CULTIVATING AN ECOLOGICAL CONSCIENCE

Essays from a Farmer Philosopher

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What Constitutes Sound Science?

Both religion and science have always been in a state of continual development. . . . Science is even more changeable than theology. No [person] of science could subscribe without qualification to Galileo's beliefs, or to Newton's beliefs, or to all his own scientific beliefs of ten years ago.[1]
—Alfred North Whitehead

The vast growth of science in the last 300 years proves . . . that new aspects of reality are constantly being added to those known before.[2]
—Michael Polanyi

Marion Nestle has argued that the public no longer receives the best scientific information regarding diet and health. Nestle is a renowned nutritionist with years of experience working on nutrition and dietary guidelines for the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA). She outlines in her provocative book, *Food Politics,* how the food industry regularly stifles the scientific community when its findings conflict with the financial interests of the industry.[3]

Nestle, in fact, comes to a disturbing conclusion. Science, she suggests, is now often used to defend a position already adopted rather than to discover new or truer descriptions of reality. It is science designed to persuade, rather than science meant to explore and enlighten. One can see this phenomenon at work in the genetic engineering debate. Both sides in the debate regularly attempt to use science to sustain positions they have already adopted, rather than encouraging scientists to freely investigate and pursue a fuller understanding of the biological world.

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Barry Commoner points out that substantial scientific evidence exists to question genetic engineering's core idea, the "central dogma," which is the "one-to-one correspondence of gene to protein" and the corresponding belief in biological determinism. But despite the fact that the one-to-one theory has now been largely invalidated, the dogma still stands. The reason for this intransigence, Commoner suggests, is not just the "traditional scientific economy of prestige and generous funding that follows it" but that money has distorted the entire "scientific process," which was once a "purely academic pursuit" and has now "been commercialized to an astonishing degree by researchers themselves."[4] So, has money simply corrupted science?

Evelyn Fox Keller, from MIT, notices an even greater incongruity: "The basic fact is that, at the very moment in which gene-talk has come to so powerfully dominate our biological discourse, the prowess of new analytic techniques in molecular biology and the sheer weight of the findings they have enabled have brought the concept of the gene to the verge of collapse."[5]

How could the biological sciences be dominated by a dogma that is largely discredited? Keller argues that the problem is rooted in "gene talk." Scientists, she says, "are language-speaking actors," and "the words they use play a crucial role in motivating them to act, in directing their attention, in framing their questions, and in guiding their experimental efforts." She suggests that "what is missing, and would be absolutely required for understanding the role of language in biological research, is a far deeper investigation of the material, economic, and social context in which that language functions."[6] The problem is not just with money, but also the culture of science.

The debate over how best to "feed the world" in the face of an exploding human population entails similar problems. Under the spell of the central dogma, some scientists maintain that only by increasing the yield of a few commodity crops through technological innovation will the hungry be fed. Supported by powerful economic interests, our culture of science continues to maintain that our most complex societal problems can be solved only with technological innovations.

However, recent research in biology, physics, and sociology reveals a more complex world than previously imagined. Emerging complexity does not lend itself well to linear technological manipulation, indicating the need for more humility in our interactions with the environment. As Keller concludes, "It is a rare and wonderful moment when success teaches us humility, and this, I argue, is precisely the moment at which we find ourselves at the end of the twentieth century."[7]

But humility is seldom evident among scientists who use science primarily to produce technological innovations. For example, in defending his position that the world's hungry can only be fed with transgenic technologies, Norman Borlaug insists that science has already given us all the information we need to establish the soundness of his position, and that opposition to it is based on "fear born of ignorance."[8] Such arrogance inevitably leads to the position that the science one uses to validate one's own position is sound, while the science used by one's opponent is junk.

How did we get here? How did we come to believe that science is a discipline that produces irrefutable facts and that its role is to defend those "facts"? What happened to science as process and science that encourages questioning established dogma? What happened to science that continually discovers new ways of interpreting the world around us? We need science that probes rather than proves.

What Is Science For?

How we got here can be determined, in part, by tracing the history of U.S. public science policy after World War II. The war cemented the importance of technological innovation in the public consciousness. Superior technology, we believed, enabled us to win the war. So when the Cold War emerged, we readily turned to science and technological innovation as the keys to outcompeting our new enemies, thereby proving the superiority of our economic and political system. The technological innovations required to conquer space became key symbols in the new war. Outperforming our enemies economically and developing technological innovations to win this peculiar new "war" became central to our defense strategy.

The quality of science in the United States was evaluated almost exclusively in terms of its ability to deliver technological innovation. Scientists were rewarded for developing new technologies, not for discovering how the world worked or how the synergies and synchronies of nature functioned.[9] This trend was also supported by political and business leaders and the public, all of whom wanted to explain science in simplistic terms that could be easily quantified and justified—and funded.

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President Franklin D. Roosevelt requested a report on science policy, which Dr. Vannevar Bush, director of the Office of Scientific Research and Development, published on July 25, 1945. The report, titled "Science, the Endless Frontier," began with this statement: "New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war, we can create a fuller and more fruitful employment and a fuller and more fruitful life."[10]

While the report pays lip service to the importance of basic research, referring to it as "scientific capital," such research is never regarded as valuable in its own right. Rather, it is seen as "essential to the achievement" of the goals in the report. And those goals are the technological advances that will "create more jobs," "make new and better and cheaper products," and create "more abundant crops," among other things.

The report also proposes that "the government should foster the opening of new frontiers." And it suggests that the "modern way of doing it" is to extend government support to "industrial research" and "provide suitable incentives to industry to conduct research." That could be accomplished by making research tax-deductible and by strengthening the patent system. While the report strongly supports freedom of inquiry so that "scientists are free to pursue the truth wherever it may lead," even this caveat is couched in terms of industrial competition.

This new vision for the role of science set the stage for the next fifty years of research. It launched a research funding structure that created partnerships among industry, government, and universities for the primary purpose of increasing economic competitiveness. In the 1980s, three new laws further propelled science into the business of doing research to promote private financial benefits. In 1986, Congress passed the Federal Technology Transfer Act, which amended both the 1980 Bayh-Dole Act and the Stevenson-Wydler Technology Innovation Act. These legal changes were designed to increase U.S. productivity and give the United States an advantage over foreign competition.[11] Benefits of publicly funded research were shifted from the general public to private industry, on the assumption that the public would benefit *indirectly* as a result of increased jobs, higher wages, and improved quality of life.

As a result, science has become even more narrowly focused. Efforts to understand and explore the complexity of nature have been superseded by efforts to develop technologies that could extract economic benefits from nature. Research agendas began to favor powerful industries and organizations that can demonstrate technological success, such as putting a man on the moon. As a result, centralized, linear organizations with greater power to determine the direction of future research have emerged. Winning has become more important than understanding. Applied research leading to utilitarian results was given preference over basic research leading to enhanced intellectual capacity, a transformation now generally referred to as the industrialization of science.

Overall, research is most valued if it contributes to technological advancement. Increasingly specialized, single-discipline-based inquiry that results in new and powerful technologies is favored over multidisciplinary approaches to increase wisdom. Qualitative measures to determine collective well-being are less important than quantitative measures to evaluate singular, technological tactics. The value of research is now judged almost exclusively on utilitarian results. If a research project produces a pesticide that kills a target pest, it is successful and rewarded, even if it doesn't reduce the overall amount of crop loss due to pests. Our interest is in the technological capability of killing pests, not in understanding the more complex biological systems within which pests emerge.

Utilitarian science has resulted in at least three unintended consequences that plague science today. First, utilitarian science tends to misapprehend the true nature of problems because it assumes that (1) the structure and composition of ecosystems can be simplified to achieve the efficient production of goods and services, (2) problems lend themselves to technological solutions, and (3) control management is effective.

But most problems are systemic, nonlinear, and evolutionary in character. Social and biophysical problems are dynamic and complex, and they seldom lend themselves to technological solutions or control management.[12] Most observant farmers know this well. Consequently, the public is often disillusioned by the long-term results of scientific research, despite being initially enamored by short-term successes. This tends to undermine public confidence in science.

A second unintended consequence of the utilitarian approach to science is separation from nature. Nature is something to be used, not something to which we belong. This has alienated the public from nature and science.

Science belongs to the experts. Science is something the experts use to extract benefits from nature for our benefit. It is not something that *we* use to better understand nature or our place in it.

Third, by focusing on short-term, utilitarian results, science tends to ignore potential, long-term ecological consequences. Science focuses on the immediate potential benefits of developing a technology like DDT, but it pays little attention to exploring the potential long-term effects of the release of DDT into an environment composed of millions of very complex, interdependent, living, emergent organisms. The failure to recognize these ecosystem complexities and emergent properties has led to numerous incidents in which technological innovations caused harm to human health and the environment, despite initial assurances by scientists that the technologies were safe. This tends to erode the public's trust in science.

Jennifer Wilkins, at Cornell University, examined how land-grant university educators "view complex and interrelated issues related to GE [transgenic] food crops."[13] Wilkins's study revealed "a growing constituency that questions the extent to which LGUs are upholding their original mission to improve the lives of rural people and to bring benefits to a broad constituency of common citizens."[14]

The idea that research should enhance economic competitiveness has become so entrenched in the culture of science that it is difficult to even find a venue for discussing alternative values for science. But as we enter the twenty-first century, I argue that we should emphasize research that:

- Enhances global *cooperation* rather than research that increases *competitiveness*
- Is multidisciplinary and increases our understanding of evolving complexities and interdependence of our social and biological lives, rather than disciplinary research focused on producing more new technologies
- Focuses on more secure and efficient distributive, decentralized, flexible systems rather than the highly coupled, centralized, linear systems that evolved out of our economic competitiveness research
- Pays closer attention to the "ecological overshoot" of our human economies, rather than bolstering the economy with technologies that negatively affect the planet

Such reassessments were called for in a highly publicized presidential address by Jane Lubchenco at the annual meeting of the American Association for the Advancement of Science on February 15, 1997. In that talk she called for an entirely "new social contract for science."[15] She argued that given the magnitude of the impact that humans now have on the planet's ecosystems, and our increased realization of the "intimate connections" between ourselves and the ecologies in which we live, science can no longer ignore that it now has a new, if unspoken, mandate. Lubchenco suggested that the new contract needs to "more adequately address the problems of the coming century than does our current scientific enterprise."[16] She argued that the new contract must be predicated on three assumptions. The new contract would assume that scientists should:

- Address the most urgent needs of society in proportion to their importance
- Communicate their knowledge and understanding widely in order to inform decisions of individuals and institutions
- Exercise good judgment, wisdom, and humility

There is that word "humility" again.

Lubchenco also said that "the contract should recognize the extent of human domination of the planet. It should express a commitment to harness the full power of the scientific enterprise in discovering new knowledge, in communicating existing and new understanding to the public and to policy makers, and in helping society move toward a more sustainable biosphere."[17]

Lubchenco's call for a new social contract is a challenge to radically transform the scientific community as we enter the twenty-first century. The scientific community is called to emphasize the "pursuit of knowledge about how the world works" over manipulating pieces of nature for purely human benefit, especially when such manipulations place additional burdens on the planet. The scientific community is asked to emphasize serving the public with wisdom and humility as opposed to serving narrow economic interests. The scientific community should reorder its priorities to "investigate more complex, interdisciplinary problems that span multiple spatial and temporal scales."[18]

In the years since Lubchenco issued her challenge to the scientific community, not much has changed. Why not? Does this new vision *not* constitute good science?

What Is Good Science?

The industrialization of science hardly began with Vannevar Bush or World War II. The foundation for a science that evaluates its success in terms of the technological innovations it produces has deep roots in Western culture, reaching back at least to the sixteenth and seventeenth centuries. The central dogma behind industrial science is rooted in the mathematics-based science of René Descartes, who articulated his philosophy of science in *Meditations,* published in 1641. Descartes believed that one could, and must, separate the thinking mind (or subject) from the material world (or object). By doing so, he believed one could establish objective certainty, wholly determinable and free of any subjective judgment. It was on this basis that Descartes could speak of material reality in strictly mechanical terms. His belief formed the basis of the "disinterested" sciences that produced the knowledge and the technologies, as well as the culture that made industrial science possible.

Descartes' description of the world as a mechanistic "object" represented an emerging culture at the time. Francis Bacon, a contemporary who espoused this same mechanistic philosophy, promoted the idea that nature could be controlled and manipulated for the exclusive benefit of humans. It was Bacon who first proposed the idea that it was our responsibility to "bend nature to our will." No longer was nature a teacher to whose ways we must conform; nature was a passive object that we must manipulate for our own benefit. Casting nature as an objective reality separate from us, and promoting the belief that nature could be controlled and dominated for our benefit, laid the foundation for the modern industrialization of science.

At the time even conservationists adopted Bacon's point of view. William Derham, a student of Bacon's, declared that we can "penetrate into the bowels of the earth, descend to the bottom of the deep, travel to the farthest regions of this world, to acquire wealth, to increase our knowledge, or even only to please our eye and fancy."[19] Derham even described how we should conduct research to achieve those ends: "Let us cast our eyes here and there, let us ransack all the globe, let us with the greatest accuracy inspect every part thereof, search out the inmost secrets of any of the creatures, let us examine them with all our gauges, measure them with our nicest rules, pry into them with all our microscopes."[20]

Descartes' worldview has, of course, been largely discredited, although the culture of modern science seldom acknowledges it. Descartes' assertion that it is possible to separate the thinking mind from the material world has been invalidated in philosophy by both existentialists and phenomenologists, and in science by physicists, following the discovery of quantum theory and the theory of relativity. In philosophy and physics that transformation is essentially complete, and in the field of biology it is just under way. Although the basic concepts that underlie industrial science have largely been abandoned, the segment of science engaged in technological innovation appears to still be largely unaffected by that transformation.

We now know that mass is a form of energy, and particles are not like tiny billiard balls but are more like bundles of energy that are constantly changing. We now know that organisms are not wholly determined by their genes, but by complex interactions within and among organisms, and between organisms and their environment.[21] Yet we still continue to develop technological innovations as if the world consisted of static, linear, isolated, determinable functions.

Perhaps the reason that it is so difficult for us to translate our scientific knowledge into practice is that our new knowledge about how the world works seems contrary to our ordinary experience. Our situation is not unlike that facing Copernicus in the sixteenth century. Copernicus had the difficult task of convincing his contemporaries that the Earth revolved around the sun, contrary to their everyday experience, which seemed to suggest that the sun moved around the Earth. We have the difficult task of convincing our contemporaries that we are plain members of the biotic community, when everyday experience seems to suggest that we are in charge.

In the interest of good science, we must continue to explore how the world works and adapt our technological innovations to those discoveries. Basic science is not simply the "science capital" that drives innovation, but the essential framework that determines the appropriateness of the innovations we pursue. Adapting our technological innovations to the best information that basic science can provide is particularly important when innovations have the potential to cause irreversible harm.

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All of this could be dismissed as so much philosophical rhetoric were it not for the fact that the way we *perceive* the world has profound effects on the way we *relate* to the world, and therefore on how we act upon the world.

David Abram put it succinctly: "Ecologically considered, it is not primarily our verbal statements that are 'true' or 'false,' but rather the kind of relations that we sustain with the rest of nature. . . . A civilization that relentlessly destroys the living land it inhabits is not well acquainted with *truth,* regardless of how many supposed facts it has amassed regarding the calculable properties of its world."[22]

What is scientifically true or false is not the facts we utter, but how we live in the world. Adopting a way of knowing that assumes we can act upon the world in which we live without consequences, separates us from nature, and makes us arrogant can have dire outcomes, not only for ourselves but for all the organisms in the biotic community for all generations. Living truthfully, in an ecological sense, is one of the most important decisions we all make. But how do we *know* what it means to live truthfully in an ecological sense?

Insights from the work of Michael Polanyi, a twentieth-century Hungarian physicist/philosopher, are useful for rethinking the epistemological paradigm for science for the twenty-first century.[23–26] Polanyi, who has written extensively on the epistemology of science, provides four key components of sound science:

Indwelling. Contrary to the objectivist science of Descartes, Polanyi argues that it is never possible to separate the knower from the known. We always indwell what we know. Such indwelling is not to be confused with subjectivism, however. Subjectivism and objectivism are both victims of the same fallacy. Objectivism assumes the knower can separate himself from what he experiences *externally* and therefore can establish certitude, while subjectivism assumes that the knower can separate himself from what he experiences *internally* and therefore can establish certitude. Both ignore the fact that no knowledge exists apart from the participation of the knowing person (the subjective side) in the knowing target (the objective side).

The only way we can know anything is by dwelling in the clues that point to a meaning we are struggling to understand. This is true of all knowing, whether one is struggling to understand the meaning of a black hole or the most commonly accepted mathematical formula, such as 2 + 2 = 4. Even the most explicit scientific data become knowledge only as the knower dwells in the data to understand its meaning. Apart from the participation of the knower, the data only exist as markings on a piece of paper.

All knowledge contains three poles. All knowledge is an activity that contains three poles: the knower, our subsidiary awareness (a multitude of our experiences, beliefs, memories, and sensory operations), and our focal awareness (the focus of our attention—that which we are striving to understand). All knowledge thus exists in a from-to relationship.

Given the threefold nature of the knowing process, knowledge can never be precise information. Knowledge is always a skillful act performed by the knower in which the knower is perpetually relying on what she tacitly holds to be true in order to attend to what she is struggling to understand. This means we always live in the tension between what we are and what we are seeking to understand.

Discovery. We are in a constant state of discovery. All sentient beings are inclined to struggle continually for more coherent and comprehensive integrations of meaning and satisfying interpretations of reality. The knowing process, therefore, is not a mechanical accumulation of exact, precise findings, but a heuristic enterprise that includes many false starts and many surprises.

For Polanyi, this means there is no such thing as dispassionate, value-free inquiry. Our inclination to constantly find new integrations of meaning is driven by passion, and that passion is always shaped to some extent by our tacit awareness. Einstein was convinced that the theory of relativity was correct long before he could produce scientific evidence to substantiate his conviction. His passion to discover new integrations of meaning rather than accumulating objective facts led to his discovery.

Commitment and risk. The knowing process, according to Polanyi, always begins as an act of faith. Since truth can never be established independently of the knower, the knower always has to begin with certain assumptions —that words have meaning, that the scientific method is reliable, and the truth we seek to discover exists.

Thus, all knowledge involves risk, which Polanyi describes as an unavoidable tension between our conviction that we know something and our awareness that we may be mistaken. Given this tension, we cannot escape personal vulnerability in the knowing process. Driven by passion to constantly discover higher integrations of meaning, we state our findings, despite the hazards involved. There is no way that an outside observer can compare another person's knowledge of the truth with the truth itself; he can only compare it with his own knowledge of it.

Our dependence on the perceptions of others to validate our own conclusions mandates the need for a scientific community—or what Polanyi liked to call "the society of explorers." Because we all act out of our own tacit awareness, which is by definition personal, we cannot escape our own personal histories and biases any more than we can crawl out of our own skins. There is no way that we can verify the "truth" of our perceptions without subjecting them to the perceptions of others who are focused on the same knowledge we are trying to understand. This makes a "community" of scientists indispensable to good science and humility essential to the scientific enterprise.

Implications for Good Science

Polanyi's analysis has important practical implications for the way we do science. According to Polanyi, claiming to be objective in science can be a dangerous illusion because it impedes scientific progress and emphasizes observational accuracy at the expense of understanding subject matter.[27] Once scientists have convinced themselves that a phenomenon is an irrefutable fact, they will no longer explore its veracity; thus, they will deprive the scientific community and society of any potential benefits derived from further exploration. The effort to establish irrefutable facts focuses science on quantitative analysis at the expense of higher levels of understanding that could be more beneficial to society in the long run.

Therefore, understanding *why* a pest is a pest could lead to more effective pest management than simply inventing a pesticide that can kill a measurably larger number of target pests. Attending to the complex set of factors that make farms profitable or not might help farmers more than inventing yet another technology to increase the yield of a single crop. While the latter is infinitely more quantifiable, it is less likely to help farmers understand the "truth" of the condition of their farms.

Polanyi's concept of "indwelling" invites the knower to become personally involved in what he is struggling to understand, because indwelling is essential to achieving real meaning. In fact, the detached knowing inherent in Cartesian epistemology, together with its attention to particulars at the expense of integration, prevents us from achieving real understanding and alienates us from the thing we are trying to understand. We understand things not by looking at them but by dwelling in them. The "belief that, since particulars are more tangible, their knowledge offers a true conception of things, is fundamentally mistaken," writes Polanyi.[28] Science that recognizes the importance of indwelling and integration in all knowledge might be better equipped to tackle some of the complex issues facing us in this ecological era.

Adopting Polanyi's approach could affect how science is carried out. Instead of focusing on the invention of a particular technology to be transferred to farmers, scientists might dwell in the world of farmers to gain a fuller understanding of the implications of the technology for farmers, farms, and the social and biotic communities in which farms exist.

Polanyi's way of knowing requires that scientists be free, within the bounds of professional standards. What makes freedom necessary in good science is the unspecifiability inherent in all discoveries. Any master plan for science would stifle discovery. The very act of developing a specific set of objectives and directing how science is to achieve them prevents science from following a free and consensual process. Good science is not likely to result from a prescription. Since it is the nature of science to pursue what no one yet knows, any effort to direct science ends up destroying science.

Adopting Polanyi's epistemological posture reduces the likelihood of using science to defend a position one had already adopted. Instead of using science to persuade farmers to adopt what we have invented, we might use science to revisit current systems of farming and explore alternatives.

- Because a community of scientists is essential to good science—owing to the vulnerability of our personal knowledge—any proprietary information in the knowing process is by definition bad science. All of our findings, arrived at through the process of knowing, which is grounded in our own tacit awareness, must be submitted to others who are likewise struggling to understand similar phenomena.

Thus, any science claiming validity that has not been scrutinized by a community of independent scientists exploring similar data cannot be considered good science.

- Because we always live in the tension between our convictions that we know something and our realization that we could be wrong, humility is essential to good science.
- The nature of sentient beings is to continually struggle for more coherent and comprehensive integrations of meaning. Any science that limits its investigations to linear, reductionist observations at the expense of struggling to understand the more complex, interdependent realities of which these observations are a part cannot be called good science. Despite all the technological innovations that surround us, our world is still a living, vibrant, biotic, and constantly changing community. Good science tries to make that world more transparent to our experience.

Of Science and Conversation

The environment in which we live exists only by virtue of millions of organisms modifying their environment out of the bits and pieces available to them. In the course of this activity, they create challenges and opportunities for those other species that share their space in an ecosystem.[29] The most appropriate science in such a world should not lead us to detach ourselves from this community in the interest of some kind of supposed precise information. Appropriate science would not oversimplify the complexity of the biotic community, nor presume we can know all we need to know to proceed with our technological innovations with impunity. The most appropriate science would be one that invites us into conversation with that community in all its complexity.

Stephen Talbott suggests guidelines we might use for such a science of conversation.[30] First, every technique we use, industrial process we initiate, and technology we introduce should be "a question put to nature." With each of our innovations, we are trying to remedy some ignorance, and for precisely that reason we should act with caution and humility. Thus, we should never introduce a technology as an answer to a problem, but as a question put to nature to ascertain its appropriateness.

Second, in a conversation we are always to some extent "compensating for past inadequacies." So part of any conversation involves an attempt to heal what we have harmed in prior conversations. It is always better to admit this at the outset. Ignoring the harm we have done in the past will likely lead to similar or even worse errors in the present. Part of the task of good science, then, is to learn how to continually enhance the health of the biotic community as we converse with it. And, as Aldo Leopold reminded us, health, in this context, is the capacity of the biotic community to renew itself.[31] Our task is not to "save" the environment, nor to preserve things as they are (neither of which is possible), but to enhance environmental capacity for renewal.

Third, in a conversation there is never any single right or wrong response. This is where creativity comes in. The alternatives that exist depend in large part on the alternatives we encourage. Good science is inventive. Declaring that there is only one way to feed the world is bad science.

Fourth, conversation always takes place in the particular. We cannot have a conversation with an abstraction. We can only have conversations with particular individuals. We cannot reasonably save a species, we can only engage in the work of restoring a particular habitat of a particular species. We cannot reasonably feed the world, we can only engage in activities that improve the food security of particular villages or communities.

Conversation is a useful metaphor for describing good science and good soil management, although the science of the industrial world has been a monologue rather than a dialogue. *We* decide what technological innovations to introduce, based on what we believe will enrich *us* without regard for the impact our innovations will have on the larger biotic community. In introducing innovations, we assume we know all we need to know to proceed without caution. We behave as if the biotic community belongs to *us*, rather than entertaining the possibility that together with all other organisms, we belong to the biotic community. Nothing that we now know about the workings of the biotic community justifies continuing down that path.

Good science in the future should spend more resources mapping nature's interconnections and not treat organisms like arbitrary collections of interchangeable parts. It should ensure the future productivity of agriculture by learning to understand the complex relationships among organisms and between organisms and the environment, and it should abandon the effort to invent new technologies to address singular production problems or singular pest problems.

In this regard, good science also is local. As David Abram reminds us, "We can know the needs of any particular region only by participating in its specificity—by becoming familiar with its cycles and styles, awake and attentive to its other inhabitants."[32] That suggests that good science is more likely to be conducted in the context of local cultures and local ecologies, rather than in some abstract, universal global community.

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