LETTERS

Science, Ethics, and War

WE SCIENTISTS UNDERSTAND THAT IT IS difficult to get at the facts, let alone the truth. With regard to this observation, I was intrigued by the confluence of themes in three pieces in the 28 March issue.

In his News Focus article "U.N. inspections find wisps of smoke but no smoking guns" (28 Mar., p. 1967), Richard Stone got one fact wrong. Inspectors were not "thrown out" by the Iraqi government in November 1998. Iraq did indeed end cooperation, but in August of 1998 (*1*). Three months later, on 17 November 1998, inspections resumed after Iraq once again agreed to fully cooperate (*2*). The U.N. Special Commission (UNSCOM) withdrew inspectors on 16 December 1998 upon learning that the United States and Britain would start a bombing campaign the next day. Although known weapons of mass destruction (WMD) were destroyed in 1998, the military action launched this March cut short the U.N. Monitoring, Verification, and Inspection Commission's efforts to get at the facts of current Iraqi weapons programs. And, as Donald Kennedy points out in his Editorial "Science and the war" (28 Mar., p. 1945), we are now unlikely to get at the truth.

To Kennedy's list of the role of science in this time of war, I would add research into factors that determine whether a regime change might be violent or peaceful. Can we encourage peaceful regime changes, examples of which are Poland, the former USSR, and the former Czechoslovakia among others, as an alternative to war? I would remove from his list weapons research. If, as a society, we are truly concerned about the proliferation of arms and WMD, we would not ask our scientists to work on weapons, no matter how "smart" such weapons may be. Such research is unethical and should be actively discouraged. I was thus heartened to read the letter by C. R. Craig *et al.*, "An ethical affirmation for scientists" (28 Mar., p. 1982). In an effort to "do no harm," scientists must consider the ethical, environmental, and societal implications of their research and the technologies that result. Sometimes this will mean a personal decision not to do certain research.

More generally, scientists are obligated to actively communicate their knowledge of the facts, as well as the unknowns, that pertain to the implications of their research so that decision-makers and society at large can make the most informed choices possible. Although facts are easily manipulated by governments, corporations, groups, and individuals into convenient half-truths for pecuniary or political gain, we ultimately are responsible for the impact our research has on global society.

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References
1. See for example, J. M. Goshko, *Washington Post*, 6 Aug. 1998, p. A21.
2. See for example, P. Baker, *Washington Post*, 16 Nov. 1998, p. A1.

Response

UNSCOM'S DEMISE IS INDEED CONVOLUTED and bears further explanation. On 31 October 1998, Iraq suspended all UNSCOM activities, including monitoring. The U.N. Security Council condemned that decision, and as a consequence, on 11 November, all UNSCOM inspectors were withdrawn from Iraq. Were they "thrown out"? I grant that they were not grabbed by the lapels and escorted to their plane. Iraq failed to follow through on its subsequent promise of full cooperation: According to a 15 December letter from UNSCOM's chairman to U.N. Secretary General Kofi Annan, "Iraq's conduct ensured that no progress was able to be made in either the fields of disarmament or accounting for its prohibited weapons programmes."

RICHARD STONE

UNSCOM weapons inspectors approach the United Nations headquarters in Baghdad, 23 November 1998, after having visited suspected weapons sites.

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Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 6 months or issues of general interest. They can be submitted by e-mail (science_letters@aaas.org), the Web (www.letter2science.org), or regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.

Supporting Scientists and Research in Iraq

AS POINTED OUT BY RICHARD STONE ("U.N. inspections find wisps of smoke but no smoking guns," News Focus, 28 Mar., p. 1967) and Donald Kennedy ("Science and the war," 28 Mar., p. 1945), the regime change in Iraq will have an immense impact on scientists there. Restarting and strengthening peaceful scientific work in Iraq will aid in restructuring and democratizing the country, while reducing the possibility that scientists will be attracted to weapons work elsewhere.

Among other worthwhile projects, we draw attention to the UNESCO-sponsored SESAME Project (Synchrotron-light for Experimental Science and Applications in the Middle East) (*1*) to construct a regional, international research center in Jordan, which won a competition among seven Middle East countries to host the facility. SESAME will be a high-performance 2- to 2.5-GeV x-ray source for the region in an international laboratory developed in analogy to CERN. SESAME is well under way, with eight founding members (Bahrain, Egypt, Israel, Iran, Jordan, Pakistan, Palestine, and Turkey). Other countries from the region, including Iraq, are expected to join, with support also coming from observer countries outside the region.

Along with 50 other synchrotron light sources, SESAME will provide intense beams, from infrared to hard x-rays, for frontier research, including biomedical and environmental problems in the Middle East. It will also provide opportunities for training young scientists and attracting those working abroad to return, as well as promoting peaceful cooperation and understanding in the region.

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Reference
1. See www.sesame.org.jo.

DONALD KENNEDY'S EDITORIAL "SCIENCE and the war" (28 Mar., p. 1945) makes the point that science and technology will have important parts to play in the repair of Iraq's infrastructure. It is not too soon to plan for the renewal of Iraq's scientific community, which has suffered under Saddam Hussein's rule and from war and sanctions. The Nunn-Lugar program and the International Science and Technology Centers in the former Soviet Union contribute significantly to scientists seeking to redirect their efforts to peaceful purposes. We need to plan comparable efforts in Iraq to enable its scientific community to rebuild and to rejoin the international scientific community by providing alternatives that will keep them from turning to potential weapons proliferators to support themselves and that will enable them to make their vitally needed contribution to a free and democratic nation.

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Carbon Nanotubes Provide a Charge

A RECENT REPORT BY S. GHOSH AND co-workers ("Carbon nanotube flow sensors," 14 Feb., p. 1042) describes how flowing liquid over a mat of carbon nanotubes induces a voltage parallel to the flow. The authors explain their result in terms of "a direct forcing of the free charge carriers in the nanotubes by the fluctuating Coulombic field of the liquid flowing past the nanotubes."

I suggest a more prosaic explanation: It is well known that most porous materials develop a "streaming potential" in response to a liquid flow because the flow carries along counterions that accumulate in a thin layer near the solid-liquid interface (the Debye layer). Quincke first observed this effect in 1859 in powdered glass, ivory chips, animal bladder, graphite, and iron filings, among other materials (*1*, *2*), and Helmholtz provided a quantitative explanation in 1879 (*3*). There is no reason for carbon nanotubes to be immune to it.

The purification treatment reported by Ghosh *et al.* of long exposure to concentrated HCl would leave the surface of the nanotubes negatively charged, so one would expect an excess of positive charges in the Debye layer. This is consistent with the observed sign of the voltage in their experiments. More viscous solutions produce a lower voltage because the flow penetrates a lesser distance into the interior of the mat. The saturation in the observed voltage can be explained by electrode polarization. The fact that graphite did not produce a voltage in their control experiment is not surprising, given that (i) it has vastly smaller surface area and (ii) unlike the nanotubes, it presumably was not treated with acid before the measurement.

The results of Ghosh and co-workers are interesting and may lead to useful devices, but the data presented seem consistent with classical electrokinetics.

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1. G. Quincke, *Ann. Physik* **107** (no. 2), 1 (1859).
2. G. Quincke, *Ann. Physik* **110** (no. 2), 38 (1860).
3. H. L. F. von Helmholtz, *Ann. Physik*, **7** (no. 3), 337 (1879); translated by P. Bocquet, *Two Monographs on Electrokinetics* (Engineering Research Institute, University of Michigan, Ann Arbor, MI, 1951).

Response

COHEN SUGGESTS AN ELECTROKINETIC mechanism for our observation of voltages induced by fluid flow over a mat of single-walled carbon nanotubes (SWNTs). In this purely ionic mechanism, the voltage appears as a streaming potential involving the ions carried by fluid flow in the diffuse Debye layer at the interface, while the mobile charge carriers (electrons and holes) in the solid play no role. Although an electrokinetic mechanism should suffice for the case of a nonconducting solid/liquid interface (e.g., with powdered glass, ivory chips, and so forth as the solid), we believe that it cannot effectively explain the present case of conducting nanotubes (resistivity ~ 0.02 ohm-m).

Assuming, as suggested by Cohen, that the SWNTs are negatively charged at the interface (so as to be consistent with the direction of the observed voltage), the streaming potential at the low flow velocities (u) obtained in our experiments (several orders of magnitude smaller than the thermal velocities) is expected to be linear in u, which is in strong disagreement with the observed sublinear dependence. As stated in our Report, the flow-induced voltages at these flow velocities are about 10 times smaller for multiwalled carbon nanotubes. These results again contradict the electrokinetic mechanism as a possible explanation. For a conducting solid/liquid interface (SWNTs in the present case), the charge on the solid surface is also screened by the carriers in the conducting solid. The usual treatment of the electrokinetic mechanism for the insulating solid/liquid interface is then not quite applicable per se. Figure 2 of our Report clearly shows that the induced voltage increases with increasing ionic concentration, in sharp contrast to a electrokinetic mechanism.

We believe that the classical, purely electrokinetic mechanism, although very apt in the case of an insulating solid/liquid interface, is not effective in the case of the conducting solid/liquid interface in our study. Our mechanism involves the forcing of charge carriers (electrons and holes) in the SWNT itself by the ionic flow over the interface.

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Inoculating a Science Education Epidemic

T. R. CECH'S EDITORIAL "REBALANCING teaching and research" (10 Jan., p. 165) discusses the effort being made by the Howard Hughes Medical Institute "to tilt the research/teaching balance back to a healthy equilibrium" by "providing recognition and research-level dollars to accomplished scientists who have a track record of exciting teaching and a penchant for more." Although I support the effort, this mechanism of encouraging faculty to invest more of their efforts in teaching does not combat the root of the problem; it attempts to achieve this goal by patching a flawed system.

Cech states that promotions and salaries at research universities are dependent on publications, patents, and grant funds. However, university administrations are often more interested in money to pay the school's expenses than in teaching quality and publications. Publications and grants that do not include funds for overhead appear to be a low priority for administrations at research universities. Grants with overhead money and patents that provide income are more highly regarded in the competition for promotion and salary increases.

It is a conflict of interest for administrations to put their budgetary responsibilities ahead of the university mission by forcing the faculty to bear a great part of the budgetary responsibility. Organizations that provide research grants to encourage excellence in teaching on a large scale and in a cost-effective manner must adopt a mechanism to protect against this conflict of interest when including overhead funds.

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Response

ROCCANOVA CORRECTLY IDENTIFIES OUR NEW Howard Hughes Medical Institute Professors program as a patchwork effort to empower better undergraduate science education at 20 different locations in 20 different ways. However, we do not aim to avoid change at the institutional level, but rather to stimulate it in a ground-up approach. Our funding of these 20 "experiments" in science education will be leveraged as the professors disseminate their materials, curricula, and "best practices" within their universities and to the community at large. Vehicles will include Web-based science education journals, our own Web site (www.hhmi.org), and presentations at scientific and education symposia. After all, our goal is not so much "encouraging faculty to invest more of their efforts in teaching," but rather to obtain more quality impact per hour spent teaching and to ease the way for other teachers to do the same. So, although inoculating 20 different biology, chemistry, and engineering departments across the United States with life-changing educational experiences for their undergraduates is worthwhile in itself, we are aiming for changes of more epidemic proportion.

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TECHNICAL COMMENT ABSTRACTS

COMMENT ON "Single Crystals of Single-Walled Carbon Nanotubes Formed by Self-Assembly"

Matthew F. Chisholm *et al.*

Schlittler *et al.* (Reports, 11 May 2001, p. 1136) reported the production of single crystals of single-walled carbon nanotubes (SWCNTs). In this comment, we report the reproduction of their experimental results. We suggest that the crystals formed in our experiments comprise calcium molybdenum oxide, not SWCNTs.
Full text at www.sciencemag.org/cgi/content/full/300/5623/1236b

RESPONSE TO COMMENT ON "Single Crystals of Single-Walled Carbon Nanotubes Formed by Self-Assembly"

M. E. Welland *et al.*

In our 11 May 2001 *Science* paper, we described a method to precisely control the delivery and spatial location of chemical precursors to form nanostructures. Our interpretation of the annealing of C_{60}/nickel precursors to form nanostructures on molybdenum surfaces as being crystals of SWCNTs has been subsequently shown to be incorrect.
Full text at www.sciencemag.org/cgi/content/full/300/5623/1236c