Empowerment and restraint in scientific communication

New developments make it easier to share information, but more difficult to deal with dual-use biology

Philip Campbell

These are great times to be a scientist. Never before has communication and access to information been so easy, at a time when the amount of scientific information itself is increasing exponentially. Many new technologies allow people to receive and send information and opinions in ways that are readily accessible to anybody with a shared interest. Together, these developments have empowered scientists—but not only scientists—to rise above the information deluge. However, there are also increasing concerns about the risks in making public biological information that is potentially useful for destructive purposes, either by individuals or states. These concerns, expressed mainly by politicians and security experts, have raised the prospect of restraining publication of sensitive results. This article focuses on such restraints in the context of the opportunities.

Several new software developments now provide online empowerment. RSS feeds allow the user to customize alerts to new content on websites, while social bookmarking software, such as Connotea and del.icio.us, enable people, privately or openly, to share links to websites they find interesting and valuable. The combination of these technologies can greatly reduce the obstacles to finding relevant new information quickly, even if the user did not know it existed.

Interactive weblogs give more power to both the author and the reader. Whether openly or secretly, weblogs and e-mails allow researchers to bypass standard channels of communication to reach out directly to any audience they want—as practised, for example, by US climate researchers who want to speak about their science in an often hostile environment (www.realclimate.org). Perhaps the most significant empowerment will come with the Semantic Web, a set of new standards and protocols devised by Tim Berners-Lee, which will in effect ally human web users to computers and artificial intelligence.

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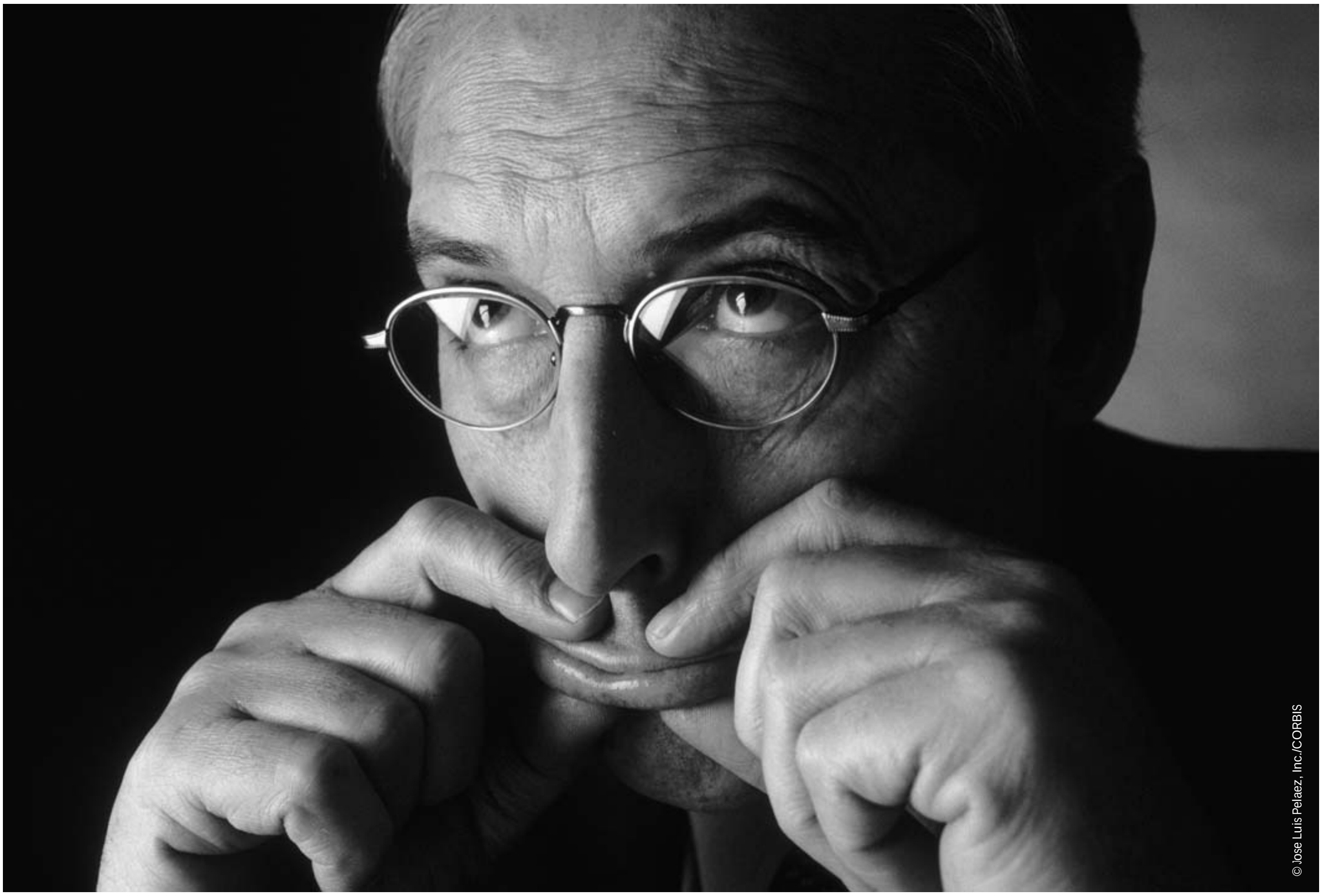
Hardware, too, is about to go through a major shift. We are only a few years away from electronic magazines and journals readable on portable platforms—yet another part of the ongoing revolution that constantly improves the ability of researchers and everybody else to engage with electronic literature. Add all that up and you have an environment in which access to information becomes unrestrainable. Even China, which has restricted its citizens' access to information more than any other country, is discovering that censorship has its limitations in the electronic age (Luard, 2004). But this wealth of publicly available information comes at a price: the risk that someone with a sufficient scientific background and a vested interest could use biological information for malign purposes—namely, to create a biological weapon.

Scientists are, in principle, no more or less responsible than any other citizen, but they are certainly expected to act responsibly by their public paymasters. As physicists discovered long ago, there are some areas of research—the results of which are applicable directly to weapons of mass destruction—that are best kept classified. Researchers working on such technologies are also used to the idea of sensitive literature, accessible only to those on permitted networks.

Biology is, of course, a different type of science. It differs from physics in that its capacity to do harm is much less constrainable, given the little effort needed and, typically, the relative conceptual ease with which an insight can be exploited in a damaging way. But, like any other science, biology is unpredictable. Anyone with experience of scientific research knows many examples of how wonderful technologies repeatedly emerge quite unexpectedly from science—or convergences of sciences—which are apparently unrelated to the original application. Who would have guessed, for example, that scientists creating petunias with new colours would uncover the mechanism of RNA interference, one of the most powerful and generic techniques in biology?

Given this combination of unpredictability and uncontainability, and the billions of dollars devoted to biomedical research each year, how likely is it that someone will turn an understanding of, say, the immune system to harmful purposes? Such concerns are stimulated anew by the



development of synthetic biology—the construction of 'biological circuits' that can be integrated into organisms to change their interactions or products or, ultimately, the synthesis of fundamentally new organisms.

And who might that malign someone be? Some more sophisticated techniques would require large laboratories. But simpler technologies can be used by anyone with the required skills in his or her own home. Some analysts have already pointed to 'biohackers' rather than Al Qaeda as the most probable source of a bioterror incident: people with a background in biology who might not be fully aware of the risks but wish to create a hazard just to show that they can, or who wish to exact revenge for some past disappointment or personal slight.

Whatever methods might be implemented to counter such risks, it is clear that funding agencies and scientific journals will receive much attention, as they have the means to deny either funding or publication of highly sensitive research and data. But it also raises the wider question of how society can put a check on the unexpected outcomes of research before it gets published—assuming that such checks are desirable.

The history of worries about bioterrorism was, before 11 September 2001, a history of denial by the biological scientific community. Most researchers simply would not discuss the riskier side of their work. But while denial is inappropriate, the appropriate, responsible approach leads to conclusions that are not much different: there is not much that can be done to make the world a safer place other than to ensure that, as far as possible, biohazards are suitably contained in secure labs. Nevertheless, that conclusion has yet to be accepted by politicians. And there needs to be a careful consideration of whether that rather sweeping assertion is justified.

Certain events are undoubtedly disquieting. In 1999, Australian researchers working on a contraceptive vaccine for pest control accidentally found a way of making mousepox more deadly. Adding a particular mouse gene to the virus did not boost the immunity of infected mice, as they expected, but instead switched off a key part of the animals' immune system, thus rendering the virus lethal to 60% of vaccinated animals. The research was eventually published after a two-year delay (Jackson *et al*, 2001). The authors and the editors of the journal decided that its benefits in helping scientists to design better vaccines outweighed the risk of nefarious abuse by terrorists to make lethal human viruses. Soon afterwards, *Nature* ran a major article that described the risks of dual-use in biology (Dennis, 2001), and an editorial that chided the biology community for not facing up to the possibilities (Anonymous, 2001).

The incident that caused a wider audience to sit up and take notice was the synthesis of the poliovirus by Eckard Wimmer and colleagues (Cello *et al*, 2002). There was a debate in the scientific community as to whether *Science* should have published the paper, with Steven Block—a professor at Stanford University who has experience in advising on security issues—accusing the editors of a "stunt", on the principal basis that it was already obvious from the literature that synthesis of a virus was possible (Block, 2002).

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The response of *Science*'s Editor-in-Chief, Donald Kennedy, was that a proof-of-principle has its own value and that the referees recommended publication. Although *Science* and *Nature* are competitors, the two journals have collaborated from time to time on policy matters of common interest. Be that as it may, and for what it is worth, *Nature* would not have published the paper, given that the techniques described were not particularly novel and that it revealed no new insights about how the world works. The achievement of synthesizing a virus certainly deserved public attention. But to highlight to a large public audience exactly how to do so—in the absence of significant innovation or insight—ran the risk of unnecessarily reducing public trust in scientists' sense of responsibility. And so it proved, as US Congress duly expressed its alarm.

Meanwhile, other journals published research that might also be considered alarming because of its double-edged nature. For example, after some agonizing, *Nature Medicine* published a paper that described the molecular causes of the lethality of the H5N1 flu virus (Seo *et al*, 2002). And *Nature* published the genome sequence of anthrax (Read *et al*, 2003). The latter provided a clear example of the benefits of publication even in the light of security concerns. In an article in *New Scientist* in 2002, Paul Keim, a bacterial geneticist at Northern Arizona University (Flagstaff, AZ, USA), was quoted as saying "If the *Bacillus anthracis* genome had not been released, we would not have been able to develop the high resolution system that is currently so important [to the investigation of last year's anthrax attacks]" (MacKenzie & Westphal, 2002).

Nevertheless, an increased sense of alarm in the aftermath of the terrorist tragedies of 11 September 2001 led the USA to consider dual-use biology. Three aspects have been of particular relevance to journals: first, there were discussions within the Bush administration about the possible introduction of a category of sensitive but unclassified information. Despite reports from Congressional research staff (Library of Congress, 2003, 2004) and considerations by the Office of Management and Budget, nothing has come of this idea so far, publicly at least. Second, a meeting arranged by the US National Academy of Sciences (NAS; Washington, DC, USA), immediately followed by a meeting of journal editors, in January 2003, led to a statement that journals might choose not to publish an article for fear of dual-use risks (Atlas *et al*, 2003). It also led to agreements by most journals represented to introduce additional risk-assessment protocols to cope with papers that might fall into this category, requiring additional consultation with biosecurity experts. Third, the US government established the National Science Advisory Board for Biosecurity (NSABB) under the auspices of the US National Institutes of Health (Bethesda, MD, USA). NSABB consists of experts from the fields of biology and security, with ex officio members from all relevant government departments. It includes a working group devoted to communications, chaired by Paul Keim.

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Meanwhile, others have been thinking through the issues too. The NAS published several reports on the topic (National Research Council, 2004, 2006). Another useful source is an article by Raymond Zilinskas and Jonathan Tucker that explores the possibilities of restricting information, and lays out developments that the authors thought were too risky to be published (Zilinskas & Tucker, 2002). This was also the outcome of a meeting at the Monterey Institute of International Studies' Center for Nonproliferation Studies (Monterey, CA, USA), which considered placing restrictions on research that involves a "select biological agent" and that aims at achieving one or more of six weapon-related goals: enhancing pathogen infectivity, pathogenicity, antibiotic resistance, or resistance to host immunological defences; improving a pathogen's ability to remain viable and virulent during prolonged storage and/or after release into the environment; facilitating the dissemination of biological agents as a fine-particle aerosol; facilitating the dissemination of a biological agent by contamination of food or water sources; creating a pathogen that is able to evade current detection methods or host immune defences; or synthesizing the genome of a pathogenic microorganism.

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At the 2003 NAS meeting, George Poste, now head of Arizona State University's Biodesign Institute (Tempe, AZ, USA), emphasized that microbiology is just one part of research that could be abused, and outlined other threats: deliberate engineering of immune escape; overproduction of host inflammatory mediators to produce toxic shock; knocking out genes that regulate key cell processes such as cell proliferation; developing molecules that disrupt molecular circuits, for instance networks in the immune response, the blood clotting system or in higher brain function. These developments are sophisticated but perfectly plausible. They are the downside of research that will surely bring benefits, and which would certainly be published.

At the time of writing, NSABB has shouldered the burden of thinking through, on behalf of everybody, the issues of dual-use biology: criteria in assessing risks, codes of practice, particular security issues in the new field of synthetic genomics, international aspects and scientific communication. This group is finding it no less difficult to make progress than did previous experts, many of whom found it easy enough to identify papers describing techniques of weaponization as beyond the pale, but still find it impossible to suggest basic biology papers for which publication should be constrained.

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At its most recent open meeting at the end of March, NSABB's Working Group on Communication of Dual-Use Research issued an endorsement of openness. Its significance lies in the people who sign up to it. If NSABB members with a military and security background recognize the importance of openness as a fundamental value in biology and biomedical research—despite the inevitable risks—and set the threshold for constraints at a very high level, it will mark a step forwards. The NSABB communication group also produced a draft checklist to help researchers and others assess the potential risks and benefits in disseminating the results of certain research. The checklist itself is hardly profound, but represents an attempt to spread awareness about the issues.

What is still needed is guidance about what a researcher should do if he or she is significantly concerned about possible risks in publishing research. This lack of clarity was highlighted—embarrassingly for the US government, in retrospect—in the case of a paper submitted last year to the *Proceedings of the National Academy of Sciences*, analysing the threat of a possible introduction of botulinum toxin to the US milk supply (Wein & Liu, 2005). One of the authors had contacted the US Department of Health and Human Services (HHS; Washington, DC, USA) to check whether publication was acceptable. There are divergent accounts of exactly what happened, but a breakdown in communication led to the paper's submission and then to it being placed on hold after acceptance when HHS, alerted by a reporter, had a discussion with the Academy's president and the journal's editor-in-chief. In the end, and against the wishes of the government, publication went ahead (Alberts, 2005).

The episode reportedly highlighted not only existing communications problems, but worse: the tendency of government officials to be conservative and to err on the side of caution when it comes to any risk associated with openness. It is in this context that an open consideration of the issues by NSABB could be especially valuable if, in its conclusions, it establishes a climate in which the clear presumption is one of openness. However, the community will need to be on guard if new arrangements lead to a bureaucratic tendency to play safe in preventing sensitive work from being published.

This raises the immediate questions whether and how journals themselves might get involved in constraining information. Indeed, the Monterey meeting mentioned above examined ways in which that could happen. It was proposed that submission of a paper about a "restricted" research project should be accompanied by a letter from the funding agency denoting which portions of the paper were sensitive and warranted restrictions on distribution. However, this suggestion carries significant problems: for any journal worthy of the name, this contravenes a fundamental principle of published science—that it be both open and replicable, rather than an advertisement.

But assuming a journal goes along with this proposal, there are significant practical difficulties. If the embargoed material is to be disseminated to a restricted list of scientists, who vets the lists—which will vary from paper to paper—and from where do journals obtain the resources to maintain the appropriate databases? If access to sensitive data is to be provided through secure, password-controlled websites, with substantial fines and other sanctions such as denial of access imposed in cases of unauthorized transfers, how is this to be policed?

Other challenges in such systems are that there is no definition or consensus on what needs to be restricted; that any such system needs to be international; and that it does not prevent informal dissemination over the Internet. And last, but not least, who, in fact, would be given access? Such a scheme would certainly be met with opposition by universities. To quote a Massachusetts Institute of Technology (Boston, MA, USA) review of security issues, such an approach "opens [us] to potential arbitrary dictates…however well intended" (MIT, 2002).

The prospect of such controls brings with it issues of compliance, both at universities and at journals. Compliance with regulations is relatively well policed in universities for safety and research involving animals and humans, but less well established for other codes of practice. A framework of compliance is well established in scientific journals for sharing materials, data deposition and research on humans, but is less systematic for ethical boundaries and reporting cases of misconduct externally. There is no inter-journal framework for biosecurity concerns, or national or international framework that incorporates journals.

It might be that all of this is a fuss about little, in practice. I am aware of no case in which a basic research paper has been rejected by any journal because of security risks in publishing it. But politicians might become motivated to implement legislation if they do not understand how science works or if they have the perception that scientists refuse to take responsibility for security concerns—which is not the least of reasons why the issues being discussed by the NSABB do matter. Nevertheless, in the end, it is hard to counter the following justification of openness given by M.R.C. Greenwood, then Provost of the University of California, in evidence to Congress in 2002: "The traditions and structure of research…depends on replication and refutation, which means that sufficient data and methods to allow that must be published in peer-reviewed journals. Such publication also mitigates fraudulent results, sloppy science, and political biases guiding important policy decisions" (Greenwood, 2002).

REFERENCES

Alberts B (2005) Modeling attacks on the food supply. *Proc Natl Acad Sci USA* **102:** 9737–9738

Anonymous (2001) A call to arms. *Nature* **411:** 223

Atlas R *et al* (2003) Statement on the consideration of biodefence and biosecurity. *Nature* **421:** 771

Block SM (2002) A not-so-cheap stunt. *Science* **297:** 769–770

Cello J, Paul AV, Wimmer E (2002) Chemical synthesis of poliovirus cDNA: generation of infectious virus in the absence of natural template. *Science* **297:** 1016–1018

Dennis C (2001) The bugs of war. *Nature* **411:** 232–235

Greenwood MRC (2002) *Conducting Research During the War on Terrorism: Balancing Openness and Security.* Testimony before the House Science Committee, 10 Oct. www.house.gov
Jackson RJ, Ramsay AJ, Christensen CD, Beaton S, Hall DF, Ramshaw IA (2001) Expression of mouse interleukin-4 by a recombinant ectromelia virus suppresses cytolytic lymphocyte responses and overcomes genetic resistance to mousepox. *J Virol* **75:** 1205–1210
Library of Congress (2003) *"Sensitive But Unclassified" and other Federal Security Controls on Scientific and Technical Information: History and Current Controversy.* Washington, DC, USA: Library of Congress
Library of Congress (2004) *Laws and Regulations Governing the Protection of Sensitive but Unclassified Information.* Washington, DC, USA: Library of Congress
Luard T (2004) Chinese activists evade web controls. *BBC News online*, 30 Jan. http://news.bbc.co.uk
MacKenzie D, Westphal SP (2002) Should the genetic sequences of deadly diseases be kept secret? *New Scientist*, 20 Jul, p7
MIT (2002) *In the Public Interest: Report of the Ad Hoc Faculty Committee on Access to and Disclosure of Scientific Information.* Cambridge, MA, USA: Massachusetts Institute of Technology
National Research Council (2004) *Biotechnology Research in an Age of Terrorism.* Washington, DC, USA: National Academies Press
National Research Council (2006) *Globalization, Biosecurity, and the Future of the Life Sciences.* Washington, DC, USA: National Academies Press
Read TD *et al* (2003) The genome sequence of *Bacillus anthracis* Ames and comparison to closely related bacteria. *Nature* **423:** 81–86
Seo SH, Hoffmann E, Webster RG (2002) Lethal H5N1 influenza viruses escape host anti-viral cytokine responses. *Nat Med* **8:** 950–954
Wein LM, Liu Y (2005) Analyzing a bioterror attack on the food supply: the case of botulinum toxin in milk. *Proc Natl Acad Sci USA* **102:** 9984–9989
Zilinskas RA, Tucker JB (2002) Limiting the contribution of the open scientific literature to the biological weapons threat. *J Homeland Sec*. www.homelandsecurity.org/newjournal

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