sets the stage for understanding why Oppenheimer later fell from grace: the gravity of postwar reality made the fall inevitable. However, Thorpe's analysis of the postwar years is much less impressive than his wartime study. The problem is that Oppenheimer was positioned to shape and be shaped by the compact, insular, war-focused Los Alamos, but the same was not true for postwar society. Thorpe tries to argue that Oppenheimer's experience in this period extends to all scientists — that work on the bomb joined science and the national security state together, leaving scientists compromised. Maybe they were compromised (as others have argued), but what happened to Oppenheimer cannot be seen as typical; he was too eccentric and his experience was unique. The Los Alamos portrait is apt, in fact, because it shows the precise relationship between a quirky leader and an odd community under unusual circumstances.

Understanding the evolving and complex relationship between scientists and the national security state requires a much wider focus than Oppenheimer's life. Indeed, understanding Oppenheimer's life in this postwar period requires a wider focus than McCarthy-era politics. Surely he was strongly influenced by his personal life, a subject Thorpe glosses over. Here, Thorpe lags behind the competition. The books by McMillan and by Pais and Crease provide a superior explanation of the security hearings, and those by Cassidy and by Bird and Sherwin provide a more comprehensive account of the entirety of Oppenheimer's life. Nonetheless, Thorpe's book provides the best perspective yet for understanding Oppenheimer's Los Alamos years, which were critical, after all, not only to his life but, for better or worse, the history of mankind. ■

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Safety first

Intervention: Confronting the Real Risks of Genetic Engineering and Life on a Biotech Planet
by Denise Caruso
Hybrid Vigor Institute: 2006. 272 pp. $17.95

Allison Snow

In *Intervention*, Denise Caruso challenges scientists to do a better job of evaluating the safety of genetically modified organisms (GMOs) and communicating unbiased findings to the public. Caruso, who founded the non-profit Hybrid Vigor Institute, examines with a healthy dose of scepticism the recent history of the regulatory policies affecting biotechnology in the United States. How, for example, can the Department of Agriculture simultaneously promote biotech research and agribusiness while also protecting the public and the environment from possible harm? In a broader context, how can the science of genetic engineering move forward and benefit society with sufficient oversight to prevent disasters? Caruso's answer is that we need to develop more transparent and democratic methods for incorporating scientific evidence in formal risk analysis and public policy.

One of the major strengths of the book is its accessibility to a general audience. Caruso, a former journalist, describes dry topics such as RNA interference and the US Coordinated Framework for Regulation of Biotechnology in terms that entertain the reader with wry humour and an appreciation for the absurd. In her view, molecular biology has "the whiff of the Holy Grail", and if you question the experts who promote GMOs, "you'll generally get a scorching look of suspicion". Sadly, many of the experts and industry representatives whom she targets are unlikely to read the book, although they should. I disagree with many of Caruso's conclusions, but I appreciate her thesis that the immense power of molecular biologists to redesign living organisms requires more scrutiny with each passing year. The release of certain transgenic crops, trees, fish, insects, viruses and bacteria into the environment could do much more harm than good. Malicious uses, such as designing transgenic organisms for bioterrorism, provide a worst-case scenario.

Warning sign: the number of genetically modified organisms released into the environment could increase rapidly.

ALAMY

Despite her frustrations with scientific experts, Caruso is respectful of reports from the US National Academy of Sciences that deal with GMOs and risk assessment, especially the National Research Council's *Understanding Risk*. She notes that these reports offer constructive recommendations that have yet to be implemented, either in the United States or elsewhere. At the same time, she boldly challenges a fundamental tenet of the reports and all US regulatory policy, namely the notion that risk assessment should focus on the actual products or traits of GMOs case by case, rather than the engineering process used to obtain them. Mainstream scientists and regulatory agencies typically assume that the use of recombinant DNA is irrelevant to risk assessment because genetically modified products are carefully examined for unintended effects before deregulation. In other words, genetically modified products such as insect-resistant maize are "generally regarded as safe" unless proven otherwise. Likewise, the US Food and Drug Administration accepts the idea that expert opinion and a battery of lab tests are sufficient to prove that genetically modified food is "substantially equivalent" to its non-transgenic counterparts (which can also have genes that cause unwanted health effects).

Caruso develops a series of worst-case scenarios, some of which are rather far-fetched, to illustrate why the doctrine of "product, not process" may be wrong. She contends that the overconfident zeal of molecular biologists and strong economic pressures to rush genetically modified products into global markets have squelched legitimate scientific enquiry into the possible risks, including dangerous outcomes that could be inherent to any GMO. What if gene splicing causes novel interactions between native and introduced DNA in a given transgenic crop, resulting in subtle yet harmful effects on human health? Have government agencies and the biotech industry fully examined this possibility? No, she asserts, because "our appointed arbiters of risk" are not willing to discuss the limitations of their knowledge. Moreover, she makes a convincing argument for why it is exceedingly difficult to predict the long-term and large-scale effects on human health and the environment of intentionally produced genetically modified traits. Recognizing that all new technologies bring a mixture of risks and benefits, she then discusses the advantages of allowing ethicists, social scientists, environmental scientists and others to participate in discussions about risk analysis and public policy. Her point that risk assessments involve value judgements beyond the realm of pure science is well taken.

Countering the industry's spin on the benefits of biotech in both developed and developing countries, Caruso focuses on the dark side of genetically modified crops. Her book echoes many of the themes from Deborah Koons Garcia's *The Future of Food*, a documentary film that attacks all unsustainable and chemically intensive modern agriculture (www.thefutureoffood.com). Unfortunately, Caruso's reliance on websites, unofficial reports and news media for citations means that many of her findings should be checked for accuracy and context. For example, she describes reports that the cultivation of genetically modified crops has already harmed soil organisms, created superweeds, contributed to severe economic hardships, and made people and livestock sick by increasing their exposure to herbicides. Similar criticisms could be made of some non-transgenic crops. Indeed, certain transgenic crops offer greater health benefits than their conventionally produced counterparts. Regarding Terminator technology for producing non-viable seeds, she states that "critics fear that these plants would irreversibly spread their sterility to non-transgenic crops and across species to other plants by contamination". However, these yet-to-be-released crops would not bear viable offspring and so could not spread their genes through reproduction.

Caruso's fears that transgenes could spread willy-nilly to the genomes of unrelated plants and animals — and even to humans — are overly paranoid because distantly related multicellular organisms are not capable of interbreeding. In a flight of hyperbole, she states: "Billions of transgenics have already been released into the marketplace and thus into our food, our water and the air that we breathe, breeding and exchanging their genetic material with each other and with us." But perhaps today's hyperbole could be a prelude to the future, if GMOs are released indiscriminately around the world.

Reading *Intervention* made me more aware of the value of confronting uncertainty in the complicated process of assessing risks and benefits. This ambitious and engaging book does a good job of defending the layperson's frustrations and concerns about genetically modified organisms. ■

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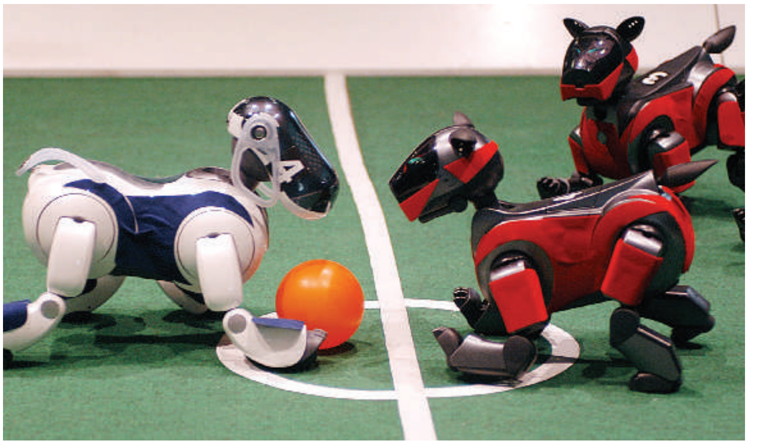
MORE ON GENETIC ENGINEERING

GM Crops: The Impact and the Potential/ Seeds for the Future: The Impact of Genetically Modified Crops on the Environment
by Jennifer A. Thomson
CSIRO Publishing/University of Cornell Press



Playing ball: robots must collaborate if they are to succeed at team sports.

MESSE BREMEN

Intelligence in a changing world

How the Body Shapes the Way We Think: A New View of Intelligence
by Rolf Pfeifer & Josh Bongard
Bradford Books: 2006. 394 pp. $39.95, £25.95

Hiroaki Kitano

The study of intelligence, once dominated by biologists, has for decades been a focus for computer scientists. The question of whether a machine can be intelligent is as old as computers themselves, but was thrust into the spotlight ten years ago when IBM computer Deep Blue beat world champion Garry Kasparov at chess. Whether it really showed intelligence as we know it is still a matter for debate, but researchers have identified that 'intelligence' in the context of chess depends on having a huge database, computing power to search for moves and the ability to learn from past games to obtain a 'goodness score' for each possible move.

However, there are clear differences between the way humans and computers play chess: a chess computer, unlike a human, does not have a body to enable it to interact with its environment, for example. This distinction differentiates two views on intelligence. One view is that intelligence is independent of the body and is unaffected by its existence, shape and function. The other view is that intelligence is contained within a physical body and that the body shapes the mind, an idea often referred to as physical embodiment or the presence of a behaviour-based agent. There is increasing recognition in the artificial-intelligence and robotics communities that the nature of the body significantly affects the mind, although it does not totally control it.

How The Body Shapes The Way We Think by Rolf Pfeifer and Josh Bongard provides an excellent perspective on how artificial-intelligence and robotics researchers have been tackling this issue. It is full of examples and thought-provoking discussions so that readers can easily follow some of the central debates on intelligence developed over decades. It also presents a chronological development of the field where appropriate.

The major focus of this book is to discover the design principle of an intelligent agent that has a physical and mobile body, has a high degree of autonomy, interacts with its environment and exhibits a broader range of behaviours than those single-task chess computers. It is not a book about how the body of an existing life form shapes its own mind, so there are only limited references to biology and neuroscience. Nevertheless, there are several parallels between artificial systems and biological systems. In one of the design principles, the authors point out the importance of redundancy, which also applies to biological systems. Some of these commonalities between artificial and biological systems can be seen as system-level principles that seem fundamental to a system's ability to exhibit intelligence, at least to an observer's eye.

One salient difference between the intelligent agents discussed in this book and traditional artificial-intelligence systems, as represented by chess computers, is the contextual thickness of system behaviours. Many of the robotics systems discussed in the book can cope, at least to some extent, with changes in the expected environment, tasks and other assumed conditions, whereas chess computers and other traditional artificial-intelligence systems are usually extremely fragile when faced with even a small change in such conditions. Behaviour-based robots should be able to perform almost flawlessly if the size of road or unevenness of terrain deviates from the initial assumption. However, the results will be catastrophic if a chess computer is given a chess board with nine rows and columns, rather than eight, as they are tuned specifically for the existing rules of chess. Imagine a thought experiment on a chess game between a behaviour-based system and an existing chess computer. The chess computer would be unbeatable with the defined rules, but if the rules were modified the behaviour-based system may do better.

The authors discuss learning, development