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Whither Bioscience? Benevolence or Bioviolence?

Bioviolence: Preventing Biological Terrorism and Crime. Barry Kellman. Cambridge University Press, New York, 2007, 390 pp. $28.99 (9780521709699 paper).

In his book *Bioviolence*, DePaul University International Law Professor Barry Kellman seeks to mobilize the world to counter the deliberate use of microorganisms to inflict harm—a uniquely dangerous yet uniquely accessible threat.

The title, *Bioviolence,* cuts through long-standing debates over whether one person's terrorist could be another's freedom fighter, or whether a given act of violence is a crime, an act of terrorism, or an act of war. These different cases need to be treated differently in detail, but considering them all as "bioviolence" reinforces the global norm that *any* use of a biological agent to inflict harm is categorically condemned.

Kellman outlines the threat historically and technically, covering both state and nonstate programs. He points out that the power of biological weapons to kill and injure; their silent, delayed, and potentially transmissible effects; their accessibility; and their potential for subsequent attacks make them not only potent but also particularly disruptive. "If you want to stop modern civilization in its tracks," says Kellman, "bioviolence is the way to go."

Although Kellman acknowledges that our lack of experience with biological attacks leaves considerable room for controversy regarding the magnitude of their threat, he takes issue with those who would discount either the intent of terrorists to use bioviolence or their ability to do so successfully. He addresses intent with an impressive collection of evidence regarding Al Qaeda's interest in biological weapons, while reminding us that "even more worrisome is the bio-offender that we do not know about." And to those who question the ability of groups to master an unfamiliar set of technologies, Kellman replies that such skepticism may be "well-founded for the moment, but [it] offers absolutely no security for tomorrow. Indisputably, bioviolence is getting easier to do with each passing day." The evolution in the power and accessibility of bioscience—while clearly to the benefit of mankind—also increases the risk of illegitimate applications. Stating his concerns in a legal vernacular, Kellman finds that "there is opportunity and there is motive."

Kellman lays out a comprehensive and far-reaching set of responses to the threat of bioviolence, some of which will no doubt prove to be even more controversial than his assertions about the threat. His strategy consists of four components:

1. complication, or measures to deny terrorists the capabilities they need and to make their efforts easier to detect;
2. resistance, or the conduct of research to counter bioviolence (i.e., through development of therapeutics, prophylactics, and vaccines) in ways that minimize the exacerbation of bioviolence;
3. preparedness, or mitigating damage in an attack through early detection, response, and containment; and
4. nonproliferation, or measures to inhibit state-level development of biological weapons in violation of the existing Biological Weapons Convention.

Preparedness may be the most straightforward. Kellman presents a thorough explanation of preparedness and response options, and particularly their legal implications. The reader gets an overview of the strengths and weaknesses of measures such as protecting air circulation systems and water supplies, the deployment of environmental sensors to detect pathogens, health surveillance systems, microbial forensics, treatment of victims, and the stockpiling and distribution of medical resources. In addition, the author devotes attention to legal issues such as compulsory medical treatment of victims, quarantines, and the right to privacy of medical information. In a later section, Kellman also takes on liability and intellectual property issues related to development of therapeutics and vaccines. Overall, he finds the magnitude of the preparedness and response mission to be daunting, and the measures now in place to be insufficient—reasons why prevention (or, as he calls it, *complication*) need to be pursued as well. "Now and for the foreseeable future," he concludes, "response planning is in many respects a self-congratulatory myth."

Kellman's discussion of *resistance* addresses the fact that advances in science and technology to fight disease will inevitably develop knowledge and capability that could be misused to exacerbate that threat. In this section, he comes down firmly against governmental constraints on the conduct or communication of science, on the basis not only of the adverse consequences of limiting beneficial research and constraining freedom of inquiry but also out of concern as to what might become the politicized control of science. Consistent with this position, Kellman forcefully argues that the capacity to conduct scientific research must be bolstered in developing countries—including those that might be thought likely havens for terrorist groups. These countries, more than others, need to understand and apply the tools to deal with bioviolence.

Kellman recounts the conclusions of a National Academies panel (on which he served) that focused on the risks posed by the misuse of biological research. That panel's landmark 2004 study, *Biotechnology Research in an Age of Terrorism,* acknowledges the risks posed by developments in bioscience and biotechnology, but argues that the way to deal with them is through increased awareness and self-governance on the part of the scientific community (NRC 2004). Kellman appears to support this report's

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findings, but he does not believe they go far enough. In addition to urging a substantially strengthened role for law enforcement—discussed below—he calls for the bioscience community to "demonstrate a more substantial commitment" to policies the National Research Council did not address, such as professional certification of scientists (extending all the way to identification of their individual activities) and the encouragement and protection of whistleblowers.

The most controversial aspects of Kellman's approach fall under *complication,* which he assigns to law enforcement. The problem, however, is that law enforcers in most nations have inadequate authority and woefully insufficient information to fulfill this mission. The first requirement, therefore, is to criminalize activities that could lead to bioviolence, which has been done in the United States but in too few other countries. Such laws are necessary to give police the authority to conduct investigations, but the US statute illustrates the difficulties: it is a federal crime to possess a biological agent only when doing so is "not reasonably justified" by bona fide research or other legitimate purpose, and when the agent has not been cultivated or extracted from its natural source.

While cautioning against overbroad regulation, infringement on scientific autonomy, or the violation of personal privacy, Kellman proposes closing the information gap by requiring the submission of information on pathogens, critical laboratory equipment, and facilities, and by linking such information with data on criminal networks to uncover indications of illicit activity. He also posits such mechanisms as marking pathogens by coding their DNA and tracking equipment with global positioning system transponders, and he anticipates eventually extending such a monitoring system internationally. It is not clear whether the activities of individual scientists would be monitored: his discussion of data reporting states that they would not be, whereas a different section on scientific self-governance concludes that oversight that does not "identify individual scientists and...keep track of their activities" is not real oversight at all. Perhaps the distinction is who would be doing the monitoring.

[I]f there is a choice between attempting to monitor scientific activity in the name of security and attempting to control it, I would support monitoring.

Whether these proposals should be implemented is a different question from whether they should be discussed. In general, if there is a choice between attempting to monitor scientific activity in the name of security and attempting to control it, I would support monitoring—and given the globally consequential nature of the misuse of bioscience and biotechnology, the option of "neither one" may not be available. I therefore welcome Kellman's willingness to offer proposals such as these, and I hope they will receive serious attention.

On the other hand, his case for extensive monitoring and reporting of scientific activity is far from compelling. Any successful measure to mitigate bioviolence has to be *useful,* in that it has to have some reasonable expectation of reducing risk, as well as *feasible,* in that it must be implementable at acceptable cost (see Epstein 2003). Monitoring systems face the challenge of being sensitive enough to identify questionable activity without being rendered useless by false alarms. I doubt that the system described here would pass that test unless it would be far more intrusive than any party would find acceptable, given the diversity and extent of the legitimate global bioscience and biotechnology enterprise, along with the relatively low barriers facing those who would work outside it. But in laying out this proposal, Kellman puts the onus on critics to come up with something better, or to demonstrate that its costs exceed its anticipated benefits.

Under the fourth component of his strategy—nonproliferation—Kellman addresses two challenges to the Biological Weapons Convention regime: the development of "nonlethal" or incapacitating biological agents, and the national pursuit of biodefense research programs. For the former, he provides an excellent portrayal of pro and con positions. For the latter—which at the technical level can be very difficult to distinguish from an offensive weapons program—he calls for measures that include *translucency,* or partial openness, in information sharing. Although complete transparency might allay suspicion that an ostensibly defensive program was actually a front for secret offensive activity, it would also confer undue advantage to those seeking to defeat those defenses.

In the concluding section of the book, Kellman returns to his original disciplinary base—international law—to discuss global governance. He finds that the confluence of evolving bioscience and nonstate threats transcend and undercut the ability of nation-states to ensure their own security, and he calls for additional United Nations (UN) bodies to take on coordination, harmonization, and investigation. The latter mission, the most contentious of these, would not build on the existing Biological Weapons Convention but rather draw on the much more robust powers of the UN Security Council.

All told, this is an important book. It provides a comprehensive view of the bioviolence threat and proposes a diverse, integrated, and provocative set of approaches for dealing with it. It challenges our thinking and forces us to revisit assumptions regarding individual liberty and community responsibility. We can disagree with this book—but we cannot ignore it.

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SCIENTISTS AND DEMOCRACY

The Honest Broker: Making Sense of Science in Policy and Politics. Roger A. Pielke Jr. Cambridge University Press, Cambridge, United Kingdom, 2007. 188 pp., illus. $29.99 (ISBN 9780521694810 paper).

The Honest Broker is a must-read for any scientist with even a modest interest in environmental policy or politics, and I recommend it especially to scientists unfamiliar with the continuing controversy over how scientists misuse science in environmental policy and politics. The book will also be of interest to political scientists and others well versed in the scholarly literature concerning science, scientists, and public policy, but Roger Pielke's core analysis and message will not be surprising to these readers.

Pielke begins by recognizing that scientists and science can and should play useful roles in environmental policy and democratic politics, but they can also confuse, muddle, or otherwise impede sound decisionmaking. In a healthy democracy, policymakers and citizens need accurate, relevant, and unbiased science to decide how best to proceed on environmental issues.

The book is an easy read and explores the subject systematically, starting with an in-depth description of the options available for how scientists can participate in policy and politics. On one end of the spectrum is the *pure scientist,* who plays a role that is as independent and isolated from policy and politics as possible. For a pure scientist, research is published in academic journals and no effort is made to help resolve society's current policy challenges. At the other end of the spectrum is the *issue advocate,* a scientist who uses his or her science and scientific credentials to advocate for the policies he or she supports.

Pielke makes the case that another, more helpful role for scientists to play is that of the *honest broker.* He describes how honest brokers of science are essential to a well-functioning democracy and for the overall, long-term health of the scientific enterprise. In short, he recommends that scientists play the role of honest brokers of policy alternatives. A scientist playing this role seeks to expand the scope of policy choices available to decisionmakers and describes as accurately as possible the consequences of each possible choice. This scientist presents the relevant scientific information to the public and policymakers in a very policy-neutral manner.

I found his presentation of the different roles that scientists and science might play in policy and politics to be both fair and accurate. It is apparent that he is appalled by the behavior of some scientists (for example, couching policy advocacy in science), but he nevertheless offers the best arguments available that support such roles. His arguments are often nuanced, but he leaves little doubt where he stands regarding the proper role for scientists.

Case studies are offered to illustrate the proper (and improper) roles of science and scientists. The case studies (such as public controversy over *The Skeptical Environmentalist*, the political storms involving the science and politics of climate change, and the role of intelligence prior to the decision to go to war in Iraq) are very effective in illustrating how science is used and misused in informing decisionmakers and the public. For example, Pielke illustrates how much of the climate "science" debate can be characterized in terms of stealth policy advocacy, in which debates about values and policy preferences are thinly veiled by various competing claims about science. From Pielke's perspective, much of the policy advocacy is unfortunately offered by scientists purportedly operating as policy-neutral scientists.

Pielke illustrates major inconsistencies in how many scientists treat "facts" versus "values." Using the decision to go to war in Iraq as an example (in part on the basis of the likelihood of weapons of mass destruction), everyone agrees that the facts—intelligence assessments—used by politicians ought to be free of policy preference or political spin. Scientists, and others, are appalled when they are not. Many scientists, however, feel no reluctance to argue in favor of their policy preferences regarding stem cell research, abortion, or climate change, even though the facts are only one element of the policy debate.

For many scientists, particularly those in environmental or ecological disciplines, Pielke's message may hit uncomfortably close to home. For political scientists and those who study the roles of science and scientists in public policy, the information and recommendations will be perceived as a summary of widely accepted assertions.

As for weaknesses in the book, sometimes the main themes or take-home messages are repeated excessively. Perhaps I reacted that way because I agree with his message, and I was convinced early in the book that his argument was compelling. Despite the repetition, the use of case studies helped me learn something new about a number of interesting and timely science and policy issues and how science was used and abused in each.

Sometimes people who really offer nothing but political advocacy cloak themselves in scientific ideas and masquerade their policy as science.

Pielke's message will not find a warm reception among those scientists who are also policy advocates. Fair or not, it is true that scientists, at least as perceived by many people, are just another political advocacy group, who, for example, argue for or against ratifying Kyoto, participating in the Biodiversity Convention, and pro-

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tecting marine areas. Sometimes people who really offer nothing but political advocacy cloak themselves in scientific ideas and masquerade their policy as science.

In summary, *The Honest Broker* is an important book, and it should be read by everyone. Healthy democracies need science and scientists to provide what only they can provide: relevant, policy-neutral, understandable science—not stealth policy advocacy. Offering policy advocacy masquerading as science hurts, over the long-term, both democracy and the scientific enterprise.

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MONEY TALKS

Science for Sale: The Perils, Rewards, and Delusions of Campus Capitalism. Daniel S. Greenberg. University of Chicago Press, 2007. 288 pp. $25.00 (ISBN 9780226306254).

Since World War II, the foundation of American science policy has been the notion that science is different from other social activities, and so must be governed differently. This claim to exceptionalism rests on two beliefs: first, that science can thrive only if it is left to govern itself through such activities as peer review and the independent replication of research results; and second, that if society wants to enjoy the benefits of science, it must leave science to police itself, to pursue new knowledge according to its own lights. Of course, the reality is that American science has never been anything close to pure, at least not since the founding of the land grant college system in 1862, which formalized the obligation of university research to serve the needs of the nation's farmers. During the Cold War, American science was central to what President Dwight Eisenhower termed the "military industrial complex," and in recent decades, science has been increasingly called upon to enhance national competitiveness. Nevertheless, exceptionalism is still strong in the rhetoric of science, and it is in this space between base reality and high-minded ideals that the distinguished science journalist Daniel Greenberg has worked for the past 40 years or more.

Whereas in the 1960s only a handful of universities aspired to be national leaders in research across many scientific fields, today virtually every university is engaged in what Greenberg terms an "academic 'arms race'" for more research dollars, more scientific superstars, and more expensive equipment.

In *Science for Sale: The Perils, Rewards, and Delusions of Campus Capitalism,* Greenberg explores the intimate connections between academic biomedical research, government funding agencies, and the pharmaceutical industry. In particular, he is concerned about the increasing emphasis on entrepreneurialism and commercialization in universities, and about whether these values are compromising the integrity and priorities of academic researchers and science.

Although *Science for Sale* has the tone of a polemic, it is in fact a conspicuously well-balanced assessment, grounded both in abundant new evidence collected by Greenberg (mostly from extensive interviews) and his deep knowledge of US science policy. If the tone is somewhat cranky (and vintage Greenberg), this is perhaps an unavoidable consequence of the tension between the "pious" (one of his favorite words) rhetoric of scientists and science advocates and the reality of universities and their researchers engaged in a desperate, never-ending battle for resources—a reality that creates enormous opportunity for conflict.

It's not that Greenberg has any illusions about a former golden age of academic science. His previous books (*The Politics of Pure Science,* 1967; and *Science, Money, and Politics,* 2001) were painstaking chronicles of science as a profoundly political activity. But something important has changed. Whereas in the 1960s only a handful of universities aspired to be national leaders in research across many scientific fields, today virtually every university is engaged in what Greenberg terms an "academic 'arms race'" for more research dollars, more scientific superstars, and more expensive equipment. Greenberg pokes fun at the "megalomaniac proclamations" issuing from places like Quinnipiac University, with its "bold and far-reaching Strategic Plan for Academic Excellence and National Prominence," and Northeastern, which announced a "five-year, $75-million Academic Investment Plan [to build] research strength in four fields of great importance to the welfare of our society" (p. 30). But any university that fails to compete effectively in the arms race will rapidly lose resources, high-quality faculty, the capacity to attract donors and good students, and, perhaps worst of all, standing in the *U.S. News and World Report* rankings. Meanwhile, the rising cost of doing research (and hiring superstars) continues to outstrip increases in the federal science budget.

Common wisdom would have it that the arms race is increasingly supported by corporate funding for university research, but Greenberg correctly points out that there is nothing new about the cozy relationship between academia and industry, and that the percentage of academic research directly supported by the private sector remains rather low (4.9 percent in 2004). In fact, Greenberg documents that pharmaceutical firms are generally unenthusiastic about paying for basic academic research because of the meager returns and the bureaucratic hassles involved. "There is no truth," Greenberg asserts categorically, "to the frequent,

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wholesale depictions of university-based science as a passive appendage of corporate America" (p. 45).

Science for Sale portrays a more multifaceted but nonetheless troubling situation, where a confluence of factors ensures that economic values compete strongly with scientific ones in the laboratory. The factors include the irresistible pressure on universities to expand their research activities and make money off them, public policies that encourage the commercialization of academic research, and a pharmaceutical industry interested primarily in getting products to market. The competition in turn creates an environment that invites conflicts of interest and wishful thinking about how universities can meld the creation of knowledge with new streams of revenue.

The first half of the book is devoted to the pressures and changes occurring in academic biomedical science. Greenberg presents chapter-long treatments of several interrelated problems: the continual searches for corporate benefactors, the increasing (and typically unsuccessful) focus on intellectual property and technology transfer as a way of generating new revenue, and the ethical lapses in the conduct of science, especially industry-funded clinical research. He details oft-told stories, such as the "repulsive circumstances" (p. 151) surrounding the death of Jesse Gelsinger during a gene-therapy experiment at the University of Pennsylvania, as well as less-familiar tales, such as the political machinations associated with efforts of the National Institutes of Health to improve and enforce human subjects regulations. These efforts led to the brief shutdown of research at two alpha-dog institutions, Johns Hopkins (also following a patient death) and Duke University.

The obsession with the commercialization of science at American universities is commonly blamed on the 1980 Bayh-Dole Act, which encourages university patenting of innovations arising from federal research support. Greenberg correctly dismisses this view as simplistic. Rather, Bayh-Dole is one of an array of factors implicated in a powerful cultural shift within academia.

Commercial applications are no longer viewed as an ancillary outcome of research, but rather as both a responsibility of scientists and a central part of the growth strategies of most research universities.

Commercial applications are no longer viewed as an ancillary outcome of research, but rather as both a responsibility of scientists and a central part of the growth strategies of most research universities. Greenberg captures the ambiguity of this cultural change. The traditional belief that useful research is somehow less intellectually worthy is no longer sustainable. But there is a cost, as scientists focus on problems with the potential for more immediate payback, and as the results of university research are increasingly protected by patents and thus excluded from the free marketplace of scientific ideas.

In the second half of the book, Greenberg presents six fascinating interviews with important players in the university-government-corporate scrum, including a scientist who abandoned traditional basic research to pursue the development and commercialization of Taxol, a professor who heads the conflict-of-interest committee at the University of California at San Francisico, and a high-level academic administrator who oversees technology transfer activities at the University of Wisconsin. What emerges is a Rashomon-like picture of the rapidly evolving biomedical research enterprise that complements the earlier chapters.

Of these interviews, the most troubling is that with Drummond Rennie, the deputy editor of *JAMA.* Journals are on the frontlines of the ethical dilemmas that constitute the heart of *Science for Sale,* because the act of publishing a research result is also an act of legitimating the integrity, at least, of the science. Rennie states outright that "what we're talking about is the influence of money on research.... And this distorting influence is huge" (pp. 244–245). Especially in the realm of clinical trials, Rennie has little confidence that journals are able to filter out the bias in experimental design and results, or to fully root out conflicts of interest, introduced by the increasingly intimate ties between academic biomedical researchers and pharmaceutical companies.

In the end, the indignation of reform-minded insiders like Rennie apparently allows Greenberg to adopt a guarded optimism: "Overall, for protecting the integrity of science and reaping its benefits for society, wholesome developments now outweigh egregious failings—though not by a wide margin" (p. 258). This view is driven not by confidence in the ideals of autonomous science, but by Greenberg's hard-nosed understanding of the political context. Biomedical researchers and administrators, like all regulated communities, continue to resist government oversight. But the biomedical community also largely recognizes that government funding depends on public support, and that such support can dissolve—although scientists as a whole seem particularly loath to understand themselves as political actors rather than political victims.

Greenberg closes with some worthy suggestions for reform, including stricter enforcement of patenting criteria and a few more radical suggestions, such as using public funds to pay for all drug trials. Above all, he points to the need for an increased commitment to transparency so that the sources of potential bias are there for all to assess. Investigative journalism has long played a crucial role in maintaining this transparency, and Greenberg again proves himself to be the most important practitioner of this craft in the realm of science and technology.

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APPRECIATING PARASITES

Riddled with Life: Friendly Worms, Ladybug Sex, and the Parasites That Make Us Who We Are. Marlene Zuk. Harcourt, Orlando, FL, 2007. 336 pp. $25.00 (ISBN 9780151012251 cloth).

Wine appreciation courses teach a deeper understanding of wine. Marlene Zuk says her book *Riddles with Life* is an infectious disease appreciation course. It is, but I think it does more than just generate a deeper understanding of infectious diseases. Her evolutionary view of infectious disease offers us a deeper understanding of ourselves.

As with the theory of natural selection, the argument is obvious in retrospect, but the consequences have yet to be fully worked out. First, infectious diseases are not an aberration, a fall from clean, hygienic perfection. Being infected is natural: almost germ-free health and hygiene is a rich-world oddity made possible only by modern sanitation and, to a lesser extent, modern medicine. Second, infectious diseases cannot be banished. They always have and they always will evolve around our control measures and exploit the new niches our changing proclivities open up. Third, infectious diseases can do amazing things, and their hosts—us included—do amazing things in response. For instance, infectious diseases can make animal hosts more secretory (think mucus, vomit, feces), more mobile, obvious, angry, brave, hungry, long-lived, paintolerant, sterile, larger. In turn, animals respond to infections by having more sex, or becoming monogamous, committing suicide, engaging in self medication, developing germ phobias, rolling in feces of other species, eating spicy food, having acne, eating dirt, living in groups, living alone, engaging in herbal medicine. Maybe the evidence for some of these responses is a little flaky, but you have to include the gee-whiz stuff in a pop science book, and given the sheer volume of such phenomena, it's hard not to agree that host-parasite interactions are powerful forces.

Infectious disease is thus a pervasive force in historical and contemporary life. Zuk lays out a number—a good number—of reasons why that is important. My bet is that she has not got them all. But if you have not read any evolutionary medicine, and you think, for instance, that all disease symptoms are bad, that parasites eventually evolve to be nice, or that failures in our genomes are a sufficient explanation of common "genetic" disorders, Zuk's book is as good a place as any to start. Indeed, her style is lighter and more fun than the pop-Darwinian medicine competition (cats have "bad fur days," hygienic nest builders are "avian Martha Stewarts"), and she revels in wordplay and punchy sound bites even when they are not her own (from Norman Stoll: humans have worms because of man's "ineffective insulation from his own excretory products"). Unlike other popular science books written by practicing scientists, this one is not an excruciating read. As you romp though the book, you can't help but think Zuk enjoyed writing the thing.

If you really need a male, why not mate with the first one you find? Why do you need new, different, or particular genes in your offspring?

There are also other popular accounts of the evolutionary conundrums posed by sexual reproduction and mate choice. Why throw away half your genetic representation in the next generation by letting a male fertilize your eggs? If you really need a male, why not mate with the first one you find? Why do you need new, different, or particular genes in your offspring? The answer, favored by Zuk and others, is that genetic change is always necessary to keep up with pathogens, whose evolution makes resistance inevitably transient. But unlike the pop-science competition, Zuk draws a rather profound conclusion from this. If mate choice is about infections, then a very large component of the human condition evolved in response to disease pressure. Moreover, we are all different because our parents had sex. That I am different from you is a legacy of infections past. Celebrate human diversity. It exists because of the bugs.

Celebrate human diversity. It exists because of the bugs.

But the most interesting implication of the evolutionary perspective is a tantalizing view of the future of neuroscience. The argument is analogous to the hygiene hypothesis, one of the hot topics in immunology. Asthma, allergy, and other autoimmune problems became much more common in the 20th century, at least in the rich world. A growing body of evidence supports the view that deworming was responsible. Parasitic worms secrete substances to dampen our immune response. The hygiene hypothesis posits that our immune systems evolved to cope with this down regulation. Remove that down regulation and you have excessively aggressive immune reactions. Increasingly, it looks as though there is something in this idea. Give worms to people with autoimmune "dysfunction," and they get better.

Which, as Zuk points out, raises a very interesting question: which other organ systems evolved to deal with infections? Surely all of them. Which of these are misfiring as we make people "healthier"? And here's the shocking notion: Throughout the animal kingdom, infections are capable of manipulating host behavior to boost their own transmission, no question of that. It would be extraordinarily odd if parasitic infections were not continually probing human sensory and decisionmaking systems in an ongoing attempt to manipulate our behavior to enhance their transmission. They may even be constantly failing—maybe our brains are more robust than our immune systems—but they must be probing. How much of our neural complexity is a necessary defense against manipulative invaders? How much of the enormous redundancy is to provide

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system-level redundancy against attack? How much of the complex process of wiring a brain during development is actually to prevent covert attack? If our brains have evolved to deal with a continual barrage of manipulative intruders, what happens when that attack is removed by hygiene and modern medicine? Can the mind of a healthy body be healthy?

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RUNNING OUT OF SOIL

Dirt: The Erosion of Civilizations. David R. Montgomery. University of California Press, Berkeley, 2007. 285 pp., illus. $24.95 (ISBN 9780520248700 cloth).

The most overlooked, yet most crucial, material that sustains life on earth is dirt—or to use the more technical term, soil. David R. Montgomery's *Dirt: The Erosion of Civilizations* presents a cultural history of the degradation of this vital resource and aims to show how soil exhaustion has shaped the course of human civilizations. Montgomery, a professor of earth and space sciences at the University of Washington, uses an approach similar to the one taken by Jared Diamond in *Collapse* (*Dirt* and *Collapse* even share some case histories: Easter Island, Hispaniola, and the Mayan empire). Montgomery looks at environmental failures of the past to deduce lessons about the future of societies.

The book documents how societies have overused soils despite depending on them for the provision of drinking water, the production of food, and a range of other environmental services. The author refers to a multitude of cultures, from the first agricultural civilizations in Mesopotamia to the Greek, Roman, and Mayan empires; to central European societies; and finally to colonial North America. (Sometimes the jumps between places and eras are quite sudden.) He identifies a common pattern in most of these societies: the development of agriculture in fertile valleys leads to a growing population, the rising food demands of a growing population trigger the farming of marginal land, these sensitive lands soon become eroded, and agricultural yields decrease. In the end, soil degradation predisposes civilizations to failure, unless societies are able to shift their unsustainable demands for agricultural land elsewhere: for example, central European states that had access to "fresh land" in their colonies overseas, and the United States, which step by step absorbed the wealth of previously undeveloped agricultural land in the American West.

The failure to maintain the thin organic layer between rocks and vegetation in the long run is not merely a problem of the past. The book reveals alarming figures: More than 10 percent of the world's land surface is affected by desertification, an area the size of China and India combined has been degraded by moderate to extreme soil erosion since 1945, and around 1 percent of the world's arable lands are lost every year. Montgomery attributes such land degradation to the use of heavy farm machinery and of agrochemicals—the fundamentals of modern industrial agriculture—pointing out that the discovery and large-scale supply of mineral fertilizers made nutrient provision from soils seem superfluous, which led to neglect of soil fertility, the segregation of crop production from animal husbandry, and the rise of large-scale monocultures. But by freeing agriculture from local soil conditions, the introduction of machinery, mineral fertilizer, and pesticides created a new dependency—on fossil fuels.

Some people consider advances in biotechnology, nanotechnology, and other technologies to be a pathway to sustainable farming (e.g., Lal 2007). Montgomery does not. He doubts the promises of greatly improved crop yields from genetic engineering, and points out the social and environmental risks. Nor does Montgomery consider hydroponics—the cultivation of food under conditions that allow full control of vegetative growth through the manipulation of water, light, and nutrients—a plausible option for feeding the world on a large scale.

Rather, he expressly proposes an array of low-tech solutions to restore soils, to make them fertile and rich in organic matter. The book calls for the application of sound agroecological principles, and especially for the use of locally adapted practices stemming from both traditional insights and knowledge and modern ecology. Two agroecological strategies that seem particularly promising are organic and no-till agriculture, both of which are designed to sustain soil fertility and indeed may offer solutions to at least some of the negative aspects of industrial farming. To reduce the dependency of food production on petroleum, the book further suggests an "unglobalization" of agriculture to be achieved by strengthening small, local markets. Montgomery emphasizes that every acre of agricultural land will be needed in the future and pleads for an end to the conversion of farmland to other uses, which is now a dominant feature of many parts of the world.

An unusual case history from Cuba demonstrates how necessity can promote alternative farming at the national scale, at least in a totalitarian state. Cuba faced a severe shortage of fossil fuels, fertilizer, and pesticides after the fall of the Soviet Union. The country had needed to double its food production while the supply of inputs required by conventional agriculture was halved. Cuba responded with the development of low-input and no-till farming methods, including traditional farming, organic agriculture, and small-scale urban agriculture. It thus became an unexpected experiment in how to scale up these techniques.

In my opinion, Montgomery's most important contribution is his critique of the worldwide homogenization of farming through large agribusinesses and his proposal that agricultural practices be adapted to local environmental conditions (and not vice versa). His narrative of environmental degradation through-

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out the history of civilizations appears too generalized over time and space and seems pessimistic to me. For example, Grove and Rackham (2001) conclude that the Mediterranean Basin— which *Dirt* describes as a case of environmental degradation—is far from being a "ruined landscape." The long-lasting human impact on the Mediterranean landscapes, according to their account, has rather created resilient ecosystems with high species diversity, productivity, and utility to society. I wonder whether it wouldn't be more instructive to draw lessons from civilizations that succeeded in managing their environments than to focus just on societal collapses. Many cultures have developed agricultural systems that sustained agricultural productivity, conserved or improved soil fertility, and moreover supported a unique biodiversity over long periods of time—the parklands of Western Africa, the terraced olive groves of the Aegean, ancient agricultural systems in the Andes, and the home gardens of the Pacific Islands are but a few. These intensive, diversified, and permanent farming practices demonstrate that dense population and soil erosion do not have to be inevitably linked, as Montgomery suggests (compare, e.g., with Netting [1993]).

Dirt is a mixture of disciplinary depth (focusing on soil geomorphology) and an impressive interdisciplinary breadth (combining aspects of archaeology, geology, and environmental sciences). The meaningful historical photographs and sketches are especially worth mentioning. The book uses accessible language, but it does not match the brilliant standard of Diamond's *Collapse,* and its structure is a bit difficult to grasp. However, all in all, the book offers fascinating insights into what may be our most precious natural resource and gives important pointers toward sustainable land management.

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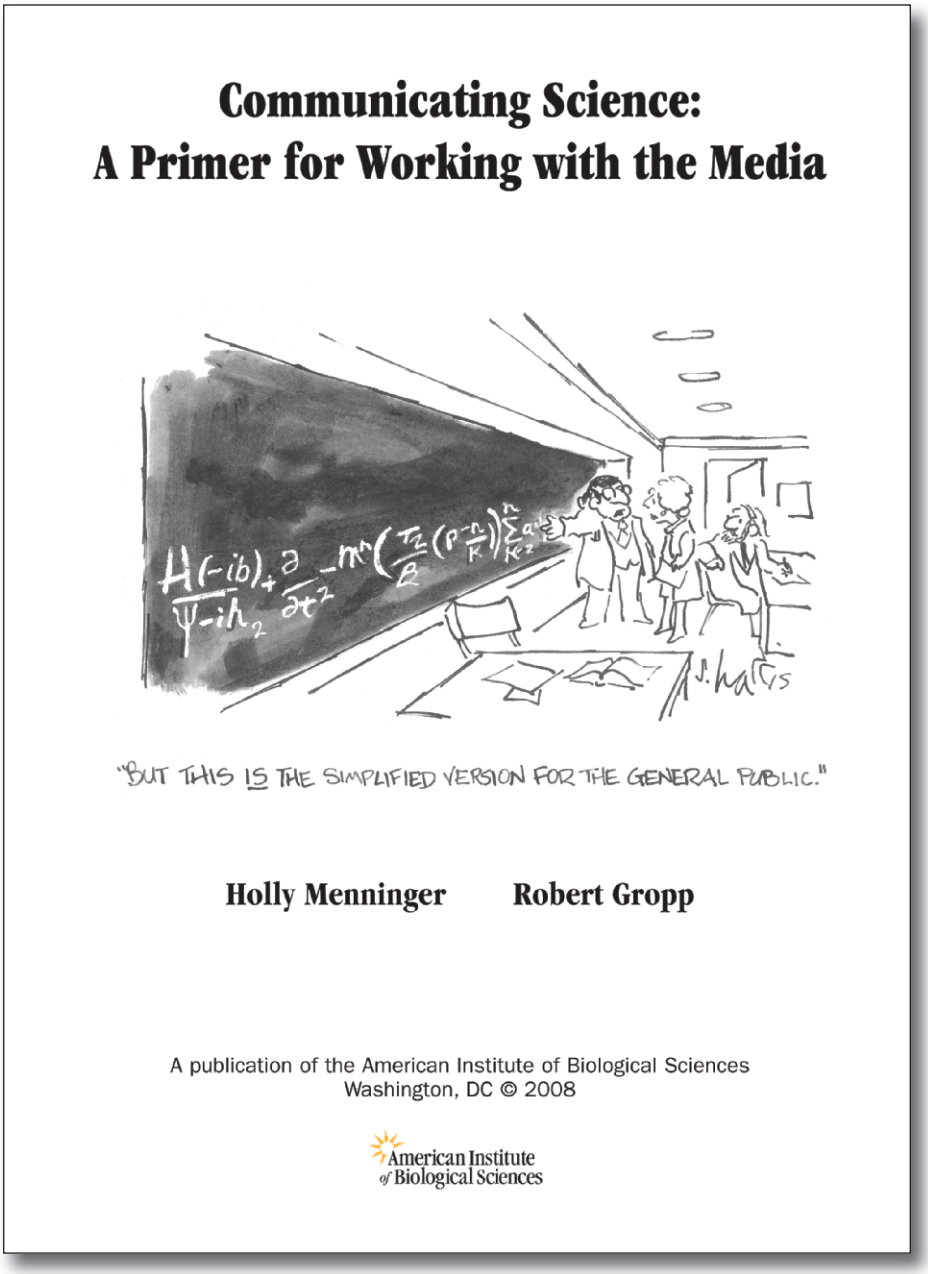
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