Science in a Skeptical Age

by John Bellamy Foster

John Gillott and Manjit Kumar *Science and the Retreat from Reason* (New York: Monthly Review Press, 1998) $18.00 [paper], pp. 248.

We live in a skeptical age. All of the basic concepts of the Enlightenment, including progress, science and reason are now under attack. At the center of this skepticism lie persistent doubts about science itself, emanating both from within and from without the scientific community. Recent titles by scientists give an idea of the extent of the crisis in confidence *within* science: *Science: The End of the Frontier?* (1991) by Nobel prize winner Leon Lederman; *The End of Certainty* (1996) by Nobel laureate Ilya Prigogine; and *The End of Science* (1996) by *Scientific American* writer John Horgan.

Attacks on science from *without* are legion and while emanating from both right and left are increasingly associated with the post-modernist left, leading to the publication of numerous conservative attacks on the academic left for besmirching the name of science, as in the case of *The Higher Superstition: The Academic Left and its Quarrels with Science* (1994) by Paul Gross and Norman Levitt.

Science and the Retreat from Reason is undoubtedly one of the best introductions one can find to the crisis of confidence within science itself, and has some interesting things to say about the attacks on science from without. Unfortunately, Gillott and Kumar frequently write as though the attacks on science from without emanate today primarily from environmentalists, who are blamed for questioning the goal of the complete domination of the natural world by science

John Bellamy Foster, a member of the Board of the Monthly Review Foundation, teaches sociology at the University of Oregon and is coeditor of *Organization & Environment.* He is the author of *The Theory of Monopoly Capitalism* (1986) and *The Vulnerable Planet* (1994), both published by Monthly Review Press.

and technology and for raising the issue of natural limits to human activity, thereby "belittling humanity" (p. 31). As Gillott and Kumar put it: "The growing consensus behind 'green' ideas, which broadly elevate the natural world above human attempts to modify it, has put science on the defensive" (p. 4).

What these authors know best is science, and the bulk of this book, including all of its major chapters but one, concentrate on the growing uncertainty within science emanating from such developments as quantum mechanics, chaos theory and complexity theory (sometimes lumped together under the rubric of "the new sciences"). They focus in particular on the philosophical interpretations placed on these developments, which have frequently led scientists to reject progress and causality, and to emphasize discontinuity, uncertainty, chaos, complexity, relativism, the limits of human knowledge and control, purely aesthetic paths to truth, etc. Some scientists, they argue, have simply given up on the application of reason to reality and have retreated into pure research for its own sake; others have turned to aesthetics (the Platonic quest for beauty) as a way of discovering truth, where reason by itself will not do.

For Gillott and Kumar there has been, over the course of the twentieth century, a "combined advance of science and retreat from reason" (p. 140)—a contradiction that has deepened over the last half century. Although pointing to the First and Second World Wars, Hiroshima and the Cold War as major factors in the loss of confidence in science, these authors avoid the view that the crisis of physics brought about by the rise of quantum mechanics after 1925 had sources that were simply "external to physics" (p. 184). The crisis within science, as represented by the three scientific theories that are currently being "mobilized against progress" and reason (p. 29)—quantum mechanics, chaos theory, and complexity theory—has causes which to a considerable extent are internal to science itself. How this interacts with the wider sociology of science is therefore a very complex issue and one that can only be discussed after the internal crisis of science has been examined.

"Quantum mechanics," as the authors of *Science and the Retreat from Reason* point out, "is one of the most successful theories that science has produced to date. It has helped to unravel the structure of the atom, explain the nature of the chemical bond, and predict the existence of anti-matter. At a more practical level, quantum mechanics has been central to the development of electronics from the transistor to the microprocessor" (pp. 33-34). But quantum

mechanics also disrupted the old Newtonian physics, creating shock waves within science that have never entirely abated. Quantum mechanics brought indeterminacy, probability, and statistical descriptions to the fore in scientific analysis, disrupting the deterministic bases of the old (pre 1925) quantum theory (and of science in general). More important, it called into question "realism—the view that nature has an objectivity independent of human consciousness" (p. 34).

Quantum physics has been described as a physics of "lumps and jumps" as in the concept of "quantum leaps." More important it is characterized by a wave/particle duality. While the old physics had seen the world as consisting of particles and waves, quantum mechanics found the world to be made up—as Ian Marshall and Danar Zohar explain in *Who's Afraid of Schrödinger's Cat?*—"of indeterminate things with the potentiality to behave like waves in some circumstances and particles in others....A quantum entity is *both* its capacity to manifest itself as a wave, in which case it has momentum, *and* its capacity to manifest itself as a particle, which has position. We can never know the position and the momentum of the entity simultaneously." The limits of knowledge in this respect have been formalized within physics as "Heisenberg's uncertainty principle."[1]

Obviously, the indeterminacy that arises from such a physics raises important problems. For Gillott and Kumar the real difficulty does not lie with the scientific breakthrough represented by quantum mechanics itself, but with the broader *interpretation* within the philosophy of science (specifically the attacks on realism and causality and the emphasis on uncertainty), to which it gave rise. The weird results of quantum mechanics baffled physicists. As a means of dealing with this, a scientific consensus was developed around what has been called the Copenhagen interpretation—so named because of its origin in the ideas of two of the founders of quantum physics, Niels Bohr and Werner Heisenberg, both of whom were associated with the Institute of Theoretical Physics in Copenhagen. Bohr and Heisenberg took the position that quantum mechanics reduced classical notions of causality to shambles. As Bohr himself put it, quantum mechanics points to a "final renunciation of the classical ideal of causality and a radical revision of our attitude toward the problem of physical reality" (p. 36).

The Copenhagen interpretation, out of which the contemporary scientific consensus with respect to the philosophical implications of quantum mechanics arose, sought to deal with these problems by abandoning realism. In essence, the Copenhagen inter-

pretation, as Gillott and Kumar explain, argued that "*observation constructs reality.* Bohr wrote of 'fundamental limitations' within atomic physics, in the 'objective existence of phenomena independent of their means of observation'" (p. 68). No elementary phenomenon, it was argued, exists independent of observation. Indeed Bohr lapsed into a kind of solipsism arguing that "It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we say about nature" (p. 76).

Strong opposition to the Copenhagen interpretation was mounted by two other founders of quantum mechanics, Albert Einstein and Erwin Schrödinger. Schrödinger's famous, paradoxical thought-experiment known as "Schrödinger's Cat," which has ironically become a sort of symbol and "mascot" for quantum physics, was actually introduced to demonstrate the weird, anti-realist philosophy that had come to dominate quantum mechanics, by bringing what was being said about the micro world into focus with a macro world example. "Take a cat, said Schrödinger, and place it [shut it up] in a box together with a bottle of cyanide. Arrange things so that a hammer placed over the bottle will smash it when a single decay of a radioactive substance, also placed in the box, occurs" (p. 74). According to common sense the cat would either be alive or dead. But according to the philosophical interpretation currently attached to quantum mechanics, both possibilities coexist. If we open the box and look we see a cat that is either alive or dead. But our observations change things, the observer is part of what he or she observes, while the quantum world continues to retain both possibilities simultaneously, always remaining at one remove from the world of observation.[2]

Einstein supported the physics of quantum mechanics but tried to change the philosophy associated with it, bringing it back into conformity with realism and the idea of an objective world, though his views did not prevail. For Einstein, in opposition to the Copenhagen interpretation, "it is basic for physics that one assumes a real world existing independently from any act of perception" (p. 76). Warning of the dual dangers of "positivism" and "solipsism," Einstein insisted that the hegemonic philosophy associated with quantum mechanics was a partial, "tranquilizing" one, a product of the failure to recognize that a new, more radical approach to the entirety of physics (challenging the old Newtonian physics in a more complete way) was needed.[3] As he wrote, "The Heisenberg-Bohr tranquilizing philosophy—or religion?—is so delicately contrived that, for the time being, it provides a gentle pillow for the

true believer from which he cannot very easily be aroused. So let him lie there" (pp. 76-78).

Gillott and Kumar insist that Einstein's approach was clearly the right one, and that an approach based on realism will ultimately win out, though the Copenhagen interpretation remains triumphant at present, and symbolizes the "retreat from reason" within science. Similar issues, these authors argue, have been raised by the rise to prominence more recently of chaos theory and complexity theory.

Edward Lorenz, the founder of chaos theory, has defined chaos as "sensitive dependence" (p. 81). Chaos theory is a mathematical discipline that was dramatized by a talk given in 1972 by Lorenz at the American Association for the Advancement of Science meetings, entitled "Predictability: Does the Flap of a Butterfly's Wings in Brazil Set off a Tornado in Texas?"—a talk that produced the term "the butterfly effect." The butterfly effect is meant to convey nature's supersensitivity to certain ranges of phenomena. Lorenz, a MIT meteorologist, had been concerned with discovering equations that govern the world's weather. What he eventually discovered, however, was that weather is so highly non-linear that even the tiniest perturbation (the flap of a butterfly's wings) in the data, constantly fed back and magnified, can have a cumulative effect on an entire weather pattern. His conclusion was that global weather systems are supersensitive, so much so that prediction and control become impossible.[4]

Complexity theory is associated most closely with the work of the Nobel prize winning chemist Ilya Prigogine. Prigogine's work starts with the classical second law of thermodynamics which says that natural systems tend over time to generate disorder or entropy—out of which arises the concept of "the arrow of time," or irreversibility, which applies to the whole natural world. Prigogine, however, argued that in far from equilibrium systems, which characterizes the phenomenon of life, order rather than disorder is created, through a process of "self-organization" and growing complexity (order on the edge of chaos). The new order acts as a "strange attractor" that is able to pull energy into the complex pattern. Such "far from equilibrium systems" do not contradict the second law of thermodynamics which applies to nature as a whole, since such complex structures of self-organization can be described as "dissipative structures," in that they create order by dissipating disorder into their environments. Hence, local regions of order are created within a world nonetheless characterized by growing entropy.

Far from equilibrium systems, according to Prigogine, can adapt by selecting for increasing complexity (or greater self-organization) rather than being ruled simply by change caught on the wing, or by frozen accidents, as described by a more Darwinian tradition. Complexity theory thus generates models that appear to be the absolute antithesis of reductionist science, requiring complex, nonlinear equations that have to be run through computers. Moreover, it tends to point like chaos theory to the notion that the world is far too complex/chaotic for predictability. The result is what Prigogine calls "the end of certainty"[5]

For Gillott and Kumar the doubts regarding reason raised by chaos and complexity theories are akin to those raised by quantum mechanics but have "even graver" significance since the scope of the claims is wider. "Not only all of nature but the whole of human society is said to be governed by laws beyond our control" (p. 186). Indeed, a kind of "empire-building" is at work where these theories are now seen as keys to the workings of human society as well as nature (*Ibid.*). Complexity theory is seen by many of its proponents as equally applicable to the weather, the stock market and the human mind. Yet, all of this, Gillott and Kumar argue, leads inexorably to the "belittling" of humanity. Since chaos theory suggests that there is no way of controlling or even fully understanding natural processes the scope for human self-determination is thereby much lessened.

Complexity theory, for its part, these authors contend, conveys a kind of "teleological" view on the one hand, and on the other suggests (as in chaos theory) that nature is too complex for rational intervention. This attack on the scope of human reason, these authors argue, can be traced ultimately to "The Green desire to take humanity down a peg or two from 'the pinnacle of some self-defined evolutionary hierarchy,'" which "is one of the driving forces of excess in complexity theory" (p. 187).

John Horgan, in his controversial book *The End of Science*, has usefully described chaos and complexity theories as "ironic science" in the sense that they tend to point to results that are interesting, even paradoxical, and that highlight the limitations to human knowledge, but which are questionable in terms of their usefulness.[6] In that respect these theories seem to reflect the skeptical and ironic climate of "postmodern culture" in which doubts about the possibilities of human knowledge and rational control of both the social and natural environments are rampant.

Gillott and Kumar are therefore right to warn us of the dangers of the uncritical application of this kind of ironic science to all of reality. With respect to chaos theory the threat is perhaps less since the range of such theories are clearly limited even in their application to nature. The mathematical result of chaos—even with respect to nature—arises in part, Gillott and Kumar argue, because of the very simple set of variables taken into account. Chaos theories are therefore open to the criticism, especially with respect to ecology, that they often ignore key aspects of the reality they set out to describe, and that once these other aspects are added chaos disappears. According to Gillott and Kumar some systems are chaotic but the application is clearly limited. "Linear models plus 'noise,'" it is suggested, might work better (p. 87).

The imperialistic tendencies of complexity theory are harder to argue against, and indeed social scientists have jumped onto complexity theory to bolster their own perspectives, often in widely contradictory ways. For example, Bruce Rich, a director of the conservative environmental organization The Environmental Defense Fund, has turned to complexity theory in his widely influential book, *Mortgaging the Earth*, in order to argue that we cannot "predict, plan, and manage 'global environmental crises'" (p. 30). This may seem to exhibit a degree of rationality from an environmental perspective; but it also suggests that we cannot plan sustainable development, and thus has an eerie connection (made more credible because of the Environmental Defense Fund's close connection to business) to the proposition of another strong proponent of complexity theory, Friedrich Hayek. In his final book, *The Fatal Conceit* Hayek launched an attack on the whole Enlightenment notion of rationalism as exemplified by "socialistically-inclined" thinkers like Einstein and Bertrand Russell, on the grounds that society was too complex for rational planning and that the market system was in effect an institutional recognition of that fact. The moral: nothing should be done to interfere with the self-organization of the market, which was, Hayek suggested, akin to the self-organization of nature as envisioned by complexity theory (p. 115).[7]

Postmodern leftists (and indeed left thinkers of all kinds) of course have also borrowed heavily from chaos and complexity theories—and have been widely criticized by the right for their "higher superstition" in doing so.[8] Indeed, Gillott and Kumar argue that the right may reject reason more fully but they never truly reject science as power (in contrast to leftists who are willing to extend

their rejection to the latter). As a result the retreat from science as well as reason, they argue, is a malady that is particularly characteristic of the left.

For Gillott and Kumar it wasn't the first New Left, represented by figures like E.P. Thompson and C. Wright Mills, who were responsible for the retreat from reason, but "a quite different movement, which has also come to be known as the 'New Left,'" that "emerged later on" (p. 154). Here they point to the influence of the Frankfurt School, and in particular Max Horkheimer, Theodore Adorno, and Herbert Marcuse who brought a kind of Weberian critique of the Enlightenment to the left, and who rejected technology and the idea of "the human domination over nature" (p., 155).

One would naturally expect this observation to be followed by a critique of the postmodernist left, which developed to a considerable extent out of the ideas of the "second new left," and of the uncritical way in which these postmodern thinkers grabbed on to the "new sciences" in order to bolster their attacks on Enlightenment values.[9] There is however little to be found in the way of a critique of postmodernism in Gillott and Kumar's book (despite the occasional references to Paul Feyerabend and Andrew Ross). Rather *Science and the Retreat from Reason* clearly focuses, in what is its penultimate chapter—also entitled "Science and the Retreat from Reason"—on environmentalists as the main contemporary enemies of science and reason, and the most potent force in the attack on science from without. For Gillott and Kumar science and reason are essentially Baconian, i.e. aimed at "the enlarging of the bounds of human empire" to the control of all of nature, or they are not, properly speaking, science and reason at all.[10]

Here their book goes through a strange metamorphosis, and from a strong and in many ways brilliant defense of science and reason it turns, in my view, into the opposite, by taking on all of the assumptions of what Paul and Anne Ehrlich, in their book *The Betrayal of Science and Reason*, have described as the current "brownlash" against environmentalism.[11] For Gillott and Kumar the retreat from science and reason associated with environmentalism can be traced to Rachel Carson who "in her polemic against the use of insecticides, *Silent Spring*" argued "that life, including insect life was a miracle 'beyond our comprehension,'" and that it "'deserved reverence and humility from human beings.'" Placing her in the same camp as Horkheimer, Adorno, and Marcuse (in terms of her critique of technology and the Enlightenment), Gillott and Kumar criticize her

for "her attack on science as conceited and arrogant" (p. 156). The "nightmares of Carson and Marcuse" and the "fear of the Revenge of Nature" that they spawned have become, we are told, part of "mainstream culture" and a source of growing irrationalism (p. 159).

At another point in their argument Rachel Carson and Vance Packard are presented as examples of those who attack science not for its "unfulfilled potential" but for the reckless and heedless imposition of science and technology within a vulnerable world. "From Vance Packard's *The Waste Makers* through to today, the radical critique of capitalism was and remains that it was producing and consuming too much not too little. The problem was seen and remains seen as one of *waste*, and in particular humanity's seemingly deep-seated tendency to go about *laying waste to the natural environment*" (p. 142). No doubt for Gillott and Kumar, works like *Monopoly Capital* by Baran and Sweezy, which more than any other political economic critique of contemporary capitalism related issues of surplus production and absorption to problems of economic waste, fall in the same category.

Certainly their attack on environmentalism doesn't stop short of criticism of contemporary Marxian political economy. Indeed, one thinker who is singled out for special condemnation in their argument is the Marxist economist Elmar Altvater, who Gillott and Kumar pair with the right-wing eugenicist and Malthusian Garrett Hardin—as if there really weren't any difference between the two! Altvater is roundly condemned for his application of the second law of thermodynamics (or the concept of entropy) to the realm of economics in his important work *The Future of the Market*, and for his attempts to connect this to Marx's political economy.

In Gillott and Kumar's view, Altvater has simply done a "*volte face*" by turning from the crisis of slow capitalist growth (in his earlier work, focusing simply on the economy) to the problem of too much capitalist growth (in his more recent ecologically-informed analysis). Failing to understand the nature of Altvater's analysis—its theoretical roots in the work of Nicholas Georgescu-Roegen, its connection to the whole tradition of ecological economics, and its relation to Prigogine's work on dissipative structures—Gillott and Kumar are simply content to say that the earth is not a closed system since it gets energy from the sun, and that there "are no absolute limits to the energy at mankind's disposal, nor will there be for millennia" (p. 163). The fact that the world capitalist economy is a massive, ever increasing, and highly intensive "dissipative structure" (to borrow

Prigogine's term) that creates its only kind of competitive order by drawing on low entropy energy and resources and dissipating disorder (high entropy) into its environment seems to have passed Gillott and Kumar by. But it is a vital element in explaining the growing scale of the contemporary ecological crisis—and in the critique of capital accumulation for its role in engendering this crisis. In Altvater's words, "As a rule ... high rates of accumulation are bound up with high use of energy and materials and may thus accelerate the entropy increase of the natural system.[12]

Science and the Retreat from Reason goes on to attack Malthusian fears of overpopulation, as exemplified in the work of mainstream liberal Paul Kennedy. Some of the points that they make are good ones. Nevertheless, they attack Kennedy for treating the population of 10 or 11 billion projected for the end of the twenty-first century as a disaster. They counter by claiming that "It has been estimated that, *using agricultural techniques already in existence*, the Third World alone could feed 32 billion people, without the help of the vast fertile areas of Russia and the Ukraine" (pp. 165-66).

Here I rubbed my eyes in disbelief. What kind of agricultural techniques are being referred to—those of U.S. agribusiness? Even granting their initial premise which focuses on food supply, what would be the wider ecological impact on the earth's carrying capacity of the implementation of these current agribusiness techniques (requiring intensive utilization of fertilizers, pesticides, machinery, etc.) on such a planetary scale?

A naïve willingness to accept all technology without question is evident throughout *Science and the Retreat from Reason*. Thus Gillott and Kumar write as if the left is simply being irrational in being skeptical about the wisdom of obtaining "cheap electricity from atomic power" or the application of "genetic engineering" (p. 173)—as if these technologies did not raise quite horrific possibilities. Even the *Bulletin of Atomic Scientists* is attacked, by Gillott and Kumar, for its unwillingness in 1992 to celebrate the 50th anniversary of Enrico Fermi's success at producing the first controlled, self-sustaining, nuclear chain reaction—because of the subsequent history of how this scientific discovery was applied (p. 170).

Not ones to stop half-way in their criticisms, Gillott and Kumar go on to contend that all of those who believe that there are ecological limits to economic growth (even ecological limits to capital accumulation) have succumbed to "a mass psychosis about limits in nature" (p. 166). Such views, we are told, are anti-science

and anti-reason. Yet the fact remains that they are held by many, probably most, scientists, and hence cannot simply be presented—as Gillott and Kumar are wont to do—as attacks on science from without. Moreover, the arguments offered in support of the view that human society is more and more in conflict with its own ecological life support systems are often models of the application of human reason—in the simplicity and incontrovertibility of their arguments. Thus, in his last book, *Billions and Billions*, Carl Sagan observed that,

> ... today we face an absolutely new circumstance, unprecedented in all of human history. When we started out, hundreds of thousands of years ago, say, with an average population of a hundredth of a person per square kilometer or less, the triumphs of our technology were hand axes and fire; we were unable to make major changes in the global environment. The idea would never have occurred to us. We were too few and our powers too feeble. But as time went on, as technology improved, our numbers increased exponentially, and now here we are with an average of some ten people per square kilometer, our numbers concentrated in cities, and an awesome technological armory at hand—the powers of which we understand and control only incompletely....We are now able, intentionally or inadvertently, to alter the global environment. Just how far along we are in working the various prophesied planetary catastrophes is still a matter of scholarly debate. But that we are able to do so is now beyond question.[13]

For Sagan it is scientists who have been most consistently and rationally concerned about environmental issues: "Except for millenarians of the various denominational persuasions and the tabloid press, the only group of people that seems routinely to worry about the new claims of disasters—catastrophes unglimpsed in the entire written history of our species—are the scientists."[14] Ultimately, it is not just environmentalists who come under attack in Gillott and Kumar's book but all of those, among scientists and philosophers, who have raised questions about the role of science in contemporary society. Thus among those who are supposed to have retreated from science and reason we find, astonishingly, such names as Robert Oppenheimer (because of his quote from the *Bhagavad Gita*—"I am become death, the destroyer of worlds"—when viewing the first atomic blast), Bertrand Russell and Alfred North Whitehead (pp. 22, 113, 197).

It is difficult to understand, in fact, how a book that began with such a brilliant defense of science and reason, and indeed of realism, could lead in the end to such a state of unreason. The importance of Gillott and Kumar's book is that they provide a critical, to some extent socially informed, view of twentieth century revolutions in science, and of the crisis of confidence that has resulted. Their discussion of the conflicts within science over quantum mechanics, chaos theory and complexity theory stand as an important warning for those who wish to adopt hasty conclusions and to carry them over

into the philosophy of science, and indeed into the social science and humanities. It helps us to understand more fully the faulty origins of some contemporary postmodern nonsense. Yet, the view that they present is insufficiently critical of capitalism, and its shaping of science and technology—to the point of denying fundamental social and ecological problems, and presenting a simple-minded (and in some ways quite reactionary) glorification of the human domination of nature. Thus with their book we get the bad with the good.

It is crucial to remember that quantum mechanics, chaos theory, and complexity theory are complex theories, open to different interpretations—some more in line with reason, some less so. It is important to be cautioned against some of the dangerous (and unreasoning) ways that these theories can be applied—a problem that in some ways parallels the Darwinian revolution of the nineteenth century (when the most common application within the social world was social Darwinism with its notion of "the survival of the fittest"). It is certain that chaos and complexity theory can be misused. But they also provide us with new ecological insights—and hence (like all important scientific achievements) cannot be simply rejected outright. As Whitehead once wrote, "A civilisation that cannot burst through its current abstractions is doomed to sterility after a very limited period of progress."[15]

Environmentalists, Gillott and Kumar's complaints notwithstanding, are not simply uncritical promoters of chaos and complexity theory. Indeed, chaos theory has been used by some (in post-Odum ecology) to derail notions of ecological planning and even the concept of ecosystems, resulting in a crushing critique by environmental historian Donald Worster of the roles that chaos and to a lesser extent complexity theory are playing in some contemporary environmental thought.[16] Environmentalists are therefore on both sides of this controversy. Others see the "new sciences" as leading to a new holism—a shift toward Whitehead's dialectical process philosophy—that will eventually unite the natural and human sciences.

In the end there is no way of addressing the issue of the status of science and reason in our age except by recognizing both the wealth and the poverty of science. Our capacity to judge the extent of both the former and the latter is affected by the extent to which we take seriously the critique of capitalist society and capitalist ideology. One thing we do know, and that Marx insisted on, is that

in the alienated present the "pure light of science seems unable to shine but on the dark background of ignorance."[17]

This is a problem that many natural and physical scientists themselves have struggled with, recognizing that the poverty of science lies in its reductionist, instrumentalist use—ultimately traceable to the estranged nature of contemporary society.

In defending the wealth of science in the face of those postmodernists who would abandon it completely, we need not blind ourselves to the fact that this same wealth of science (much of which is merely potential) is accompanied by its impoverishment in practice. Nor should we ignore the fact that the harnessing of science to the narrow, mindless goal of profit maximization has brought humanity to such an end that an ecological crisis of truly planetary proportions now threatens. Under these circumstances, those who do not ruthlessly critique contemporary science and technology and the uses to which they have been put, as Carl Sagan warns (quoting the biblical Proverbs), are setting "an ambush for their own lives"—and those of all of humanity.[18] At one point Gillott and Kumar lead us out of this ambush only to lead us back again in the end. Readers of this interesting and provocative book—and I hope there are many—should therefore be on their guard.

NOTES

1. Ian Marshall and Danah Zohar, *Who's Afraid of Schrödinger's Cat?* (New York: William Morrow, 1997), pp. 181-84, 295-99.
2. *Ibid.*, pp. xiii-xv; Walter Moore, *Shrödinger: Life and Thought* (New York: Cambridge University Press, 1989), pp. 306-09.
3. Albert Einstein, "Remarks Concerning the Essays Appearing in this Co-Operative Volume," in Paul Arthur Schilpp, ed., Albert Einstein *Philosopher-Scientist Vol. II* (New York: Harper and Brothers, 1951), pp. 667-73.
4. Marshal and Zohar, *Who's Afraid*, pp. 77-78.
5. See Ilya Prigogine, *The End of Certainty* (New York: The Free Press, 1996).
6. John Horgan, *The End of Science* (New York: Bantam, 1996), pp. 6-8.
7. For a critique of Hayek's *Fatal Conceit* see John Bellamy Foster, "Market Fetishism and the Attack on Social Reason: A comment on Hayek, Polanyi and Wainwrite," *Captialism, Nature, Socialism*, vol. 6, no. 4 (December, 1995), pp. 101-07.

8. In an extremely biased, hypocritical, and distorted right-wing "critique," two science writers, Paul Gross and Norman Levitt, make much of the scientific lacunae (with respect to knowledge of the new sciences) in the work of such thinkers as Stanley Aronowitz, Steven Best, Sandra Harding, Carolyn Merchant, and Andrew Ross, also taking time out to deride Immanuel Wallerstein. One of the things that makes Gross and Levitt's account so biased—despite the inanities of postmodern theory that they are able to point to—is that these authors try to conceal the wide range of disagreement among leading scientists themselves about the implications of these ideas, pretending that the whole controversy was simply invented by academic leftists in the social sciences, particularly feminist and environmentalists. There is of course no suggestion that right-wing icons within social science, like Friedrich Hayek, might also be worth scrutiny in this respect. See Paul R. Gross and Norman Levitt, *The Higher Superstition: The Academic Left and Its Quarrels with Science* (Baltimore: John Hopkins, 1994).
9. For a discussion of the first and second new lefts see Ellen Meiksins Wood, "A Chronology of the New Left and its Successors," in Leo Panitch, ed., *The Socialist Register*, 1995 (New York: Monthly Review Press, 1995), pp. 22-49.
10. Baconianism, it should be remarked, is a complex philosophy, the most influential statement of the entire scientific project that emerged in the sixteenth and seventeenth centuries. Arising from a revolutionary bourgeoisie, the breakthroughs in science (and even more in the philosophy of science) at the time, have inspired widely diverging traditions. Much of contemporary anti-ecological thought can be traced to ideas generated by Bacon. But Bacon's ideas also generated critical ecological insights. While it would be too much perhaps to claim that there has been a green (ecological) Baconianism, as well as a brown (anti-ecological) Baconianism, Bacon's influence can clearly be seen on both sides of this debate. For example, Marx and Engels ecological views often reflected a critical appropriation of key Baconian ideas, such as his famous maxim that nature can only be commanded by being obeyed. I owe much of my own understanding of this, I should acknowledge, to conversations that I have had with my colleague John Mage, a member of the Monthly Review Foundation Board.
11. Paul and Anne Ehrlich, *The Betrayal of Science and Reason* (Washington, D.C.: Island Press, 1996). Unfortunately, the brownlash that the Ehrlich's describe is also occurring within Marxism, and not only in the work of Gillott and Kumar. For example, in *Rethinking Marxism* Blair Sandler criticizes Barry Commoner, James O'Connor, Victor Wallis, and myself for arguing that there is an inherent conflict between capital accumulation and ecological sustainablility; and for presenting the view that capitalism has engendered an ecological crisis which it can no longer control and that may play a part in its undoing. For Sandler, in contrast, capitalism is already greening itself in fundamental ways, under the leadership of multinational corporations. See Blair Sandler, "Grow or Die: Marxist theories of Capitalism and the Environment," *Rethinking Marxism*, vol. 7, no. 2 (Summer, 1994), pp. 38-57.
12. Elmar Altvater, *The Future of the Market* (New York: Verso, 1993), p. 203; Nicholas Georgescu-Roegen. *The Entropy law and the Economic Process* (Cambridge, MA: Harvard University Press, 1971).
13. Carl Sagan, *Billions and Billions* (New York: Random House, 1997), pp. 72-73.
14. *Ibid.*, p. 75.
15. Alfred North Whitehead, *Science and the Modern World* (New York: New Amercian Library, 1925), p. 59.
16. Donald Worster, "The Ecology of Order and Chaos," in Char Miller and Hal Rotham, ed., *Out of the Woods: Essays in Environmental History* (Pittsburgh: University of Pittsburgh Press, 1997), pp. 3-17.
17. Karl Marx, "Speech at the Anniversary of *The People's Paper*," in Marx and Engels, *Collected Works*, Vol. 14 (New York: International Publishers, 1980), pp. 655-56.
18. Sagan, *Billions and Billions*, p. 98.