosophers who had challenged the authority
of science in one way or another. The meeting’s great irony was that one of
the scientists who spoke, Gunther Stent, a biologist at the University
of California at Berkeley, had for years promulgated a much more dramatic
scenario than the one posited by the symposium. Stent had asserted that
science itself might be ending, and not because of the skepticism of a few
academic sophists. Quite the contrary. Science might be ending because it
worked so well.

Stent is hardly a fringe figure. He was a pioneer of molecular biology; he
founded the first department dedicated to that field at Berkeley in the
1950s and performed experiments that helped to illuminate the machinery
of genetic transmission. Later, after switching from genetics to the study of
the brain, he was named chairman of the neurobiology department of the
National Academy of Sciences. Stent is also the most astute analyst of
the limits of science whom I have encountered (and by astute I mean of
course that he articulates my own inchoate premonitions). In the late 1960s,
while Berkeley was racked with student protests, he wrote an astonishingly
prescient book, now long out of print, called The Coming of the Golden Age:
A View of the End of Progress. Published in 1969, it contended that
science—as well as technology, the arts, and all progressive, cumulative enterprises—was coming to an end.²

Most people, Stent acknowledged, consider the notion that science might soon cease to be absurd. How can science possibly be nearing an end when it has been advancing so rapidly throughout this century? Stent turned this inductive argument on its head. Initially, he granted, science advances exponentially through a positive feedback effect; knowledge begets more knowledge, and power begets more power. Stent credited the American historian Henry Adams with having foreseen this aspect of science at the turn of the century.³

Adams’s law of acceleration, Stent pointed out, has an interesting corollary. If there are any limits to science, any barriers to further progress, then science may well be moving at unprecedented speed just before it crashes into them. When science seems most muscular, triumphant, potent, that may be when it is nearest death. “Indeed, the dizzy rate at which progress is now proceeding,” Stent wrote in Golden Age, “makes it seem very likely that progress must come to a stop soon, perhaps in our lifetime, perhaps in a generation or two.”⁴

Certain fields of science, Stent argued, are limited simply by the boundedness of their subject matter. No one would consider human anatomy or geography, for example, to be infinite endeavors. Chemistry, too, is bounded. “[T]hough the total number of possible chemical reactions is very great and the variety of reactions they can undergo vast, the goal of chemistry of understanding the principles governing the behavior of such molecules is, like the goal of geography, clearly limited.”⁵ That goal, arguably, was achieved in the 1930s, when the chemist Linus Pauling showed how all chemical interactions could be understood in terms of quantum mechanics.⁶

In his own field of biology, Stent asserted, the discovery of DNA’s two-corkscrew structure in 1953 and the subsequent deciphering of the genetic code had solved the profound problem of how genetic information is passed on from one generation to the next. Biologists had only three major questions left to explore: how life began, how a single fertilized cell develops into a multicellular organism, and how the central nervous system processes information. When those goals are achieved, Stent said, the basic task of biology, pure biology, will be completed.

Stent acknowledged that biologists could, in principle, continue exploring specific phenomena and applying their knowledge forever. But according to Darwinian theory, science stems not from our desire for truth per se, but from our compulsion to control our environment in order to increase the likelihood that our genes will propagate. When a given field of science begins to yield diminishing practical returns, scientists may have less incentive to pursue their research and society may be less inclined to pay for it.

Moreover, just because biologists complete their empirical investigations, Stent asserted, does not mean that they will have answered all relevant questions. For example, no purely physiological theory can ever really explain consciousness, since the “processes responsible for the wholly private experience will be seen to degenerate into seemingly quite ordinary, workday reactions, no more or less fascinating than those that occur in, say, the liver . . .”⁷

Unlike biology, Stent wrote, the physical sciences seem to be open-ended. Physicists can always attempt to probe more deeply into matter by smashing particles against each other with greater force, and astronomers can always strive to see further into the universe. But in their efforts to gather data from ever-more-remote regimes, physicists will inevitably confront various physical, economic, and even cognitive limits.

Over the course of this century, physics has become more and more difficult to comprehend; it has outrun our Darwinian epistemology, our innate concepts for coping with the world. Stent rejected the old argument that “yesterday’s nonsense is today’s common sense.”⁸ Society may be willing to support continued research in physics as long as it has the potential to generate powerful new technologies, such as nuclear weapons and nuclear power. But when physics becomes incomprehensible, Stent predicted, society will surely withdraw its support.

Stent’s prognosis for the future was an odd mixture of optimism and pessimism. He predicted that science, before it ends, might help to solve many of civilization’s most pressing problems. It could eliminate disease and poverty and provide society with cheap, pollution-free energy, perhaps through the harnessing of fusion reactions. As we gain more dominion over nature, however, we may lose what Nietzsche called our “will to power”; we may become less motivated to pursue further research—especially if such research has little chance of yielding tangible benefits.
As society becomes more affluent and comfortable, fewer young people may choose the increasingly difficult path of science or even of the arts. Many may turn to more hedonistic pursuits, perhaps even abandoning the real world for fantasies induced by drugs or electronic devices feeding directly into the brain. Stent concluded that sooner or later, progress would "stop dead in its tracks," leaving the world in a largely static condition that he called "the new Polynesia." The advent of beatniks and hippies, he surmised, signaled the beginning of the end of progress and the dawn of the new Polynesia. He closed his book with the sardonic comment that "millennia of doing arts and sciences will finally transform the tragicomedy of life into a happening."9

A Trip to Berkeley

In the spring of 1992 I traveled to Berkeley to see how Stent thought his predictions had held up over the years.10 Strolling toward the university from my hotel, I passed what appeared to be the detritus of the sixties: men and women with long gray hair and ragged clothes asking for spare change. Once on the campus, I made my way to the university's biology building, a hulking, concrete complex shadowed by dusty eucalyptus trees. I took an elevator one floor up to Stent's laboratory and found it locked. A few minutes later the elevator door slid open and out walked Stent, a red-faced, sweaty man wearing a yellow bicycle helmet and rolling a dirt-encrusted mountain bike.

Stent had moved to the United States from Germany as a youth, and his gruff voice and attire still bore traces of his origins. He wore wire-rimmed glasses, a blue, short-sleeved shirt with epaulets, dark slacks, and shiny black shoes. He led me through his laboratory, crammed with microscopes, centrifuges, and scientific glassware, to a small office at the rear. The hall outside his office was adorned with photographs and paintings of Buddha. When Stent closed the door of his office behind us, I saw that he had tucked to the door's inner surface a poster from the 1989 meeting at Gustavus Adolphus College. The top half of the poster was covered with the word SCIENCE, written in huge, luridly colored letters. The letters were melting, oozing downward into a pool of Day-Glo protoplasm. Beneath this psychedelic puddle big black letters asked, "The End of Science?"

Stent, at the beginning of our interview, seemed rather suspicious. He asked pointedly if I was following the legal travails of the journalist Janet Malcolm, who had just lost a round in her interminable legal battle with a former profile subject, the psychoanalyst Jeffrey Masson. I mumbled something to the effect that Malcolm's transgressions were too minor to merit any punishment, but that her methods did seem rather careless. If I were writing something critical about a person as obviously volatile as Masson, I told Stent, I would be sure to have all my quotes on tape. (As I spoke, my own tape recorder was silently spinning between us.)

Gradually, Stent relaxed and began to tell me about his life. Born in Berlin to Jewish parents in 1924, he escaped from Germany in 1938 and moved in with a sister living in Chicago. He obtained a doctorate in chemistry at the University of Illinois, but upon reading Erwin Schrödinger's book What Is Life? he became entranced by the mystery of genetic transmission. After working at the California Institute of Technology with the eminent biophysicist Max Delbrück, Stent obtained a professorship at Berkeley in 1952. In these early years of molecular biology, Stent said, "none of us knew what we were doing. Then Watson and Crick found the double helix, and within a few weeks we realized we were doing molecular biology."

Stent began pondering the limits of science in the 1960s, partly in reaction to Berkeley's free-speech movement, which challenged the value of Western rationalism and technological progress and other aspects of civilization that Stent held dear. The university appointed him to a committee to "deal with this, to calm things down," by talking to students. Stent sought to fulfill this mandate—and to resolve his own inner conflicts over his role as a scientist—by delivering a series of lectures. These lectures became The Coming of the Golden Age.

I told Stent that I could not determine, after finishing The Coming of the Golden Age, whether he believed that the new Polynesia, the era of social and intellectual stasis and universal leisure, would be an improvement over our present situation. "I could never decide this!" he exclaimed, looking genuinely distressed. "People called me a pessimist, but I thought I was an optimist." He certainly did not think such a society would be in any sense utopian. After the horrors wreaked by totalitarian states in this century, he explained, it was no longer possible to take the idea of utopia seriously.

Stent felt that his predictions had held up reasonably well. Although hippies had vanished (except for the pitiful relics on Berkeley's streets),
American culture had become increasingly materialistic and anti-intellectual; hippies had evolved into yuppies. The cold war had ended, although not through the gradual merging of communist and capitalist states that Stent had envisioned. He admitted that he had not anticipated the resurgence, in the wake of the cold war, of long-repressed ethnic conflicts. “I’m very depressed at what’s happening in the Balkans,” he said. “I didn’t think that would happen.” Stent was also surprised by the persistence of poverty and of racial conflict in the United States, but he believed these problems would eventually diminish in importance. (Aha, I thought. He was an optimist after all.)

Stent was convinced that science was showing signs of the closure he had predicted in *Golden Age*. Particle physicists were having difficulty convincing society to pay for their increasingly expensive experiments, such as the superconducting supercollider. As for biologists, they still had much to learn about how, say, a fertilized cell is transformed into a complex, multicellular organism, such as an elephant, and about the workings of the brain. “But I think the big picture is basically over,” he said. Evolutionary biology in particular “was over when Darwin published *The Origin of Species*,” Stent said. He scoffed at the hope of some evolutionary biologists—notably Edward Wilson of Harvard—that they could remain occupied indefinitely by doing a thorough survey of all life on earth, species by species. Such an enterprise would be a mindless “glass bead game,” Stent complained.

He then plunged into a diatribe against environmentalism. It was at heart an antihuman philosophy, one that contributed to the low self-esteem of American youth and poor black children in particular. Alarmed that my favorite Cassandra was revealing himself to be a crank, I changed the subject to consciousness. Did Stent still consider consciousness to be an unsolvable scientific problem, as he had suggested in *Golden Age*? He replied that he thought very highly of Francis Crick, who late in his career had turned his attention to consciousness. If Crick felt that consciousness was scientifically tractable, Stent said, then that possibility must be taken seriously.

Stent was still convinced, though, that a purely physiological explanation of consciousness would not be as comprehensible or as meaningful as most people would like, nor would it help us to solve moral and ethical questions. Stent thought the progress of science might give religion a clearer role in the future rather than eliminate it entirely, as many scientists had once hoped. Although it could not compete with science’s far more compelling stories about the physical realm, religion retained some value in offering moral guidance. “Humans are animals, but we’re also moral subjects. The task of religion is more and more in the moral realm.”

When I asked about the possibility that computers might become intelligent and create their own science, Stent snorted in derision. He had a dim view of artificial intelligence, and particularly of its more visionary enthusiasts. Computers may excel at precisely defined tasks such as mathematics and chess, he pointed out, but they still perform abysmally when confronted with the kind of problems—recognizing a face or a voice or walking down a crowded sidewalk—that humans solve effortlessly. “They’re full of it,” Stent said of Marvin Minsky and others who have predicted that one day we humans will be able to download our personalities into computers. “I wouldn’t rule out the possibility that in the twenty-third century you might have an artificial brain,” he added, “but it would need experience.” One could design a computer to become an expert in restaurants, “but this machine would never know what a steak tastes like.”

Stent was similarly skeptical of the claims of investigators of chaos and complexity that with computers and sophisticated mathematics they would be able to transcend the science of the past. In *The Coming of the Golden Age*, Stent discussed the work of one of the pioneers of chaos theory, Benoit Mandelbrot. Beginning in the early 1960s, Mandelbrot showed that many phenomena are intrinsically indeterministic: they exhibit behavior that is unpredictable and apparently random. Scientists can only guess at the causes of individual events and cannot predict them with any accuracy.

Investigators of chaos and complexity were attempting to create effective, comprehensible theories of the same phenomena studied by Mandelbrot, Stent said. He had concluded in *Golden Age* that these indeterministic phenomena would resist scientific analysis, and he saw no reason to change that assessment. Quite the contrary. The work emerging from those fields demonstrated his point that science, when pushed too far, always culminates in incoherence. So Stent did not think that chaos and complexity would bring about the rebirth of science? “No,” he replied with a rakish grin. “It’s the end of science.”
What Science Has Accomplished

We obviously are nowhere near the new Polynesia that Stent envisioned, in part because applied science has not come nearly as far as Stent had hoped (feared?) when he wrote The Coming of the Golden Age. But I have come to the conclusion that Stent’s prophecy has, in one very important sense, already come to pass. Pure science, the quest for knowledge about what we are and where we came from, has already entered an era of diminishing returns. By far the greatest barrier to future progress in pure science is its past success. Researchers have already mapped out physical reality, ranging from the microrealm of quarks and electrons to the macrorealm of planets, stars, and galaxies. Physicists have shown that all matter is ruled by a few basic forces: gravity, electromagnetism, and the strong and weak nuclear forces.

Scientists have also stitched their knowledge into an impressive, if not terribly detailed, narrative of how we came to be. The universe exploded into existence 15 billion years ago, give or take 5 billion years (astronomers may never agree on an exact figure), and is still expanding outward. Some 4.5 billion years ago, the detritus of an exploding star, a supernova, condensed into our solar system. Sometime during the next few hundred million years, for reasons that may never be known, single-celled organisms bearing an ingenious molecule called DNA emerged on the still-hellish earth. These Adamic microbes gave rise, by means of natural selection, to an extraordinary array of more complex creatures, including Homo sapiens.

My guess is that this narrative that scientists have woven from their knowledge, this modern myth of creation, will be as viable 100 or even 1,000 years from now as it is today. Why? Because it is true. Moreover, given how far science has already come, and given the physical, social, and cognitive limits constraining further research, science is unlikely to make any significant additions to the knowledge it has already generated. There will be no great revelations in the future comparable to those bestowed upon us by Darwin or Einstein or Watson and Crick.

The Anticlimax of Immortality

Applied science will continue for a long time to come. Scientists will keep developing versatile new materials; faster and more sophisticated com-
anything more than a trivial level seem increasingly unlikely. We no longer have the will or the money to indulge in technological muscle flexing for its own sake. Humans, made of flesh and blood, may someday travel to other planets here in our solar system. But unless we find some way to transcend Einstein's prohibition against faster-than-light travel, chances are that we will never even attempt to visit another star, let alone another galaxy. A spaceship that can travel one million miles an hour, a velocity at least one order of magnitude greater than any current technology can attain, would still take almost 3,000 years to reach our nearest stellar neighbor, Alpha Centauri.11

The most dramatic advance in applied science I can imagine is immortality. Many scientists are now attempting to identify the precise causes of aging. It is conceivable that if they succeed, scientists may be able to design versions of Homo sapiens that can live indefinitely. But immortality, although it would represent a triumph of applied science, would not necessarily change our fundamental knowledge of the universe. We would not have any better idea of why the universe came to be and of what lies beyond its borders than we do now. Moreover, evolutionary biologists suggest that immortality may be impossible to achieve. Natural selection designed us to live long enough to breed and raise our children. As a result, senescence does not stem from any single cause or even a suite of causes; it is woven inextricably into the fabric of our being.12

That's What They Thought 100 Years Ago

It is easy to understand why so many people find it hard to believe that science, pure or impure, might be ending. Just a century ago, no one could imagine what the future held in store. Television? Jets? Space stations? Nuclear weapons? Computers? Genetic engineering? It must be as impossible for us to know the future of science—pure or applied—as it would have been for Thomas Aquinas to anticipate Madonna or microwave ovens. There are marvels, utterly unpredictable, lying in wait for us just as there were for our ancestors. We will only fail to seize these treasures if we decide that they do not exist and cease striving to find them. The prophecy can only be self-fulfilling.

This position is often expressed as the that's-what-they-thought-at-the-end-of-the-last-century argument. The argument goes like this: As the nineteenth century wound down, physicists thought they knew everything. But no sooner had the twentieth century begun, than Einstein and other physicists discovered—invented?—relativity theory and quantum mechanics. These theories eclipsed Newtonian physics and opened up vast new vistas for modern physics and other branches of science. Moral: Anyone who predicts that science is nearing its end will surely turn out to be as shortsighted as those nineteenth-century physicists.

Those who believe science is finite have a standard retort for this argument: the earliest explorers, because they could not find the edge of the earth, might well have concluded that it was infinite, but they would have been wrong. Moreover, it is by no means a matter of historical record that late-nineteenth-century physicists felt they had wrapped things up. The best evidence for a sense of completion is a speech given in 1894 by Albert Michelson, whose experiments on the velocity of light helped to inspire Einstein's theory of special relativity.

While it is never safe to say that the future of Physical Science has no marvels even more astonishing than those of the past, it seems probable that most of the grand underlying principles have been firmly established and that further advances are to be sought chiefly in the rigorous application of these principles to all the phenomena which come under our notice. It is here that the science of measurement shows its importance—where quantitative results are more to be desired than qualitative work. An eminent physicist has remarked that the future truths of Physical Science are to be looked for in the sixth place of decimals.13

Michelson's remark about the sixth place of decimals has been so widely attributed to Lord Kelvin (after whom the Kelvin, a unit of temperature, is named) that some authors simply credit him with the quote.14 But historians have found no evidence that Kelvin made such a statement. Moreover, at the time of Michelson's remarks, physicists were vigorously debating fundamental issues, such as the viability of the atomic theory of matter, according to the historian of science Stephen Brush of the University of Maryland. Michelson was so absorbed in his optics experiments, Brush suggested, that he was "oblivious to the violent controversies raging
among theorists at the time.” The alleged “Victorian calm in physics,” Brush concluded, is a “myth.”

**The Apocryphal Patent Official**

Other historians, predictably, disagree with Brush’s assessment. Questions concerning the mood of a given era can never be completely resolved, but the view that scientists in the last century were complacent about the state of their field has clearly been exaggerated. Historians have provided a definitive ruling on another anecdote favored by those reluctant to accept that science might be mortal. The story alleges that in the mid-1800s the head of the U.S. Patent Office quit his job and recommended that the office be shut down because there would soon be nothing left to invent.

In 1995, Daniel Koshland, editor of the prestigious journal Science, repeated this story in an introduction to a special section on the future of science. In the section, leading scientists offered predictions about what their fields might accomplish over the next 20 years. Koshland, who, like Gunther Stent, is a biologist at the University of California at Berkeley, exulted that his prognosticators “clearly do not agree with that commissioner of patents of yesteryear. Great discoveries with great import for the future of science are in the offing. That we have come so far so fast is not an indication that we have saturated the discovery market, but rather that discoveries will come even faster.”

There were two problems with Koshland’s essay. First, the contributors to his special section envisioned not “great discoveries” but, for the most part, rather mundane applications of current knowledge, such as better methods for designing drugs, improved tests for genetic disorders, more discerning brain scans, and the like. Some predictions were negative in nature. “Anyone who expects any human-like intelligence from a computer in the next 50 years is doomed to disappointment,” proclaimed the physicist and Nobel laureate Philip Anderson.

Second, Koshland’s story about the commissioner of patents was apocryphal. In 1940, a scholar named Eber Jeffery examined the patent commissioner anecdote in an article entitled “Nothing Left to Invent,” published in the *Journal of the Patent Office Society,* Jeffery traced the story to congressional testimony delivered in 1843 by Henry Ellsworth, then the commissioner of patents. Ellsworth remarked at one point, “The advance-

ment of the arts, from year to year, taxes our credulity and seems to presage the arrival of that period when human improvement must end.”

But Ellsworth, far from recommending that his office be shut down, asked for extra funds to cope with the flood of inventions he expected in agriculture, transportation, and communications. Ellsworth did indeed resign two years later, in 1845, but in his resignation letter he made no reference to closing the patent office; rather, he expressed pride at having expanded it. Jeffery concluded that Ellsworth’s statement about “that period when human improvement must end” represented “a mere rhetorical flourish intended to emphasize the remarkable strides forward in inventions then current and to be expected in the future.” But perhaps Jeffery was not giving Ellsworth enough credit. Ellsworth was, after all, anticipating the argument that Gunther Stent would make more than a century later: the faster science moves, the faster it will reach its ultimate, inevitable limits.

Consider the implications of the alternative position, the one implicitly advanced by Daniel Koshland. He insisted that because science has advanced so rapidly over the past century or so, it can and will continue to do so, possibly forever. But this inductive argument is deeply flawed. Science has only existed for a few hundred years, and its most spectacular achievements have occurred within the last century. Viewed from a historical perspective, the modern era of rapid scientific and technological progress appears to be not a permanent feature of reality, but an aberration, a fluke, a product of a singular convergence of social, intellectual, and political factors.

**The Rise and Fall of Progress**

In his 1932 book, *The Idea of Progress*, the historian J. B. Bury stated: “Science has been advancing without interruption during the last three or four hundred years; every new discovery has led to new problems and new methods of solution, and opened up new fields for exploration. Hitherto men of science have not been compelled to halt, they have always found means to advance further. But what assurance have we that they will not come up against impassable barriers?” [Italics in the original.]

Bury had demonstrated through his own scholarship that the concept of progress was only a few hundred years old at most. From the era of the
Roman Empire through the Middle Ages, most truth seekers had a degenerative view of history; the ancient Greeks had achieved the acme of mathematical and scientific knowledge, and civilization had gone downhill from there. Those who followed could only try to recapture some remnant of the wisdom epitomized by Plato and Aristotle. It was such founders of modern, empirical science as Isaac Newton, Francis Bacon, René Descartes, and Gottfried Leibniz who first set forth the idea that humans could systematically acquire and accumulate knowledge through investigations of nature. These ur-scientists believed that the process would be finite, that we could attain complete knowledge of the world and then construct a perfect society, a utopia, based on that knowledge and on Christian precepts. (The new Polynesia!)

Only with the advent of Darwin did certain intellectuals become so enamored with progress that they insisted it might be, or should be, eternal. "In the wake of the publication of Darwin's *On the Origin of Species,*" Gunther Stent wrote in his 1978 book, *The Paradoxes of Progress,* "the idea of progress was raised to the level of a scientific religion. . . . This optimistic view came to be so widely embraced in the industrialized nations... that the claim that progress could presently come to an end is now widely regarded [to be] as outlandish a notion as was in earlier times the claim that the Earth moves around the sun."²⁰

It is not surprising that modern nation-states became fervent proponents of the science-is-infinite creed. Science spawned such marvels as The Bomb, nuclear power, jets, radar, computers, and missiles. In 1945 the physicist Vannevar Bush (a distant relative of former president George Bush) proclaimed in *Science: The Endless Frontier* that science was "a largely unexplored hinterland" and an "essential key" to U.S. military and economic security.²¹ Bush's essay served as a blueprint for the construction of the National Science Foundation and other federal organizations that thereafter supported basic research on an unparalleled scale.

The Soviet Union was perhaps even more devoted than its capitalist rival to the concept of scientific and technological progress. The Soviets seemed to have taken their lead from Friedrich Engels, who in *Dialectics of Nature* sought to show off his grasp of Newton's inverse square law of gravity in the following passage.

What Luther's burning of the papal Bull was in the religious field, in the field of natural science was the great work of Copernicus. . . . But from then on the development of science went forward in great strides, increasing, so to speak, proportionately to the square of the distance in time of its point of departure, as if it wanted to show the world that for the motion of the highest product of organic matter, the human mind, the law of inverse squares holds good, as it does for the motion of inorganic matter.²²

Science, in the view of Engels, could and would continue striding forward, at an accelerating pace, forever.

Of course, powerful social, political, and economic forces now oppose this vision of boundless scientific and technological progress. The cold war, which was a major impetus for basic research in the United States and the Soviet Union, is over; the United States and the former Soviet republics have much less incentive to build space stations and gigantic accelerators simply to demonstrate their power. Society is also increasingly sensitive to the adverse consequences of science and technology, such as pollution, nuclear contamination, and weapons of mass destruction.

Even political leaders, who have traditionally been the staunchest defenders of the value of scientific progress, have begun voicing antiscience sentiments. The Czech poet and president Václav Havel declared in 1992 that the Soviet Union epitomized and therefore eternally discredited the "cult of objectivity" brought about by science. Havel expressed the hope that the dissolution of the communist state would bring about "the end of the modern era," which had been "dominated by the culminating belief, expressed in different forms, that the world—and Being as such—is a wholly knowable system governed by a finite number of universal laws that man can grasp and rationally direct for his own benefit."²³

This disillusionment with science was foreseen early in this century by Oswald Spengler, a German schoolteacher who became the first great prophet of the end of science. In his massive tome, *The Decline of the West,* published in 1918, Spengler argued that science proceeds in a cyclic fashion, with romantic periods of investigation of nature and the invention of new theories giving way to periods of consolidation during which scientific knowledge ossifies. As scientists become more arrogant and less tolerant of
other belief systems, notably religious ones, Spengler declared, society will rebel against science and embrace religious fundamentalism and other irrational systems of belief. Spengler predicted that the decline of science and the resurgence of irrationality would begin at the end of this millennium.  

Spengler's analysis was, if anything, too optimistic. His view of science as cyclic implied that science might one day be resurrected and undergo a new period of discovery. Science is not cyclic, however, but linear; we can only discover the periodic table and the expansion of the universe and the structure of DNA once. The biggest obstacle to the resurrection of science—and especially pure science, the quest for knowledge about who we are and where we came from—is science's past success.

No More Endless Horizons

Scientists are understandably loath to state publicly that they have entered an era of diminishing returns. No one wants to be recalled as the equivalent of those allegedly shortsighted physicists of a century ago. There is always the danger, too, that predictions of the demise of science will become self-fulfilling. But Gunther Stent is hardly the only prominent scientist to violate the taboo against such prophecies. In 1971, Science published an essay titled "Science: Endless Horizons or Golden Age?" by Bentley Glass, an eminent biologist and the president of the American Association for the Advancement of Science, which publishes Science. Glass weighed the two scenarios for science's future posited by Vannevar Bush and Gunther Stent and reluctantly came down on the side of Stent. Not only is science finite, Glass argued, but the end is in sight. "We are like the explorers of a great continent," Glass proclaimed, "who have penetrated to its margins in most points of the compass and have mapped the major mountain chains and rivers. There are still innumerable details to fill in, but the endless horizons no longer exist."  

According to Glass, a close reading of Bush's Endless Frontier essay suggests that he, too, viewed science as a finite enterprise. Nowhere did Bush specifically state that any fields of science could continue generating new discoveries forever. In fact, Bush described scientific knowledge as an "edifice" whose form "is predestined by the laws of logic and the nature of human reasoning. It is almost as though it already existed." Bush's choice of this metaphor, Glass commented, reveals that he considered scientific knowledge to be finite in extent. Glass proposed that the "bold title" of Bush's essay was "never intended to be taken literally, but supposed merely to imply that from our present viewpoint so much yet remains before us to be discovered that the horizons seem virtually endless."

In 1979, in the Quarterly Review of Biology, Glass presented evidence to back up his view that science was approaching a culmination. His analysis of the rate of discoveries in biology showed that they had not kept pace with the exponential increase in researchers and funding. "We have been so impressed by the undeniable acceleration in the rate of magnificent achievements that we have scarcely noticed that we are well into an era of diminishing returns," Glass stated. "That is, more and more scientific effort and expenditure of money must be allocated in order to sustain our progress. Sooner or later this will have to stop, because of the insuperable limits to scientific manpower and expenditure. So rapid has been the growth of science in our own century that we have been deluded into thinking that such a rate of progress can be maintained indefinitely."

When I spoke to him in 1994, Glass confessed that many of his colleagues had been dismayed that he had even broached the subject of science's limits, let alone prophesied its demise. But Glass had felt then, and still felt, that the topic was too important to ignore. Obviously science as a social enterprise has some limits, Glass said. If science had continued to grow at the same rate as it did earlier in this century, he pointed out, it would soon have consumed the entire budget of the industrialized world. "I think it's rather evident to everybody that there must be brakes put on the amount of funding for science, pure science." This slowdown, he observed, was evident in the decision of the U.S. Congress in 1993 to terminate the superconducting supercollider, the gargantuan particle accelerator that physicists had hoped would propel them beyond quarks and electrons into a deeper realm of microworld, all for a mere $8 billion.

Even if society were to devote all its resources to research, Glass added, science would one day still reach the point of diminishing returns. Why? Because science works; it solves its problems. After all, astronomers have already plumbed the farthest reaches of the universe; they cannot see what, if anything, lies beyond its borders. Moreover, most physicists think that the reduction of matter into smaller and smaller particles will eventually end, or may have already ended for all practical purposes. Even if physicists...
unearth particles buried beneath quarks and electrons, that knowledge will
make little or no difference to biologists, who have learned that the most
significant biological processes occur at the molecular level and above.
"There's a limit to biology there," Glass explained, "that you don't expect to
be able to ever break through, just because of the nature of the constitution
of matter and energy."

In biology, Glass said, the great revolutions may be in the past. "It's hard
to believe, for me, anyway, that anything as comprehensive and earthshak-
ing as Darwin's view of the evolution of life or Mendel's understanding of
the nature of heredity will be easy to come by again. After all, these have
been discovered!" Biologists certainly have much to learn, Glass empha-
sized, about diseases such as cancer and AIDS; about the process whereby
a single fertilized cell becomes a complex, multicellular organism; about the
relation between brain and mind. "There are going to be new additions to
the structure of knowledge. But we have made some of the biggest possible
advances. And it's just a question of whether there are any more really big
to changes in our conceptual universe that are going to be made."

Hard Times Ahead for Physics

In 1992, the monthly journal Physics Today published an essay entitled
"Hard Times," in which Leo Kadanoff, a prominent physicist at the Univer-
sity of Chicago, painted a bleak picture for the future of physics. "Nothing
we do is likely to arrest our decline in numbers, support or social value," Kadanoff declared. "Too much of our base depended on events that are now
becoming ancient history: nuclear weapons and radar during World
War II, silicon and laser technology thereafter, American optimism and
industrial hegemony, socialist belief in rationality as a way of improving
the world." Those conditions have largely vanished, Kadanoff contended;
both physics and science as a whole are now besieged by environmentalists,
animal-rights activists, and others with an antiscientific outlook. "In recent
decades, science has had high rewards and has been at the center of social
interest and concern. We should not be surprised if this anomaly disap-
ppears."

Kadanoff, when I spoke to him over the telephone two years later,
sounded even gloomier than he had been in his essay. He laid out his
worldview for me with a muffled melancholy, as if he were suffering from
an existential head cold. Rather than discussing science's social and politi-
cal problems, as he had in his article in Physics Today, he focused on
another obstacle to scientific progress: science's past achievements. The
great task of modern science, Kadanoff explained, has been to show that
the world conforms to certain basic physical laws. "That is an issue which
has been explored at least since the Renaissance and maybe a much longer
period of time. For me, that's a settled issue. That is, it seems to me that the
world is explainable by law." The most fundamental laws of nature are
embodied in the theory of general relativity and in the so-called standard
model of particle physics, which describes the behavior of the quantum
realm with exquisite precision.

Just a half century ago, Kadanoff recalled, many reputable scientists still
clung to the romantic doctrine of vitalism, which holds that life springs
from some mysterious élan vital that cannot be explained in terms of
physical laws. As a result of the findings of molecular biology—beginning
with the discovery of the structure of DNA in 1953—"there are relatively
few well-educated people" who admit to belief in vitalism, Kadanoff said.

Of course, scientists still have much to learn about how the fundamental
laws generate "the richness of the world as we see it." Kadanoff himself is a
leader in the field of condensed-matter physics, which studies the behavior
not of individual subatomic particles, but of solids or liquids. Kadanoff has
also been associated with the field of chaos, which addresses phenomena
that unfold in predictably unpredictable ways. Some proponents of
chaos—and of a closely related field called complexity—have suggested
that with the help of powerful computers and new mathematical methods
they will discover truths that surpass those revealed by the "reductionist"
science of the past. Kadanoff has his doubts. Studying the consequences of
fundamental laws is "in a way less interesting" and "less deep," he said, than
showing that the world is lawful. "But now that we know the world is
lawful," he added, "we have to go on to other things. And yes, it probably
excites the imagination of the average human being less. Maybe with good
reason."

Kadanoff pointed out that particle physics has not been terribly exciting
lately either. Experiments over the past few decades have merely confirmed
existing theories rather than revealing new phenomena requiring new laws;
the goal of finding a unified theory of all of nature's forces seems impossi-
bly distant. In fact, no field of science has yielded any truly deep discoveries
for a long time, Kadanoff said. "The truth is, there is nothing—there is nothing—of the same order of magnitude as the accomplishments of the invention of quantum mechanics or of the double helix or of relativity. Just nothing like that has happened in the last few decades." Is this state of affairs permanent? I asked. Kadanoff was silent for a moment. Then he sighed, as if trying to exhale all his world-weariness. "Once you have proven that the world is lawful," he replied, "to the satisfaction of many human beings, you can't do that again."

Whistling to Keep Our Courage Up

One of the few modern philosophers to devote serious thought to the limits of science is Nicholas Rescher of the University of Pittsburgh. In his 1978 book, *Scientific Progress*, Rescher 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. He argued that science, as a fundamentally empirical, experimental discipline, faces economic constraints. As scientists try to extend their theories into more remote domains—seeing further into the universe, deeper into matter—their costs will inevitably escalate and their returns diminish.

"Scientific innovation is going to become more and more difficult as we push out further and further from our home base toward more remote frontiers. If the present perspective is even partly correct, the half-millennium commencing around 1650 will eventually come to be regarded among the great characteristic developmental transformations of human history, with the age of The Science Explosion as unique in its own historical structure as The Bronze Age or The Industrial Revolution or The Population Explosion."

Rescher tackled what he apparently thought was a happy coda onto his depressing scenario: science will never end; it will just go slower and slower and slower, like Zeno's tortoise. Nor should scientists ever conclude that their research must degenerate into the mere filling in of details; it is always possible that one of their increasingly expensive experiments will have revolutionary import, comparable to that of quantum mechanics or Darwinian theory.

Bentley Glass, in a review of Rescher's book, called these prescriptions "whistling to keep one's courage up in the face of what, for most practitioners of science, is a bleak and imminent prospect." When I telephoned Rescher in August 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 temperatures, or higher 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."

But Rescher insisted that "big plums, first-rate discoveries," might—must!—lie ahead. He could not say whence those discoveries might arise. "It's like the jazz musician who was asked where jazz is going, and he said, 'If I knew we'd be there by now.' " Rescher, finally, fell back on the that's-what-they-thought-at-the-end-of-the-last-century argument. The fact that such scientists as Stent, Glass, and Kadanoff seemed to fear that science was drawing to a close, Rescher said, gave him confidence that some marvelous discovery was pending. 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?

The Meaning of Francis Bacon's Plus Ultra

The second most common response to the suggestion that science is ending—after "that's what they thought at the end of the last century"—is the old maxim "Answers raise new questions." Kant wrote in *Prolegomena to Any Future Metaphysics* that "every answer given on principles of experience begets a fresh question, which likewise requires its answer and thereby clearly shows the insufficiency of all physical modes of explanation to satisfy reason." But Kant also suggested (anticipating the arguments of Gunther Stent), that the innate structure of our minds constrains both the questions we put to nature and the answers we glean from it.

Of course, science will continue to raise new questions. Most are trivial,
incapable of remaining content with half-knowledge.”35 The most important function of ironic science is to serve as humanity’s negative capability. Ironic science, by raising unanswerable questions, reminds us that all our knowledge is half-knowledge; it reminds us of how little we know. But ironic science does not make any significant contributions to knowledge itself. Ironic science is thus less akin to science in the traditional sense than to literary criticism—or to philosophy.

No matter how far empirical science goes, our imaginations can always go farther. That is the greatest obstacle to the hopes—and fears—of scientists that we will find The Answer, a theory that quenches our curiosity forever. Francis Bacon, one of the founders of modern science, expressed his belief in the vast potential of science with the Latin term plus ultra, “more beyond.” But plus ultra does not apply to science per se, which is a tightly constrained method for examining nature. Plus ultra applies, rather, to our imaginations. Although our imaginations are constrained by our evolutionary history, they will always be capable of venturing beyond what we truly know.

Even in the new Polynesia, Gunther Stent suggested, a few persistent souls will keep striving to transcend the received wisdom. Stent called these truth seekers “Faustian” (a term he borrowed from Oswald Spengler). I call them strong scientists (a term I coopted from Harold Bloom’s The Anxiety of Influence). By raising questions that science cannot answer, strong scientists can continue the quest for knowledge in the speculative mode that I call ironic science even after empirical science—the kind of science that answers questions—has ended.

The poet John Keats coined the term negative capability to describe the ability of certain great poets to remain “in uncertainties, mysteries, doubts, without any irritable reaching after fact and reason.” As an example, Keats singled out his fellow poet Samuel Coleridge, who “would let go by a fine isolated verisimilitude caught from the penetratium of mystery, from being
The End of Philosophy

Twentieth-century science has given rise to a marvelous paradox. The same extraordinary progress that has led to predictions that we may soon know everything that can be known has also nurtured doubts that we can know anything for certain. When one theory so rapidly succeeds another, how can we ever be sure that any theory is true? In 1987 two British physicists, T. Theocaris and M. Psimopoulos, excoriated this skeptical philosophical position in an essay entitled “Where Science Has Gone Wrong.” Published in the British journal Nature, the essay blamed the “deep and widespread malaise” in science on philosophers who had attacked the notion that science could achieve objective knowledge. The article printed photographs of four particularly egregious “betrayals of the truth”: Karl Popper, Imre Lakatos, Thomas Kuhn, and Paul Feyerabend.¹

The photographs were grainy, black-and-white shots of the sort that adorn a lurid exposé about a venerable banker who has been caught swindling retirees. These, clearly, were intellectual transgressors of the worst sort. Feyerabend, whom the essayists called “the worst enemy of science,” was the most wicked-looking of the bunch. Smirking at the camera over glasses perched on the tip of his nose, he was clearly either anticipating or relishing the perpetration of some diabolical prank. He looked like an intellectual version of Loki, the Norse god of mischief.

The main complaint of Theocaris and Psimopoulos was silly. The skepticism of a few academic philosophers has never represented a serious threat to the massive, well-funded bureaucracy of science. Many scientists, particularly would-be revolutionaries, find the ideas of Popper et al. comforting; if our current knowledge is provisional, there is always the possibility that great revelations lie ahead. Theocaris and Psimopoulos did make one intriguing assertion, however, that the ideas of the skeptics are “flagrantly self-refuting—they negate and destroy themselves.” It would be interesting, I thought, to put this argument to the philosophers and see how they responded.

Eventually I had the opportunity to do just that with all the “betrayers of the truth” except for Lakatos, who died in 1974. During my interviews, I also tried to find out whether these philosophers were really as skeptical, as doubtful of science’s ability to achieve truth, as some of their own statements implied. I came away convinced that Popper, Kuhn, and Feyerabend each believed very much in science; in fact, their skepticism was motivated by their belief. Their biggest failing, perhaps, was to credit science with more power than it actually has. They feared that science might extinguish our sense of wonder and therefore bring science itself—and all forms of knowledge seeking—to an end. They were trying to protect humanity, scientists included, from the naive faith in science exemplified by such scientists as Theocaris and Psimopoulos.

As science has grown in power and prestige over the past century, too many philosophers have served as science’s public relations agents. This trend can be traced to such thinkers as Charles Sanders Peirce, an American who founded the philosophy of pragmatism but could not keep a job or a wife and died penniless and miserable in 1914. Peirce offered a definition of absolute truth: it is whatever scientists say it is when they come to the end of their labors.²

Much of philosophy since Peirce has merely elaborated on his view. The dominant philosophy in Europe early in this century was logical positivism, which asserted that we can only know that something is true if it can be logically or empirically demonstrated. The positivists upheld mathematics and science as the supreme sources of truth. Popper, Kuhn, and Feyerabend—each in his own way and for his own reasons—sought to counter this fawning attitude toward science. These philosophers realized that in an age when science is ascendant, the highest calling of philosophy should be to serve as the negative capability of science, to infuse scientists with doubt. Only thus can the human quest for knowledge remain open-ended, potentially infinite; only thus can we remain awestruck before the mystery of the cosmos.

Of the three great skeptics I interviewed, Popper was the first to make his
mark. His philosophy stemmed from his effort to distinguish pseudoscience, such as Marxism or astrology, or Freudian psychology, from genuine science, such as Einstein’s theory of relativity. The latter, Popper decided, was testable; it made predictions about the world that could be empirically checked. The logical positivists had said as much. But Popper denied the positivist assertion that scientists can prove a theory through induction, or repeated empirical tests or observations. One never knows if one’s observations have been sufficient; the next observation might contradict all that preceded it. Observations can never prove a theory but can only disprove, or falsify it. Popper often bragged that he had “killed” logical positivism with this argument.

Popper expanded his falsification tenet into a philosophy that he called critical rationalism. One scientist ventures a proposal and others try to bat it down with contrary arguments or experimental evidence. Popper viewed criticism, and even conflict, as essential for progress of all kinds. Just as scientists approach the truth through what he calls “conjecture and refutation,” so do species evolve through competition and societies through political debate. A “human society without conflict,” he once wrote, “would be a society not of friends but of ants.” In *The Open Society and Its Enemies*, published in 1945, Popper asserted that politics, even more than science, required the free play of ideas and criticism. Dogmatism inevitably led not to utopia, as Marxists and fascists alike claimed, but to totalitarian repression.

I began to discern the paradox lurking at the heart of Popper’s work—and persona—when, prior to meeting him, I asked other philosophers about him. Queries of this kind usually elicit rather dull, generic praise, but in this case my interlocutors had nothing good to say. They revealed that this man who inveighed against dogmatism was himself almost pathologically dogmatic and demanding of fealty from students. There was an old joke about Popper: *The Open Society and Its Enemies* should have been titled *The Open Society by One of Its Enemies*.

To arrange my interview with Popper, I telephoned the London School of Economics, where he had taught since the late 1940s. A secretary there said that Popper generally worked at his home in Kensington, an affluent district of London, and gave me his number. I called, and a woman with an imperious, German-accented voice answered. Mrs. Mew, housekeeper and assistant to “Sir Karl.” Before Sir Karl would see me, I had to send her a sample of my writings. She gave me a reading list that would prepare me for my meeting: a dozen or so books by Sir Karl. Eventually, after numerous faxes and telephone calls, she set a date. She also provided directions to the train station near Sir Karl’s house. When I asked her for directions from the train station to the house, Mrs. Mew assured me that all the cab drivers knew where Sir Karl lived. “He’s quite famous.”

“Sir Karl Popper’s house, please,” I said as I climbed into a cab at Kensington station. “Who?” the driver replied. Sir Karl Popper? The famous philosopher? Never heard of him, the driver said. He was familiar with the street on which Popper lived, however, and we found Popper’s home—a two-story cottage surrounded by scrupulously trimmed grass and shrubs—with little difficulty.

A tall, handsome woman in black pants and shirt, with short, dark hair brushed straight back, answered the door: Mrs. Mew. She was only slightly less forbidding in person than over the telephone. As she led me into the house, she told me that Sir Karl was quite tired. He had undergone a spate of interviews and congratulations brought on by his 90th birthday the previous month, and he had been working too hard preparing an acceptance speech for the Kyoto Award, known as Japan’s Nobel. I should expect to speak to him for only an hour at the most.

I was trying to lower my expectations when Popper made his entrance. He was stooped, equipped with a hearing aid, and surprisingly short; I had assumed that the author of such autocratic prose would be tall. Yet he was as kinetic as a bantamweight boxer. He brandished an article I had written for *Scientific American* about how quantum mechanics was compelling some physicists to abandon the view of physics as a wholly objective enterprise. “I don’t believe a word of it,” he declared in an Austrian-accented growl. “Subjectivism” has no place in physics, quantum or otherwise. “Physics,” he exclaimed, grabbing a book from a table and slamming it down, “is that!” (This from a man who cowrote a book espousing dualism, the notion that ideas and other constructs of the human mind exist independently of the material world.)

Once seated, he kept darting away to forage for books or articles that could buttress a point. Striving to dredge a name or date from his memory, he kneaded his temples and gritted his teeth as if in agony. At one point, when the word mutation briefly eluded him, he slapped his forehead repeatedly and with alarming force, shouting, “Terms, terms, terms!”
Words poured from him so rapidly and with so much momentum that I began to lose hope that I could ask any of my prepared questions. "I am over 90 and I can still think," he declared, as if suspecting that I doubted it. He tirelessly touted a theory of the origin of life proposed by a former student, Günther Wächtershäuser, a German patent attorney who had a Ph.D. in chemistry. Popper kept emphasizing that he had known all the titans of twentieth-century science: Einstein, Schrödinger, Heisenberg. Popper blamed Bohr, whom he knew "very well," for having introduced subjectivism into physics. Bohr was "a marvelous physicist, one of the greatest of all time, but he was a miserable philosopher, and one couldn't talk to him. He was talking all the time, allowing practically only one or two words to you and then at once cutting in."

As Mrs. Mew turned to leave, Popper abruptly asked her to find one of his books. She disappeared for a few minutes and then returned empty-handed. "Excuse me, Karl, I couldn't find it," she reported. "Unless I have a description, I can't check every bookcase."

"It was actually, I think, on the right of this corner, but I have taken it away maybe..." His voice trailed off. Mrs. Mew somehow rolled her eyes without really rolling them and vanished.

He paused a moment, and I desperately seized the opportunity to ask a question. "I wanted to ask you about..."

"Yes! You should ask me your questions! I have wrongly taken the lead. You can ask me all your questions first."

As I began to question Popper about his views, it became apparent that his skeptical philosophy stemmed from a deeply romantic, idealized view of science. He thus denied the assertion, often made by the logical positivists, that science can ever be reduced to a formal, logical system, in which raw data are methodically converted into truth. A scientific theory, Popper insisted, is an invention, an act of creation as profoundly mysterious as anything in the arts. "The history of science is everywhere speculative," Popper said. "It is a marvelous history. It makes you proud to be a human being." Framing his face in his outstretched hands, Popper intoned, "I believe in the human mind."

For similar reasons, Popper had battled throughout his career against the doctrine of scientific determinism, which he felt was antithetical to human creativity and freedom and thus to science itself. Popper claimed to have realized long before modern chaos theorists that not only quantum systems but even classical, Newtonian ones are inherently unpredictable; he had delivered a lecture on this subject in the 1950s. Waving at the lawn outside the window he said, "There is chaos in every grass."

When I asked Popper if he thought that science was incapable of achieving absolute truth, he exclaimed, "No no!" and shook his head vehemently. He, like the logical positivists before him, believed that a scientific theory could be "absolutely" true. In fact, he had "no doubt" that some current scientific theories were absolutely true (although he refused to say which ones). But he rejected the positivist belief that we can ever know that a theory is true. "We must distinguish between truth, which is objective and absolute, and certainty, which is subjective."

If scientists believed too much in their own theories, Popper realized, they might stop seeking truth. And that would be a tragedy, since for Popper truth seeking was what made life worth living. "To search for the truth is a kind of religion," he said, "and I think it is also an ethical belief." Popper's conviction that the search for knowledge must never cease is reflected in the title of his autobiography, Unended Quest.

He thus scoffed at the hope of some scientists to achieve a complete theory of nature, one that answers all questions. "Many people think that the problems can be solved; many people think the opposite. I think we have gone very far, but we are much further away. I must show you one passage that bears on this." He shuffled off again and returned with his book Conjectures and Refutations. Opening it, he read his own words with reverence: "In our infinite ignorance we are all equal."

Popper also believed that science could never answer questions about the meaning and purpose of the universe. For these reasons he had never completely repudiated religion, although he had long ago abandoned the Lutheranism of his youth. "We know very little, and we should be modest and not pretend we know anything about ultimate questions of this kind."

Yet Popper abhorred those modern philosophers and sociologists who claim that science is incapable of achieving any truth and who argue that scientists adhere to theories for cultural and political reasons rather than rational ones. Such critics, Popper charged, resent being viewed as inferior to genuine scientists and are trying to "change their status in the pecking order." I suggested that these critics seemed to describe how science is practiced, whereas he, Popper, tried to show how it should be practiced. Somewhat to my surprise, Popper nodded. "That is a very good statement,"
he said. “You can’t see what science is without having in your head an idea of what science should be.” Popper had to agree that scientists often fell short of the ideal he had set for them. “Since scientists got subsidies for their work, science isn’t exactly what it should be. This is unavoidable. There is a certain corruption, unfortunately. But I don’t talk about that.”

Popper then proceeded to talk about it. “Scientists are not as self-critical as they should be,” he asserted. “There is a certain wish that you, people like you”—he jabbed a finger at me—“should bring them before the public.” He stared at me a moment, then reminded me that he had not sought this interview. “Far from it,” he said. “You know that I have really made not only no attempt but have not encouraged you.” Popper then plunged into an excruciatingly technical critique—involving triangulation and other arcana—of the big bang theory. “It’s always the same,” he summed up. “The difficulties are underrated. It is presented in a spirit as if this all has scientific certainty, but scientific certainty doesn’t exist.”

I asked Popper if he felt that biologists were also too committed to Darwin’s theory of natural selection; in the past he had suggested that the theory was tautological and thus pseudoscientific.10 “That was perhaps going too far,” Popper said, waving his hand dismissively. “I’m not dogmatic about my own views.” Suddenly, he pounded the table and exclaimed, “One ought to look for alternative theories! This”—he waved the paper by Günther Wächtershäuser on the origin of life—“is an alternative theory. It seems to be a better theory.” That doesn’t mean that the theory is true, Popper quickly added. “The origin of life will forever remain untestable, probably,” Popper said. Even if scientists create life in a laboratory, he explained, they can never be sure that life actually began in the same way.

It was time to launch my big question. Was his own falsification concept falsifiable? Popper glared at me. Then his expression softened, and he placed his hand on mine. “I don’t want to hurt you,” he said gently, “but it is a silly question.” Peeringsearchingly 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.

“The first thing you do in a philosophy seminar when somebody proposes an idea is to say it doesn’t satisfy its own criteria. It is one of the most idiotic criticisms one can imagine!” His falsification concept, he said, is a criterion for distinguishing between empirical modes of knowledge, namely, science, and nonempirical ones, such as philosophy. Falsification itself is “decidably 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 critics were right: falsification is a mere guideline, a rule of thumb, sometimes helpful and sometimes not.

Popper said he had never before responded to the question I had just posed. “I found it too stupid to be answered. You see the difference?” he asked, his voice gentle again. I nodded. The question seemed a bit silly to me, too, I said, but I just thought I should ask. He smiled and squeezed my hand, murmuring, “Yes, very good.”

Since Popper seemed so agreeable, I mentioned that one of his former students had accused him of not tolerating criticism of his own ideas. Popper’s eyes blazed. “It is completely untrue! I was happy when I got criticism! Of course, not when I would answer the criticism, like I have answered it when you gave it to me, and the person would still go on with it. That is the thing which I found uninteresting and would not tolerate.” If that happened, Popper would order the student out of his class.

The light in the kitchen was acquiring a ruddy hue when Mrs. Mew stuck her head in the door and informed us that we had been talking for more than three hours. How much longer, she inquired a bit peevishly, did we expect to continue? Perhaps she had better call me a cab? I looked at Popper, who had broken into a bad-boy grin but did appear to be drooping.

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.” Looking pleased with himself, Popper glanced over at Mrs. Mew, who wore an expression of horror. Popper’s own smile abruptly faded. “It would be better not to write that,” he said, turning back to me. “I have enough enemies, and I better not answer them in this way.” He stewed a moment and added, “But it is so.”

I asked Mrs. Mew if I could have a copy of the speech Popper was going to deliver at the Kyoto Award ceremony in Japan. “No, not now,” she said curtly. “Why not?” Popper inquired. “Karl,” she replied, “I’ve been typing the second lecture nonstop, and I’m a bit . . .” She sighed. “You know what I mean?” Anyway, she added, she did not have a final version. “What about an uncorrected version?” Popper asked. Mrs. Mew stalked off.

She returned and shoved a copy of Popper’s lecture at me. “Have you got
a copy of *Propensities*?” Popper asked her. She pursed her lips and stomped into the room next door, while Popper explained the book’s theme to me. The lesson of quantum mechanics and even of classical physics, Popper said, is that nothing is determined, nothing is certain, nothing is completely predictable; there are only propensities for certain things to occur. “For example,” Popper added, “in this moment there is a certain propensity that Mrs. Mew may find a copy of my book.”

“Oh, please!” Mrs. Mew exclaimed from the next room. She returned, no longer making any attempt to hide her annoyance. “Sir Karl, Karl, you have given away the last copy of *Propensities*. Why do you do that?”

“Last copy was given away in your presence,” he declared.

“I don’t think so,” she retorted. “Who was it?”

“I can’t remember,” he muttered sheepishly.

Outside, a black cab pulled into the driveway. I thanked Popper and Mrs. Mew for their hospitality and took my leave. As the cab pulled away, I asked the driver if he knew whose house this was. No, he didn’t. Someone famous, was it? Yes, actually: Sir Karl Popper. Who? Karl Popper, I replied, one of the greatest philosophers of the twentieth century. “Is that right?” murmured the driver.

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” [italics added]. But Popper’s fellow philosophers have been less kind. His oeuvre, they point out, is rife with contradictions. Popper argued that science could not be reduced to a method, but his falsification scheme was just such a method. Moreover, the arguments that he used to kill the possibility of absolute verification could also be used to kill falsification. If it is always possible that future observations will contradict a theory, then it is also possible that future observations may resurrect a theory that has previously been falsified. It is more reasonable to assume, critics of Popper have argued, that just as some scientific theories can be falsified, so some can be confirmed; there is no point in remaining uncertain, after all, that the earth is round and not flat.

When Popper died in 1994, two years after I met him, the *Economist* hailed him as having been “the best-known and most widely read of living philosophers.” It praised, in particular, his insistence on antidogmatism in the political realm. But the obituary also noted that Popper’s treatment of induction (the basis of his falsification scheme) had been rejected by later philosophers. “According to his own theories, Popper should have welcomed this fact,” the *Economist* noted drily, “but he could not bring himself to do so. The irony is that, here, Popper could not admit he was wrong.” Popper’s antidogmatism, when applied to science, had become a kind of dogmatism.

Although Popper abhorred psychoanalysis, his own work, finally, may be best understood in psychoanalytic terms. His relationship with authority figures—from scientific giants, such as Bohr, to his assistant, Mrs. Mew—was obviously complex, alternating between defiance and deference. In what is perhaps the single most revealing passage in his autobiography, Popper mentioned that his parents were both Austrian Jews who had converted to Lutheranism. He then argued that the failure of other Jews to assimilate themselves into Germanic culture—and their prominent roles in leftist politics—contributed to the emergence of fascism and state-sponsored anti-Semitism in the 1930s: “... anti-Semitism was an evil, to be feared by Jews and non-Jews alike, and it was the task of all people of Jewish origin to do their best not to provoke it.” Popper was coming close to blaming the Jews for the Holocaust.

**The Structure of Thomas Kuhn**

“Look,” Thomas Kuhn said. The word was weighted with weariness, as if Kuhn was resigned to the fact that I would misinterpret him, but he was still going to try—no doubt in vain—to make his point. Kuhn uttered the word often. “Look,” he said again. He leaned his gangly frame and long face forward, and his big lower lip, which ordinarily curled up amiably at the corners, sagged. “For Christ’s sake, if I had my choice of having written the book or not having written it, I would choose to have written it. But there have certainly been aspects involving considerable upset about the response to it.”

“The book” was *The Structure of Scientific Revolutions*, which may be the most influential treatise ever written on how science does (or does not) proceed. It is notable for having spawned the trendy term *paradigm*. It also fomented the now trite idea that personalities and politics play a large role in science. The book’s most profound argument was less obvious: scientists can never truly understand the real world or even each other.
Given this theme, one might think that Kuhn would have expected his own message to be at least partially misunderstood. But when I interviewed Kuhn in his office at the Massachusetts Institute of Technology (of all places) some three decades after the publication of Structure, he seemed to be deeply pained by the breadth of misunderstanding of his book. He was particularly upset by claims that he had described science as irrational. “If they had said ‘irrational’ I wouldn’t have minded at all,” he said with no trace of a smile.

Kuhn’s fear of compounding the confusion over his work had made him a bit press shy. When I first telephoned him to ask for an interview, he turned me down. “Look. I think not,” he said. He revealed that Scientific American, my employer, had given Structure “the worst review I can remember.” (The squib was indeed dismissive; it called Kuhn’s argument “much ado about very little.” But what did Kuhn expect from a magazine that celebrates science?)

Pointing out that I had not been at the magazine then—the review ran in 1964—I begged him to reconsider. Kuhn finally, reluctantly, agreed.

When we at last sat down together in his office, Kuhn expressed nominal discomfort at the notion of delving into the roots of his thought. “One is not one’s own historian, let alone one’s own psychoanalyst,” he warned me. He nonetheless traced his view of science to an epiphany he experienced in 1947, when he was working toward a doctorate in physics at Harvard. While reading Aristotle’s Physics, Kuhn had become astonished at how “wrong” it was. How could someone who wrote so brilliantly on so many topics be so misguided when it came to physics?

Kuhn was pondering this mystery, staring out his dormitory window (“I can still see the vines and the shade two-thirds of the way down”), when suddenly Aristotle “made sense.” Kuhn realized that Aristotle invested basic concepts with different meanings than did modern physicists. Aristotle used the term motion, for example, to refer not just to change in position but to change in general—the reddening of the sun as well as its descent toward the horizon. Aristotle’s physics, understood on its own terms, was simply different from, rather than inferior to, Newtonian physics.

Kuhn left physics for philosophy, and he struggled for 15 years to transform his epiphany into the theory set forth in The Structure of Scientific Revolutions. The keystone of his model was the concept of a paradigm. Paradigm, pre-Kuhn, referred merely to an example that serves an educational purpose; amo, amas, amat, for instance, is a paradigm for teaching conjugations in Latin. Kuhn used the term to refer to a collection of procedures or ideas that instruct scientists, implicitly, what to believe and how to work. Most scientists never question the paradigm. They solve puzzles, problems whose solutions reinforce and extend the scope of the paradigm rather than challenge it. Kuhn called this “mopping up,” or “normal science.” There are always anomalies, phenomena that the paradigm cannot account for or that even contradict it. Anomalies are often ignored, but if they accumulate they may trigger a revolution (also called a paradigm shift, although not originally by Kuhn), in which scientists abandon the old paradigm for a new one.

Denying the view of science as a continual building process, Kuhn held that a revolution is a destructive as well as a creative act. The proposer of a new paradigm stands on the shoulders of giants (to borrow Newton’s phrase) and then bashes them over the head. He or she is often young or new to the field, that is, not fully indoctrinated. Most scientists yield to a new paradigm reluctantly. They often do not understand it, and they have no objective rules by which to judge it. Different paradigms have no common standard for comparison; they are “incommensurable,” to use Kuhn’s term. Proponents of different paradigms can argue forever without resolving their differences because they invest basic terms—motion, particle, space, time—with different meanings. The conversion of scientists is thus both a subjective and a political process. It may involve sudden, intuitive understanding—like that finally achieved by Kuhn as he pondered Aristotle. Yet scientists often adopt a paradigm simply because it is backed by others with strong reputations or by a majority of the community.

Kuhn’s view diverged from Popper’s in several important respects. Kuhn (like other critics of Popper) argued that falsification is no more possible than verification; each process implies the existence of absolute standards of evidence, which transcend any individual paradigm. A new paradigm may solve puzzles better than the old one does, and it may yield more practical applications. “But you cannot simply describe the other science as false,” Kuhn said. Just because modern physics has spawned computers, nuclear power, and CD players does not mean it is truer, in an absolute sense, than Aristotle’s physics. Similarly, Kuhn denied that science is constantly approaching the truth. At the end of Structure he asserted that
science, like life on earth, does not evolve toward anything, but only away from something.

Kuhn described himself to me as a “post-Darwinian Kantian.” Kant, too, believed that without some sort of a priori paradigm the mind cannot impose order on sensory experience. But whereas Kant and Darwin each thought that we are all born with more or less the same innate paradigm, Kuhn argued that our paradigms keep changing as our culture changes. “Different groups, and the same group at different times,” Kuhn told me, “can have different experiences and therefore in some sense live in different worlds.” Obviously all humans share some responses to experience, simply because of their shared biological heritage, Kuhn added. But whatever is universal in human experience, whatever transcends culture and history, is also “ineffable,” beyond the reach of language. Language, Kuhn said, “is not a universal tool. It’s not the case that you can say anything in one language that you can say in another.”

But isn’t mathematics a kind of universal language? I asked. Not really, Kuhn replied, since it has no meaning; it consists of syntactical rules without any semantic content. “There are perfectly good reasons why mathematics can be considered a language, but there is a very good reason why it isn’t.” I objected that although Kuhn’s view of the limits of language might apply to certain fields with a metaphysical cast, such as quantum mechanics, it did not hold in all cases. For example, the claim of a few biologists that AIDS is not caused by the so-called AIDS virus is either right or wrong; language is not the crucial issue. Kuhn shook his head. “Whenever you get two people interpreting the same data in different ways,” he said, “that’s metaphysics.”

So were his own ideas true or not? “Look,” Kuhn responded with even more weariness than usual; obviously he had heard this question many times before. “I think this way of talking and thinking that I am engaged in opens up a range of possibilities that can be investigated. But it, like any scientific construct, has to be evaluated simply for its utility—for what you can do with it.”

But then Kuhn, having set forth his bleak view of the limits of science and indeed of all human discourse, proceeded to complain about the many ways in which his book had been misinterpreted and misused, especially by admirers. “I’ve often said I’m much fonder of my critics than my fans.” He recalled students approaching him to say, “Oh, thank you, Mr. Kuhn, for telling us about paradigms. Now that we know about them we can get rid of them.” He insisted that he did not believe that science was entirely political, a reflection of the prevailing power structure. “In retrospect, I begin to see why this book fed into that, but boy, was it not meant to, and boy, does it not mean to.”

His protests were to no avail. He had a painful memory of sitting in on a seminar and trying to explain that the concepts of truth and falsity are perfectly valid, and even necessary—within a paradigm. “The professor finally looked at me and said, ‘Look, you don’t know how radical this book is.’” Kuhn was also upset to find that he had become the patron saint of all would-be scientific revolutionaries. “I get a lot of letters saying, ‘I’ve just read your book, and it’s transformed my life. I’m trying to start a revolution. Please help me,’ and accompanied by a book-length manuscript.”

Kuhn declared that, although his book was not intended to be pro-science, he is pro-science. It is the rigidity and discipline of science, Kuhn said, that makes it so effective at problem solving. Moreover, science produces “the greatest and most original bursts of creativity” of any human enterprise. Kuhn conceded that he was partly to blame for some of the antiscience interpretations of his model. After all, in Structure he did call scientists committed to a paradigm “addicts”; he also compared them to the brainwashed characters in Orwell’s 1984. Kuhn insisted that he did not mean to be condescending by using such terms as mapping up or puzzle solving to describe what most scientists do. “It was meant to be descriptive.” He ruminated a bit. “Maybe I should have said more about the glories that result from puzzle solving, but I thought I was doing that.”

As for the word paradigm, Kuhn conceded that it had become “hopelessly overused” and was “out of control.” Like a virus, the word spread beyond the history and philosophy of science and infected the intellectual community at large, where it came to signify virtually any dominant idea. A 1974 New Yorker cartoon captured the phenomenon. “Dynamite, Mr. Gerston!” gushed a woman to a smug-looking man. “You’re the first person I ever heard use ‘paradigm’ in real life.” The low point came during the Bush administration, when White House officials introduced an economic plan called “the New Paradigm” (which was really just warmed-over Reaganomics). Kuhn admitted, again, that the fault was partly his, since in Structure he had not defined paradigm as crisply as he might have. At one point
paradigm referred to an archetypal experiment, such as Galileo’s legendary (and probably apocryphal) dropping of weights from the Leaning Tower of Pisa. Elsewhere the term referred to “the entire constellation of beliefs” that binds a scientific community together. (Kuhn denied, however, that he had defined paradigm in 21 different ways, as one critic claimed.) In a postscript to later editions of Structure, Kuhn recommended that paradigm be replaced with the term exemplar, but it never caught on. He eventually gave up all hope of explaining what he really meant. “If you’ve got a bear by the tail, there comes a point at which you’ve got to let it go and stand back,” he sighed.

One of the sources of Structure’s power and persistence is its profound ambiguity; it appeals to relativists and to science worshipers alike. Kuhn acknowledged that “a lot of the success of the book and some of the criticisms are due to its vagueness.” (One wonders whether Kuhn’s writing style is intended or innate; his speech is as profoundly tangled, as suffused with subjunctives and qualifiers, as is his prose.) Structure is clearly a work of literature, and as such it is subject to many interpretations. According to literary theory, Kuhn himself cannot be trusted to provide a definitive account of his own work. Here is one possible interpretation of Kuhn’s text, and of Kuhn. Kuhn focused on what science is rather than on what it should be; he had a much more realistic, hard-nosed, psychologically accurate view of science than did Popper. Kuhn realized that, given the power of modern science and the tendency of scientists to believe in theories that have withstood many tests, science may well enter a phase of permanent normalcy, in which no further revolutions, or revelations, are possible.

Kuhn also accepted, as Popper could not, that science might not continue forever, even in a normal state. “There was a beginning to it,” Kuhn said. “There are lots of societies that don’t have it. It takes very special conditions to support it. Those social conditions are now getting harder to find. Of course it could end.” Science might even end, Kuhn said, because scientists cannot make any further headway, even given adequate resources.

Kuhn’s recognition that science might cease—leaving us with what Charles Sanders Peirce defined as the truth about nature—made it even more imperative for Kuhn than for Popper to challenge science’s authority, to deny that science could ever arrive at absolute truth. “The one thing I think you shouldn’t say is that now we’ve found out what the world is really like,” Kuhn said. “Because that’s not what I think the game is about.”

Kuhn has tried, throughout his career, to remain true to that original epiphany he experienced in his dormitory at Harvard. During that moment Kuhn saw—he knew!—that reality is ultimately unknowable; any attempt to describe it obscures as much as it illuminates. But Kuhn’s insight forced him to take the untenable position that because all scientific theories fall short of absolute, mystical truth, they are all equally untrue; because we cannot discover The Answer, we cannot find any answers. His mysticism led him toward a position as absurd as that of the literary sophists who argue that all texts—from The Tempest to an ad for a new brand of vodka—are equally meaningless, or meaningful.

At the end of Structure, Kuhn briefly raised the question of why some fields of science converge on a paradigm while others, artlike, remain in a state of constant flux. The answer, he implied, was a matter of choice; scientists within certain fields were simply unwilling to commit themselves to a single paradigm. I suspect Kuhn avoided pursuing this issue because he could not abide the answer. Some fields, such as economics and other social sciences, never adhere for long to a single paradigm because they address questions for which no paradigm will suffice. Fields that achieve consensus, or normalcy, to borrow Kuhn’s term, do so because their paradigms correspond to something real in nature, something true.

Finding Feyerabend
To say that the ideas of Popper and Kuhn are flawed is not to say that they cannot serve as useful tools for analyzing science. Kuhn’s normal-science model accurately describes what most scientists now do: fill in details, solve relatively trivial puzzles that buttress rather than challenge the prevailing paradigm. Popper’s falsification criterion can help to distinguish between empirical science and ironic science. But each philosopher, by pushing his ideas too far, by taking them too seriously, ends up in an absurd, self-contradicting position.

How does a skeptic avoid becoming Karl Popper, pounding the table and shouting that he is not dogmatic? Or Thomas Kuhn, trying to communicate precisely what he means when he talks about the impossibility of true communication? There is only one way. One must embrace—even revel in—paradox, contradiction, rhetorical excess. One must acknowledge that
At the end of his 1987 book, *Farewell to Reason*, Feyerabend revealed just how deep his relativism ran. He addressed an issue that "has enraged many readers and disappointed many friends—my refusal to condemn even an extreme fascism and my suggestion that it should be allowed to thrive." The point was particularly touchy because Feyerabend had served in the German army during World War II. It would be all too easy, Feyerabend argued, to condemn Nazism, but it was that very moral self-righteousness and certitude that made Nazism possible.

I say that Auschwitz is an extreme manifestation of an attitude that still thrives in our midst. It shows itself in the treatment of minorities in industrial democracies; in education, education to a humanitarian point of view included, which most of the time consists of turning wonderful young people into colorless and self-righteous copies of their teachers; it becomes manifest in the nuclear threat, the constant increase in the number and power of deadly weapons and the readiness of some so-called patriots to start a war compared with which the holocaust will shrink into insignificance. It shows itself in the killing of nature and of "primitive" cultures with never a thought spent on those thus deprived of meaning for their lives; in the colossal conceit of our intellectuals, their belief that they know precisely what humanity needs and their relentless efforts to recreate people in their own sorry image; in the infantile megalomania of some of our physicians who blackmail their patients with fear, mutilate them and then persecute them with large bills; in the lack of feeling of many so-called searchers for truth who systematically torture animals, study their discomfort and receive prizes for their cruelty. As far as I am concerned there exists no difference between the henchmen of Auschwitz and these "benefactors of mankind."

By the time I tried to track Feyerabend down in 1992, he had retired from the University of California at Berkeley. No one there knew where he was; colleagues assured me that my efforts to find him would be in vain. At Berkeley, he had had a telephone that allowed him to make calls but not receive them. He would accept invitations to conferences and then fail to show up. By mail, he would invite colleagues to visit him. But when they arrived and knocked on the door of his house in the hills overlooking Berkeley, no one would answer.
Later, while skimming Isis, a journal of the history and philosophy of science, I found a short review by Feyerabend of a book of essays. The review displayed Feyerabend's talent for one-liners. In response to a denigrating remark the author had made about religion, Feyerabend retorted, "Prayer may not be very efficient when compared to celestial mechanics, but it surely holds its own vis-à-vis some parts of economics."26

I called the editor of Isis to ask if he knew how I could contact Feyerabend, and he gave me an address near Zurich, Switzerland. I mailed Feyerabend a fawning letter explaining that I wanted to interview him. To my delight, he responded with a chatty, handwritten note saying an interview would be fine. He divided his time between his home in Switzerland and his wife's place in Rome. He enclosed a telephone number for Rome and a photograph of himself wearing an apron and a big grin and standing before a sink full of dishes. The photograph, he explained, "shows me at my favorite activity, washing dishes for my wife in Rome." In mid-October I received another letter from Feyerabend. "This is to tell you that I should be (93%) in New York during the week from October 25 to November 1 and that we might make an interview then. I'll give you a call as soon as I arrive."

So it happened that one chilly night just a few days before Halloween I met Feyerabend at a luxurious Fifth Avenue apartment. The apartment belonged to a former student who had wisely abandoned philosophy for real estate—apparently with some success. She greeted me and led me into her kitchen, where Feyerabend was sitting at a table sipping a glass of red wine. He thrust himself up from a chair and stood crookedly to greet me, as if he suffered from a stiff back; only then did I remember that Feyerabend had been shot in the back and permanently crippled during World War II.

Feyerabend had the energy and angular face of a leprechaun. When we sat down and began talking, he declaimed, sneered, wheeled, and whispered—depending on his point or plot—while whirling his hands like a conductor. Self-deprecation spiced his hubris. He called himself "lazy" and "a bigmouth." When I asked about his position on a certain point, he winced. "I have no position!" he said. "If you have a position, it is always something screwed down." He twisted an invisible screwdriver into the table. "I have opinions that I defend rather vigorously, and then I find out how silly they are, and I give them up!"

Watching this performance with an indulgent smile was Feyerabend's wife, Grazia Borrini, an Italian physicist whose manner was as calm as Feyerabend's was manic. Borrini had taken Feyerabend's class while pursuing a second degree in public health at Berkeley in 1983; they married six years later. Borrini entered the conversation sporadically, for example, after I asked why Feyerabend thought scientists were so infuriated by his writings.

"I have no idea," he said, the very picture of innocence. "Are they?"

Borrini interjected that she had been infuriated when she first heard about Feyerabend's ideas from another physicist. "Someone was taking away from me the keys of the universe," she explained. It was only when she read his books herself that she realized Feyerabend's views were much more subtle and astute than his critics claimed. "This is what I think you should want to write about," Borrini said to me, "the great misunderstanding."

"Oh, forget it, he's not my press agent," Feyerabend said.

Like Popper, Feyerabend had been born and raised in Vienna. He studied acting and opera as a teenager. At the same time, he became intrigued with science after attending lectures by an astronomer. Far from seeing his two passions as irreconcilable, Feyerabend envisioned himself becoming both an opera singer and an astronomer. "I would spend my afternoons practicing singing, and my evenings on the stage, and then late at night I would observe the stars," he said.

Then came the war. Germany occupied Austria in 1938, and in 1942 the 18-year-old Feyerabend enlisted in an officers' school. Although he hoped his training period would outlast the war, he ended up in charge of 3,000 men on the Russian front. While fighting against (actually fleeing from) the Russians in 1945, he was shot in the lower back. "I couldn't get up," Feyerabend recalled, "and I still remember this vision: 'Ah, I shall be in a wheelchair rolling up and down between rows of books.' I was very happy."

He gradually recovered the ability to walk, although only with the help of a cane. Resuming his studies at the University of Vienna after the war, he switched from physics to history, grew bored, returned to physics, grew bored again, and finally settled on philosophy. His talent for advancing absurd positions through sheer cleverness led to a growing suspicion that rhetoric rather than truth is crucial for carrying an argument. "Truth itself is a rhetorical term," Feyerabend asserted. Jutting out his chin he intoned, "I am searching for the truth." Oh boy, what a great person."
Feyerabend studied under Popper at the London School of Economics in 1952 and 1953. There he met Lakatos, another brilliant student of Popper. It was Lakatos who, years later, urged Feyerabend to write Against Method. "He was my best friend," Feyerabend said of Lakatos. Feyerabend taught at the University of Bristol until 1959 and then moved to Berkeley, where he befriended Kuhn.

Like Kuhn, Feyerabend denied that he was antiscience. What he did claim, first, was that there is no scientific method. "That is exactly how it works in the sciences," Feyerabend said. "You have certain ideas that work, and then some new situation turns up and you try something else. It's opportunism. You need a toolbox full of different kinds of tools. Not only a hammer and pins and nothing else." This is what he meant by his much-maligned phrase "anything goes" (and not, as is commonly thought, that one scientific theory is as good as any other). Restricting science to a particular methodology—even one as loosely defined as Popper's falsification scheme or Kuhn's normal science mode—would destroy it, Feyerabend said.

Feyerabend also objected to the claim that science is superior to other modes of knowledge. He was particularly enraged at the tendency of Western states to foist the products of science—whether the theory of evolution, nuclear power plants, or gigantic particle accelerators—on people against their will. "There is separation between state and church," he complained, "but none between state and science!"

Science "provides fascinating stories about the universe, about the ingredients, about the development, about how life came about, and all this stuff," Feyerabend said. But the prescientific "mythmakers," he emphasized, such as singers, court jesters, and bards, earned their living, whereas most modern scientists are supported by taxpayers. "The public is the patron and should have a say in the matter."

Feyerabend added, "Of course I go to extremes, but not to the extremes people accuse me of, namely, throw out science. Throw out the idea science is first. That's all right. It has to be science from case to case." After all, scientists disagree among themselves on many issues. "People should not take it for granted when a scientist says, 'Everybody has to follow this way.'"

If he was not antiscience, I asked, what did he mean by his statement in Who's Who that intellectuals are criminals? "I thought so for a long time," Feyerabend responded, "but last year I crossed it out, because there are lots of good intellectuals." He turned to his wife. "I mean, you are an intellectual." "No, I am a physicist," she replied firmly. Feyerabend shrugged. "What does it mean, 'intellectual'? It means people who think about things longer than other people, perhaps. But many of them just ran over other people, saying, 'We have figured it out.'"

Feyerabend noted that many nonindustrialized people had done fine without science. The !Kung bushmen in Africa "survive in surroundings where any Western person would come in and die after a few days," he said. "Now you might say people in this society live much longer, but the question is, what is the quality of life, and that has not been decided."

But didn't Feyerabend realize how annoyed most scientists would be by that kind of statement? Even if the bushmen are happy, they are ignorant, and isn't knowledge better than ignorance? "What's so great about knowledge?" Feyerabend replied. "They are good to each other. They don't beat each other down." People have a perfect right to reject science if they so choose, Feyerabend said.

Did that mean fundamentalist Christians also had the right to have creationism taught alongside the theory of evolution in schools? "I think that 'right' business is a tricky business," Feyerabend responded, "because once somebody has a right they can hit somebody else over the head with that right." He paused. Ideally, he said, children should be exposed to as many different modes of thought as possible so they can choose freely among them. He shifted uneasily in his seat. Sensing an opening, I pointed out that he had not really answered my question about creationism. Feyerabend scowled. "This is a dried-out business. It doesn't interest me very much. Fundamentalism is not the old rich Christian tradition. But American fundamentalists are very powerful, I insisted, and they use the kinds of things Feyerabend says to attack the theory of evolution. "But science has been used to say some people have a low intelligence quotient," he retorted. "So everything is used in many different ways. Science can be used to beat down all sorts of other people."

But shouldn't educators point out that scientific theories are different from religious myths? I asked. "Of course. I would say that science is very popular nowadays," he replied. "But then I have also to let the other side get in as much evidence as possible, because the other side is always given a short presentation." Anyway, so-called primitive people often know far
more about their environments, such as the properties of local plants, than do so-called experts. “So to say these people are ignorant is just... this is ignorance!”

I unloaded my self-refuting question: Wasn’t there something contradictory about the way he used all the techniques of Western rationalism to attack Western rationalism? Feyerabend refused to take the bait. “Well, they are just tools, and tools can be used in any way you see fit,” he said mildly. “They can’t blame me that I use them.” Feyerabend seemed bored, distracted. Although he would not admit it, I suspected he was tired of being a radical relativist, of defending the colorful belief systems of the world—astrology, creationism, even fascism!—against the bully of rationalism.

Feyerabend’s eyes glittered again, however, when he began talking about a book he was working on. Tentatively titled The Conquest of Abundance, it addressed the human passion for reductionism. “All human enterprises,” Feyerabend explained, seek to reduce the natural diversity, or “abundance,” inherent in reality. “First of all the perceptual system cuts down this abundance or you couldn’t survive.” Religion, science, politics, and philosophy represent our attempts to compress reality still further. Of course, these attempts to conquer abundance simply create new abundances, new complexities. “Lots of people have been killed, in political wars. I mean, certain opinions are not liked.” Feyerabend, I realized, was talking about our quest for The Answer, the theory to end all theories.

But The Answer will—must—forever remain beyond our grasp, according to Feyerabend. He ridiculed the belief of some scientists that they might someday capture reality in a single theory of everything. “Let them have their belief, if it gives them joy. Let them also give talks about that. ‘We touch the infinite!’ And some people say”—bored voice—“‘Ya ya, he says he touches the infinite.’ And some people say”—thrilled voice—“‘Ya ya! He says he touches the infinite!’ But to tell the little children in school, ‘Now that is what the truth is,’ that is going much too far.”

Any description of reality is necessarily inadequate, Feyerabend said. “You think that this one-day fly, this little bit of nothing, a human being—according to today’s cosmology!—can figure it all out? This to me seems so crazy! It cannot possibly be true! What they figured out is one particular response to their actions, and this response gives this universe, and the reality that is behind this is laughing! ‘Ha ha! They think they have found me out!’ ”

A medieval philosopher named Dionysius the Pseudo-Areopagite, Feyerabend said, had argued that to see God directly is to see nothing at all. “This to me makes a lot of sense. I can’t explain why. This big thing, out of which everything comes, you don’t have the means. Your language has been created by dealing with things, chairs, and a few instruments. And just on this tiny earth!” Feyerabend paused, lost in a kind of exaltation. “God is emanations, you know? And they come down and become more and more material. And down, down, at the last emanation, you can see a little trace of it and guess at it.”

Surprised by this outburst, I asked Feyerabend if he was religious. “I’m not sure,” he replied. He had been raised as a Roman Catholic, and then he became a “vigorously” atheist. “And now my philosophy has taken a completely different shape. It can’t just be that the universe—Boom!—you know, and develops. It just doesn’t make any sense.” Of course, many scientists and philosophers have argued that it is pointless to speculate about the sense, or meaning, or purpose of the universe. “But people ask it, so why not? So all this will be stuffed into this book, and the question of abundance will come out of it, and it will take me a long time.”

As I prepared to leave, Feyerabend asked how my wife’s birthday party had gone the previous night. (I had told Feyerabend about my wife’s birthday in the course of arranging my meeting with him.) Fine, I replied. “You’re not drifting apart?” Feyerabend persisted, scrutinizing me. “It wasn’t the last birthday you will ever celebrate with her?”

Borrini glared at him, aghast. “Why should it be?”

“I don’t know!” Feyerabend exclaimed, throwing his hands up. “Because it happens!” He turned back to me. “How long have you been married?” Three years, I said. “Ah, just the beginning. The bad things will come. Just wait 10 years.” Now you really sound like a philosopher, I said. Feyerabend laughed. He confessed that he had been married and divorced three times before he met Borrini. “Now for the first time I am so happy to be married.”

I said that I had heard his marriage to Borrini had made him more easygoing. “Well, this may be two things,” Feyerabend replied. “Getting older you don’t have the energy not to be easygoing. And she’s certainly made a big difference also.” He beamed at Borrini, and she beamed back.

Turning to Borrini, I mentioned the photograph that her husband had
sent of himself washing dishes, along with the note saying that performing this chore for his wife was the most important thing he did now.

Borrini snorted. “Once in a blue moon,” she said.

“What do you mean, once in a blue moon!” Feyerabend bellowed.

“Every day I wash dishes!”

“Once in a blue moon,” Borrini repeated firmly. I decided to believe the physicist rather than the relativist.

A little more than a year after my meeting with Feyerabend, the New York Times reported, to my dismay, that the “anti-science philosopher” had been killed by a brain tumor.27 I called Borrini in Zurich to offer my condolences—and, yes, to satisfy my craven journalistic curiosity. She was distraught. It had happened so quickly. Paul had complained of headaches, and then a few months later... Composing herself, she told me, proudly, that Feyerabend had kept working until the end. Just before he died, he finished a draft of his autobiography. (The book, with the typically Feyerabendian title Killing Time, was published in 1995. In the final pages, which Feyerabend wrote in his final days, he concluded that love is all that matters in life.)28 What about the book on abundance? I asked. No, Paul did not have time to finish that, Borrini murmured.

Recalling Feyerabend’s exoriation of the medical profession, I could not resist asking, did her husband seek medical treatment for his tumor? Of course, she replied. He had had “total confidence” in his doctors’ diagnosis and had been willing to accept any treatment they recommended; the tumor had simply been detected too late for anything to be done.

*Why Philosophy Is So Hard*

Theocharis and Psimopoulos, the authors of the essay in *Nature* titled “Where Science Has Gone Wrong,” were right after all: the ideas of Popper, Kuhn, and Feyerabend are “self-refuting.” All skeptics, finally, fall on their own swords. They become what the critic Harold Bloom derided in *The Anxiety of Influence* as “mere rebels.” Their most potent argument against scientific truth is historical: given the rapid turnover of scientific theories over the past century or so, how can we be sure that any current theory will endure? Actually, modern science has been much less revolutionary—and more conservative—than the skeptics, and Kuhn in particular, have suggested. Particle physics rests on the firm foundation of quantum me-

chanics, and modern genetics bolsters rather than undermines Darwin's theory of evolution. The skeptics’ historical arguments are much more devastating when turned against philosophy. If science cannot achieve absolute truth, then what standing should be accorded philosophy, which has exhibited much less ability to resolve its problems? Philosophers themselves have recognized their plight. In *After Philosophy: End or Transformation?* published in 1987, fourteen prominent philosophers considered whether their discipline had a future. The consensus was philosophical: maybe, maybe not.29

One philosopher who has pondered the “chronic lack of progress” of his calling is Colin McGinn, a native of England who has taught at Rutgers University since 1992. McGinn, when I met him in his apartment on Manhattan’s upper West Side in August 1994, was disconcertingly youthful. (Of course, I expect all philosophers to have furrowed brows and hairy ears.) He wore jeans, a white T-shirt, and moccasins. He is a compact man, with a defiantly jutting chin and pale blue eyes; he could pass for Anthony Hopkins’s younger brother.

When I solicited McGinn's opinion of Popper, Kuhn, and Feyerabend, his mouth curled in distaste. They were “sloppy,” “irresponsible”; Kuhn especially was full of “absurd subjectivism and relativism.” Few modern philosophers took his views seriously any more. “I don’t think that science is provisional in an interesting sense at all,” McGinn asserted. “Some of it is provisional, but some of it isn’t!” Is the periodic table provisional? Or Darwin's theory of natural selection?

Philosophy, on the other hand, does not achieve this kind of resolution, McGinn said. It does not advance in the sense that “you have this problem and you work on it and you solve it, and then you go on to the next problem.” Certain philosophical problems have been “clarified”; certain approaches have fallen out of fashion. But the great philosophical questions—What is truth? Does free will exist? How can we know anything?—are as unresolved today as they ever were. That fact should not be surprising, McGinn remarked, since modern philosophy can be defined as the effort to solve problems lying beyond the scope of empirical, scientific inquiry.

McGinn pointed out that many philosophers in this century—notably Ludwig Wittgenstein and the logical positivists—have simply declared that philosophical problems are pseudoproblems, illusions stemming from
language or "diseases of thought." Some of these "eliminativists," in order to solve the mind-body problem, have even denied that consciousness exists. That view "can have political consequences that you might not want to accept," McGinn said. "It ends up reducing human beings to nothing. It pushes you toward extreme materialism, toward behaviorism."

McGinn offered a different, and, he suggested, more palatable explanation: the great problems of philosophy are real, but they are beyond our cognitive ability. We can pose them, but we cannot solve them—any more than a rat can solve a differential equation. McGinn said this idea came to him in a late-night epiphany when he still lived in England; only later did he realize that he had encountered a similar idea in the writings of the linguist Noam Chomsky (whose views will be aired in Chapter 6). In his 1993 book, *Problems in Philosophy*, McGinn suggested that perhaps in a million years philosophers would acknowledge that his prediction was correct. Of course, he told me, philosophers probably would cease struggling to achieve the impossible much sooner.

McGinn suspected that science, too, was approaching a cul-de-sac. "People have great confidence in science and the scientific method," he said, "and it's worked well within its own limits for a few hundred years. But from a larger perspective who's to say that it's going to carry on and conquer everything?" Scientists, like philosophers, are constrained by their cognitive limits. "It's hubris to think we've somehow now got the perfect cognitive instrument in our heads," he said. Moreover, the end of the cold war has removed a major motivation for investment in science, and as the sense of completion in science grows, fewer bright young people will be attracted to scientific careers.

"So it wouldn't surprise me if sometime during the next century people started veering away from studying science as much, except just to learn what they need to know about things, and started to go back into the humanities." In the future, we will look back on science as "a phase, a brilliant phase. People do forget that just 1,000 years ago there was just religious doctrine; that was it." After science has ended, "religion may start to appeal to people again." McGinn, who is a professed atheist, looked rather pleased with himself, and well he might. During our little chat in his airy apartment, with car honks and bus grows and the odor of greasy Chinese food drifting through the window, he had pronounced the impending doom of not just one but two major modes of human knowledge: philosophy and science.

**Fearing the Zahir**

Of course, philosophy will never really end. It will simply continue in a more overtly ironic, literary mode, like that already practiced by Nietzsche, or Wittgenstein, or Feyerabend. One of my favorite literary philosophers is the Argentinian fabulist Jorge Luis Borges. More than any philosopher I know of, Borges has explored the complex psychological relationship that we have toward the truth. In "The Zahir," Borges told the story of a man who becomes obsessed with a coin he received as change from a store-keeper. The seemingly nondescript coin is a Zahir, an object that is an emblem of all things, of the mystery of existence. A Zahir can be a compass, a tiger, a stone, anything. Once beheld, it cannot be forgotten. It grips the mind of the beholder until all other aspects of reality become insignificant, trivial.

At first, the narrator struggles to free his mind of the Zahir, but he eventually accepts his fate. "I shall pass from thousands of apparitions to one alone: from a very complex dream to a very simple dream. Others will dream that I am mad, and I shall dream of the Zahir. And when everyone dreams of the Zahir day and night, which will be a dream and which a reality, the earth or the Zahir?" The Zahir, of course, is *The Answer*, the secret of life, the theory to end all theories. Popper, Kuhn, and Feyerabend tried to protect us from *The Answer* with doubt and reason, Borges with terror.