A letter writer points out that [illegible] **A reader** [illegible] **discusses the physics of** [illegible] **A report on postdoctoral education finds that postdocs** [illegible] **And a representative of the petroleum industry squares off against what he calls** [illegible]

Scientific Literacy

In his excellent Policy commentary "The interdependence of science and law" (*Science*'s Compass. 24 Apr., p. 537), Justice Stephen Breyer incidentally exemplifies the definition of "scientific literacy" proposed by James B. Conant over four decades ago: the ability to choose one's experts wisely, being able to "communicate intelligently with men who were advancing science and applying it" (*1*). Knowing how to choose experts and to understand the limitations, uncertainties, and likely bias of their expressed opinions does not require knowledge of science itself. Rather, it is the capability of any intelligent person who has learned to reason well and to judge character. One develops this capability in many settings. Justice Breyer mentions that Presidents, the Congress, and regulatory agencies seek expert advice on a regular basis. It should be added that the chief executives of most major corporations also retain by necessity trusted science advisers on their inner councils. Consultation is a daily part of successful corporate management and is a key activity at many other levels in business, government, and educational organizations.

The National Science Education Standards (NSES) defines scientific literacy in part as the ability to develop and express reasoned positions on national issues that are scientifically and technologically informed. It proposes that this can be achieved through mastery of a large dose of science content, leavened with understanding of the process of scientific inquiry. Establishing national standards is important for improving and equalizing science education across the nation. But for those who do not follow the path laid out by the NSES, Justice Breyer sets a different and, I submit, equally valid standard for the "scientifically literate" individual.

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1. J. B. Conant, in *General Education in Science* (Harvard Univ. Press, Cambridge, MA, 1952), p. 19.
2. *National Science Education Standards*, (National Academy Press, Washington, DC, 1996), p. ix.

Big spheres cluster together in a corner.

That Corner Office

As a reader in the business world, I feel compelled to share a striking example of the "entropic force" reported to group larger particles against boundaries (D. Kestenbaum, Research News, 20 Mar., p. 1849). I speak, of course, of executives who, across every industry, end up in corner offices. And occasionally executives are forced right out, precisely as predicted by physicists' findings! What I can't explain is the curious pleasure I feel in viewing my favorite executive's office in this new light.

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The Plight of Postdocs

The *Report and Recommendations of the Committee on Postdoctoral Education* was published by the Association of American Universities (AAU) on 31 March. It takes a hard look at how U.S. universities treat and train postdoctoral researchers in science and engineering, of whom it is estimated there are at least 35,000 nationwide. The report concludes that postdocs perform a significant portion of the nation's research and enhance the success of tenured faculty, yet often are a forgotten community for whom there are few appointment or training standards. In several universities, postdocs have organized to form associations as a voice for change. The School of Medicine at the University of Pennsylvania has established an Office for Postdoctoral Programs (OPP) to oversee its appointments and training programs. The OPP currently serves 650 postdocs and ensures compliance with an institution-wide "Policy for Postdoctoral Fellows in the Physical, Biological and Health Sciences and Engineering" that was adopted in April 1996. This policy established the rights and obligations of postdoctoral researchers. The OPP has established a standardized appointment procedure that includes initial appointment letters that address the policy, stipend levels, and benefits. Such letters were recommended by the AAU report. We enforce a limit on the length of the postdoctoral appointment of 5 years so that individuals move to the next stage of their careers. We run orientation sessions for all incoming postdocs and hold roundtable discussions with them later to set new priorities. We have also established a web page (www.med.upenn.edu/postdoc) that includes funding information and a postdoctoral directory. Our hope is that the OPP is establishing policies and training for postdocs that may be emulated elsewhere.

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Strategies for Carbon Reduction

In their Policy commentary "A road map for U.S. carbon reductions" (*Science*'s Compass, 30 Jan., p. 669), Joseph Romm *et al.* make the case that the Kyoto commitments (*1*) can be a achieved with a substantial research and development (R&D) effort and a "carbon permit fee" (which is another way of saying "a tax") of $50 per ton of carbon emitted. Their conclusions come from a rosy interpretation of a study on carbon emission reductions done by five national laboratories for the Department of Energy (DOE) (*2*), but a close examination of the data available on this topic leads one to the opposite conclusion.

The conclusions stated by Romm *et al.* about the benefits of a $50 fee are based on assumptions about three sectors of the economy (industrial, transportation, and buildings), but these assumptions are not supported by a modeling analysis. The U.S. Energy Information Administration (EIA) calculates (*3*) that U.S. carbon emissions will increase at 1.5% per year, reaching 1803.2 million metric tonnes (mmt) in 2010. The Kyoto target is 1250 mmt, which would require emissions reductions of 553 mmt, far more that the 400-mmt reduction cited by Romm *et al.*

With use of the data from the EIA (*3*) and the paper by Romm *et al.*, I have estimated carbon emission trends through the year 2010 (*4*); these data include reductions in carbon emissions that should result from the introduction of new, energy-efficient technologies. Despite these new technologies, carbon emissions will continue to rise because of economic growth and relatively slow replacements of utility and industrial plants and other carbon-producing capital (*4*).

The "five-lab study" (*2*) assumes that nuclear power plants will continue to provide large amounts of electric power by extending their economic lifetimes, which is questionable. The EIA projects (*3*) that 24 additional nuclear plants in the United States will be decommissioned prematurely. There is no feasible alternative to these plants except for electricity generated by carbon-emitting fossil fuels.

Romm *et al.* assume the development and relatively rapid installation of new technologies for lowering emissions and that launching a vast collection of subsidies, rebates, and tax write-offs to achieve that goal will somehow come free. But it is likely that actual new technology costs would be far in excess of benefits (*5*).

In the five-lab study, the largest emission reduction comes from replacing coal plants prematurely with natural gas–powered facilities, but the capital costs of prematurely abandoning or converting a large number of productive power plants do not seem to be included.

Finally, the five-lab study's Executive Summary presents major conclusions not supported by the technical analysis (*5*). The section on transportation warns that an optimistic scenario assumes technological breakthroughs and a "certain degree of luck" (*2*, p. 5.3) if the Kyoto targets are to be achieved by the year 2010. Romm *et al.* make no reference to the need for luck in transportation or in any other sector. If this costly agreement were imposed on the U.S. economy, the results would not match their optimistic predictions.

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References and Notes

1. The climate treaty negotiated in Kyoto, Japan, in December 1997 awaits ratification by the U.S. Senate. The text of the treaty is available at www.unfccc.de/index.html.
2. Interlaboratory Working Group, *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond* [LBNL-40533, Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA, and ORNL/CON-444, Oak Ridge National Laboratory (ORNL), Oak Ridge, TN, 1997]. Available at www.ornl.gov/ornl/energy_eff/con444 or eande.lbl.gov/ee.html.
3. *Energy Information Administration Annual Energy Outlook 1998* [OE/EIA-0383(98), U.S. Department of Energy, Washington, DC, 1997], p. 54.
4. R. J. Sutherland, data not shown.
5. ———, "A critique of the five-lab study" (American Petroleum Institute, Washington, DC, 1998).

Response

A carbon permit fee is not "another way of saying 'a tax.'" Trading is different from taxing both in how it is implemented and in its total cost. Attempting to equate a trading system with a tax seems an effort to make our analysis unattractive.

In our commentary we stated, "Not all of these reductions will have to be met domestically, however, because the Kyoto agreement allows the United States credit for reductions through international trading of carbon permits with developed countries and through climate mitigation projects with developed countries." Sutherland appears to assume that all reductions must be achieved domestically. Many analyses suggest that the United States could obtain half or more of its emissions through international trading of carbon permits (*1*). We stand by our statement that the cases we examined in the five-lab study (*2*), with domestic reductions of up to 400 mmt, are highly relevant to analyzing U.S. domestic policy for meeting the Kyoto targets.

Extending the life of nuclear power plants accounts for only 5 mmt of carbon savings in the year 2010 in our most optimistic case and so is not particularly important to our final result. The study noted that achieving these savings would require a robust policy to extend the lifetimes of such power plants.

The five-lab study describes many energy-efficient investments (and renewable options such as wind and biomass) that would be cost-effective at $50 per ton of carbon emission. In our cost analysis (*2*, p. 1.13), we calculated "program costs" for our policies and doubled those costs for the higher bound estimate. The range of such costs would be $3.5 billion to $13 billion—hardly "free," although this cost would be largely paid back by the savings from efficiency investments. We do not agree that "actual new technology costs would be far in excess of benefits." The U.S. experience during the two decades after the oil embargo shows that significant energy savings can be achieved at a cost lower than that of new supply.

The largest emission reduction would come not from "replacing coal plants prematurely with natural gas–powered facilities," but from (i) improving efficiency in buildings, industry, and transportation and (ii) a combination of repowering existing coal plants, replacement of coal plants, and carbon-ordered dispatch. The carbon permit price makes these plants less cost-effective than the low-carbon alternatives, and the utility model we used (*3*) accounts for the relevant costs. Moreover, most of these coal plants have recovered the vast majority of their capital costs.

Sutherland says that we make "no reference to the need for luck" to meet the Kyoto targets. We did acknowledge the vagaries of R&D when we wrote, "Emerging technologies may not prove as cost-effective as we anticipate." It is only the transportation sector that relies on major technological breakthroughs, or "luck," to achieve some of its reductions. The other sectors achieve the majority of their reductions from technology that exists now, and some from technologies that are near the end of their development phase (such as the advanced turbine system in industry). Advances in the transportation sector have been accelerating. The five-lab study does not anticipate vehicles with fuel cells entering the market before 2007 in the most optimistic case, even though several manufacturers have announced they will have such vehicles on the road before then.

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References and Notes

1. For example, see J. Edmonds *et al.*, "Return to 1990: The cost of mitigating United States emissions in the post-2000 period" (PNNL 11819, Pacific Northwest National Laboatory, Richland, WA, 1997).
2. Interlaboratory Working Group, *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond* (LBNL-40533, Lawrence Berkeley National Laboratory, Berkeley, CA, and ORNL/CON-444, Oak Ridge National Laboratory, Oak Ridge, TN, 1997). Available at www.ornl.gov/ ornl/energy_eff/con444 or eande. lbl.gov/ee.html.
3. S. W. Hadley and E. A. Hirst, "ORCED: Simulating the operations and costs of bulk-power markets" (ORNL/CON-464, Oak Ridge National Laboratory, Oak Ridge TN, 1998).