points out that the prairie dog is essential to the ecology of the American plains. It is fascinating to learn that Wyoming once contained a prairie dog town 100 miles (161 km) long, or that Texas had one that covered 25,000 square miles (64,750 square km). This is all well enough; most of us can appreciate the virtue of conservation. The last chapter (titled "The Good Earth") is where the text occasionally lapses into Rachel-Carson–type hysteria. On page 171, Wolfe claims that in the case of land denuded of vegetation "several tons of topsoil can be washed from a one-acre field in a single rainstorm". I wouldn't dispute this, but certainly this would be the extreme upper limit for a steeply sloping surface. On page 182, Wolfe falsely states that atmospheric concentrations of carbon dioxide have been nearly constant for tens of thousands of years. He then says that the concentration of carbon dioxide is rising at an "alarming rate". Broad, sweeping generalizations unsupported by a critical discussion of the scientific evidence are not to my taste. This is not to say that environmental problems are not a concern. The issue is whether the approach is one that is balanced, quantitative, and factual; or emotional, qualitative, and alarmist.

In summary, I enjoyed reading this book and learned a lot from it. The book is at its strongest in the first seven chapters which are largely devoted to factual discussions of the science of the underground.

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Life Is a Miracle: An Essay Against Modern Superstition by Wendell Berry. Washington, DC: Counterpoint, 2000. 153 pp. $21.00 (cloth). ISBN 1582430586. $14.00 (paper). ISBN 1582431418.

As modern biology pursues the question "What is life?" from the point of view of a preordained answer "Life is a machine", Wendell Berry offers the alternative possibility that "Life is a miracle": It is an alternative perfectly consistent with a scientific perspective within which there remains, and will always remain, a timeless mystery.

I think Niels Bohr captured this thought as a scientific reality many years ago: "In every experiment on living organisms there must remain an uncertainty as regards the physical conditions to which they are subjected and the idea suggests itself that the minimum freedom we must allow the organism will be just large enough to permit it, so to say, to hide its secrets from us. On this view, the very existence of life must in biology be . . . [like the quantum action] taken as a basic fact that cannot be derived from ordinary mechanical physics." (Bohr, 1933: 458)

When this miracle is forgotten, Berry says, or is left out of our perspective, and instead when life is seen as just another problem to be solved, then science embraces the inevitable promise of reducing life to a machine and opens itself, both in its practice and derivative technology, to a restrictive view of causality and to a narrow accounting for success which breeds more questions and problems than it does sustainable answers and solutions. This is so because life itself is larger than any mechanistic model that can be made of it and, therefore, will always be able to demonstrate behavior that cannot be predicted from that model.

In this short but powerful essay Berry reconnects us to a broader scientific world view in which the machine metaphor for life is subjected to an exacting criticism. His major analytic tool is the English language and the subject of his analysis is the biologist E. O. Wilson and his book, *Consilience.* In the pivotal chapter three of *Miracle* Berry discusses his concerns with Wilson on such issues as materialism and mystery, imperialism, reductionism, creatures as machines, originality and the "Two cultures" of C. P. Snow, and what he calls "progress without subtraction" or the absence of any accounting for progress outside of the most narrow focus of scientific experiment and technology. When he has finished he reveals the extremely shaky ground of a reductionism hypothesis of life: It is based on the false assumption that a sufficiently large model will soon become available (it is always soon, he says, but never now), and it survives because that model is at the heart and soul of modern science and there appears to be no consensus view within science (at least as represented by E. O. Wilson) of how we are to proceed without it. Also revealed by Berry is the weak ground on which rest many of the popular views concerning the objectivity of scientific thinking: he says that scientists like Wilson are mostly unaware of their own prejudices which are then brought, unannounced, to their objective analysis. He questions, as did Thomas Kuhn in *The Structure of Scientific Revolutions* (Kuhn, 1996), the much-touted idea that knowledge and understanding are always and continuously increasing: if it is, he says, then "while it may be increasing globally it is being lost locally". And he questions the general assumption that science is unique in its ability to discover and confirm truth (whatever that may be) and that this belief, generally held, is destructive in that it breeds a collective hubris among scientists and a misplaced acceptance among the public that is dangerous: certainly, it must be counterproductive of any effort to build consilience among the arts, humanities, and sciences.

Berry is a renowned essayist and has been called the "prophet of the land" and "the prophetic voice of America", so his language is not the language of science but the language of a keen observer of nature with a great talent for plain speaking. Surprisingly, this analysis by Berry reaches many of the same conclusions about biotechnology as did Bill Joy, cofounder and Chief Scientist of Sun Microsystems (April 2000 issue of *WIRED* magazine): that elements of technology evolve at a rapid pace and provide "the nexus for the potential destruction of human life" (also reported in the American Association For The

Advancement of Science Update for Spring/Summer 2000). Mr. Joy's concerns have mostly to do with the future nexus of genetics, nanotechnology, and robotics. Berry's focus is on the present ability of corporate biotechnology and its nexus with the university to destroy the very basis of human life: the land itself. Mr. Joy asks us to step back from technology and to take the longer view but he, with most other scientists, does not give us a prescription for how to take that step. Berry is saying that such a step is not to be found within science alone but requires the consilience already described.

On a different level altogether, even Richard Lewontin, who for years has been pointing out the limits, sometimes deadly limits, of reductionism does not address how we might change the direction of modern biology. In his new book *The Triple Helix: Gene, Organism, and Environment* (Lewontin, 2000), Lewontin does address the question of what is missing from within the body of scientific research if we are to advance our understanding of the organism. His conclusion and prescription for the future emphasizes only that we should return to a proper study of the organism itself, to its development, and to other aspects of its complex organization. Good enough: he does not, however, address the need to look for reference points outside of science that might provide the kind of direction that is obviously missing from the ongoing paradigm. So it is hard to see how biology is going to recover the organism in time to save it from the kind of relentless destruction that biology is now presiding over. Lewontin together with most of us assumes that all the answers will continue to come entirely from within science; the same assumption that E. O. Wilson makes and the same assumption that Berry is critical of in his book. At the very end of *The Triple Helix*, Professor Lewontin gives his prescription: "Progress in biology depends not on revolutionary new conceptualizations, but on the creation of new methodologies that make questions answerable in practice in a world of finite resources" (p. 129). And while I certainly agree to that I find Berry's prescription to be characteristically larger. In chapter 6 of *Miracle* he relies very much on the work of Wes Jackson and on his scientific vision of Natural Systems Agriculture: "that to be enduring, agriculture must imitate the local processes of nature". In my opinion, that search for "local secrets of nature" is more open to a sought-after consilience between the quantitative-qualitative split in our world view.

This message is particularly important at this time when biology moves into the postgenomic era in a troubled state defined by an inability to define precisely how genetic information will enable biomedical and bioagricultural technologies to fulfill, finally, the many promises made over so many years. And it is important for university leaders who are now contemplating profound changes in the organization of academic biology in an attempt to meet the challenges of the post genomic millennium. Many biologists outside, and indeed many inside, the power structures of molecular biology are voicing grave doubts about the goals and purposes of this planning. While it is clear that genetic analysis, in itself, will not be sufficient to bring us to a new level of understanding of how organisms work or how nature at large works, it remains unclear what will be

required to complement genomics and informatics, etc., so that the next steps may be taken.

Not mentioned by Berry is a growing consensus within the university science community that in order to fix a broken genetic determinism, biology should be infused with healthy doses of physics, engineering, and computational science. Such an interdisciplinary move is to be welcomed, but how additions of more of the same kind of deterministic methodologies will work to fix a broken determinism in biology seems like a complete contradiction. The physicist Howard Pattee expressed this sentiment long ago at one of Conrad Waddington's meetings on theoretical biology. "To say that Life is distinguished from lifeless because it follows the conventional, normal laws of physics and chemistry of lifeless matter is a total non sequitur." The fact is that the goals and purposes of such a new science remain the same: to use these new methods for the purpose of fulfilling the old paradigm; to reduce living organisms and nature to explanations based on physics and chemistry. And many so-called complexity scientists agree with Pattee, but this is another story.

Berry is not opposed to science or to reductionism as its major tool. What he is warning us about is what is missing from it. What is missing and what has been missing all along in the otherwise steep line of progress in biology in the last century is any understanding of how these elementary units of life come together to produce a given phenotype ... a unique morphology or behavior. Also missing is a working concept of the organism alive in its many codependent worlds. In the university there are many expressions of hope and anticipation for future success in this kind of "reorganization," but there are also grave doubts.

Here again is where Berry is so important to the life sciences. His language is also one of belief and anticipation and, indeed, of religious belief. But belief is everywhere tempered in his writing by questioning. The readers of this review will need to have an example of Berry's belief and questioning because the language is so very different from the abstract language of science and yet communicates scientific truths with great clarity. Berry is everywhere and always concerned with the question: What do we do when science hesitates because it does not understand, as I think a growing sector of the biological world is now hesitating? Here is Berry's answer in terms of another of his goals, which is to bring about a consilience between art, religion, and science:

Overhanging all our thoughts and work is the question of how certain of itself human knowledge can be. I learned from the theologian Philip Sherrard to ask this question: If things are evolving, and if human consciousness is evolving along with everything else, where do we find a standpoint from which to understand the whole process? "To make the same point in a more practical way let us take ... that word 'environment' which as used proposes that reality is composed of a creature and its surroundings. But if, as in fact we know, the creature is not only in its environment but of it, and if the relationship between creature and environment is mutually formative, and if this relationship is

a process that cannot be stopped short of the creature's death, then how can we get outside the relationship in order to predict with certainty the effects of our participation? Religion begins with such questions. But even reason can see that they define the issues of propriety and scale. If we can't know with final certainty what we are doing, then reason cautions us to be humble and patient, to keep the scale small, to be careful, to go slow (pp. 150–151).

Of course, the standard answers to any call to slow down simply because we lack certainty of direction is greeted with much disdain and with the counter order "to push on" or "soldier on," as E. O. Wilson and James Watson have said. They have their reasons and in the pages of this book many of them are taken up and smartly rejected by Berry in a manner that will cause some hesitation among all but the most committed biotechnologists.

In redesigning the biology of the future as a "bioengineering" that could lead to what the well-known creator of new technologies Bill Joy fears most—a population of human-robots with powers to survive humans in future evolution—Berry is asking us to go slow. He is asking much more of science that needs to be heard and his prescription for a future biology is one very much related to the work of Wes Jackson, already mentioned, and his search for understanding the "local processes of nature".

In my opinion that same vision is applicable at all levels of biological organization, including application to those populations of organisms organized in communities of large urban centers. The urban engineer Jay Forrester, looking for a proper solution to a complex problem, put it this way: "Compensating counteractions (within the system) can be disastrous if the applied programs are expensive. The external financing may be impossible to sustain. . . . Probably no active, externally imposed program is superior to a system of modification that changes internal incentives and leaves the burden of system improvement to internal processes" (Forrester, 1969: 111).

Throughout the book Berry reminds us that propriety "is an old term . . . and is not much in favor. Its value is in its reference to the fact that we are not alone," and "makes an issue of the fittingness of our conduct to our place or circumstances. Propriety acknowledges the always pressing realities of context and of influence." The new surge of interest in epigenetic processes in living systems (context-dependent regulation of gene expression) is moving to expand our theoretical and experimental considerations to a wider context, but the need for an even wider consideration is already upon us.

In the final chapter Berry says: "The time is past when . . . you can just discover knowledge and turn it loose in the world and assume that you have done good. . . . This . . . is a sign of the need for strenuous conversation among all the branches of learning. This is a conversation that the universities have failed to produce and in fact have obstructed."

Technology produces change, novelty, clever devices, and machines, all with demonstrated effectiveness when applied in the world of everyday life. But the demonstration rests on an inadequate and flawed system of accounting where

what is added in terms of positive benefit in the short run does not include the unanticipated negative benefits in the long run and does not account for "negative externalities" that show up in areas distant from the locus of application. Berry calls this "addition without subtraction": an accounting system that would be recognized as inadequate by a ten-year-old but is held by most adults as a necessary price for "progress". Science is something else. My own preference for defining science in terms of achievement has been the definition from Edmund T. Whittaker:

> The most notable achievement of modern science is not to be sought in the multitude of inventions to which it has given rise . . . a greater weight is very properly attached to its work in revealing to mankind the hidden plan of Nature. And perhaps the most effective of all, so far as its influence on intellectual culture is concerned, is the change that it has brought about in the standard of reasoning, in precision of thought and grasp of fundamental notions; this it has accomplished by creating a new type of rigorous thinking, more accurate and penetrating than the argumentation of an earlier age. (Whittaker, 1948)

Without doubting for a moment the many advances provided for by the quantitative thinking so highly valued in modern science, I must say that Berry has caused me to doubt that scientists have any advantage at all over any intelligent observer of Nature willing to think and think again and again about the balance of human affairs that has taken place in the recent times so dominated by science and the new type of rigorous thinking. The difference between the modern scientist of Whittaker and the scientist of today, or a lay thinker like Berry of today, is a willingness to apply that rigorous scientific thinking in an evaluation of the degree of success it has provided in revealing the hidden plan of Nature. When the science of today has become the technology, which is the case in much of biology today, then there is, as Berry suggests, no opportunity for science to remove itself to an objective perspective and to a proper evaluation (addition with subtraction) of what in fact the technology has wrought. And when a Wendell Berry with no scientific credentials shows up, he is not allowed any weight for his analysis. Read him for yourself and join him outside the box of so much thought about modern science which is inside the box.

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