role of the science adviser. These statements are untenable in view of the fact that eight counties in the immediate area of the antenna system have already voted by more than a four to one margin that they are opposed to locating Project Seafarer in Michigan. The continued effort to call for public opinion polls or a second referendum involving counties outside the proposed area has resulted in a loss of confidence in both the science adviser and the governor.

There are lessons to be learned by other states considering uses of a science adviser. The science adviser needs to operate within a system of checks and balances and to be constrained by some form of public accountability. A one-man operation that is political as well as scientific is unlikely to result in good scientific advice or a gaining of public confidence. Certainly the office of science adviser must be structured so that the adviser does not appear to serve primarily to sell government programs. In Michigan, the congressman for the district involved, the new senator, both houses of the state legislature, and major newspapers have called upon the governor to "veto" Project Seafarer. President-elect Carter has stated that Project Seafarer would not be built in Michigan against the wishes of the people and has noted that referenda have been held. The office of science adviser, by locking its operations in inflexible procedures requiring at least 2 years before involving the public in any significant way, has failed to provide information in the continuing debate and has left the governor standing alone.

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Animals and Ethics

The letters from Aronson and Cooper and from Sachs (19 Nov. 1976, pp. 784 and 786) take exception to several statements in Wade's article (8 Oct. 1976, p. 162) on the cat experiments at the American Museum of Natural History. The letters are, unfortunately, in no way unusual in their failure to face squarely the broader ethical issues involved in animal experimentation. Speaking of Henry Spira, one of the leaders of the action against the museum, Aronson and Cooper remark: "In none of his articles does Spira acknowledge that any animal should ever be used for any experiment, no matter how crucial it may be judged for human welfare or survival." If it is true that Spira has deliberately evaded the problem, this is a valid criticism. By the same token, it is incumbent on scientists not to deserve the converse criticism: "In none of their writings do they acknowledge that any experiment should not be done, regardless of how much suffering it entails for the animals used."

Aronson and Cooper refer to the "simplistic, reductionist idea that 'alternatives to live animals' . . . can be substituted for animal experiments. . . ." and to the "quasi-moralistic claim that animals have 'rights' equal to the sociopolitical rights of women and minorities." They complain that Wade does not indicate that "many see such statements as being antiscience." I would like to point out that most of the "alternatives to live animals" (many of which are used very successfully in some areas) were developed for purely pragmatic, not humane, reasons; that evaluating the "rights" of living things, far from being an obvious and simple decision, is a difficult philosophical problem; and that raising moral questions is not "antiscience."

Sachs states that "The public's right to challenge the ethics and economics of animal research is unquestioned." He then goes on to say: "The present peer review system, as fallible as it may be, has been largely successful in curbing unethical excesses and in fitting research priorities to available funds." The peer review system, to my knowledge, is devoted almost exclusively to determining the scientific merit of a proposal and the capability of an investigator to carry it out. The "economics" (funding) of the proposal is considered also. But the review committees, regrettably, do not include members designated specifically as spokesmen for the experimental animals, to "challenge the ethics . . ." of the proposed research.

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Recombinant DNA Research

According to the National Environmental Policy Act (NEPA) of 1969, alternative policies for recombinant DNA technology were supposed to be under consideration last fall. Despite this requirement, it is widely believed that this technology will inevitably proliferate and that the real policy decisions have already been made. An article in *Science* (News and Comment, 15 Oct. 1976, p. 303) reflects the prevailing view: "The nuclear genie is now out of the bottle for good or ill, and the crucial time of grace for instituting control over the recombinant DNA technique is probably over."

How has this sense of inevitability been generated? If we look back on the course of events, we find that a policy of proliferation was never formally adopted. Rather, at major decision-making junctures, it was simply assumed that these techniques would be exploited on a wide scale. The "moratorium" of July 1974, while it suspended work on two classes of experiment, merely advised caution on a third class—the insertion of animal genes into bacteria—with the result that work in this area went ahead. At the Asilomar conference, the moratorium was lifted and replaced by broad guidelines for all experiments except those judged to be of highest risk. The members of the National Institutes of Health (NIH) committee which drafted the guidelines released in June worked long and hard on methods for containment of the novel microbes to be manufactured but did not weigh the need to continue research and development—possibly an equally significant factor in the risk equation.

The situation is troubling because, in principle, two mechanisms should have ensured a more careful approach to formation of policy for genetic manipulation. First, the original charge to the NIH guidelines committee required that research aimed at defining the risks precede the development of guidelines (*1*):

> The goal of the Committee is to investigate the current state of knowledge and technology regarding DNA recombinants, their survival in nature, and transferability to other organisms; to recommend programs of research to assess the possibility of spread of specific DNA recombinants and the possible hazards to public health and the environment; and to recommend guidelines on the basis of the research results.

In fact, the reverse procedure has occurred. Guidelines have appeared, but research directed specifically toward assessment of hazards is in its infancy.

Second, the application of NEPA should have ensured consideration of alternative policies for research and development. Before a government agency takes any "major action significantly affecting the quality of the human environment," NEPA requires the circulation to the public and to other government agencies of a "detailed statement" which describes the environmental impact of the proposed action and of alternatives to it. But NIH reversed this order of procedure thereby sanctioning a policy of proliferation prior to formal consideration of that policy under the laws. Guidelines were released in June, before publication of the impact statement in September. This premature release of guidelines prior to the impact statement which is required by law to precede them has been justified on the grounds that their "development was in large part tantamount to conducting an Environmental Impact Assessment" (*2*).

NEPA also requires consideration of "all reasonable courses of action, particularly those that might avoid adverse environmental effects." This wise safeguard against premature or ill-considered adoption of actions which pose significant environmental hazards has, by accident or design, been circumvented in the process by which the guidelines have been formulated and released.

If recombinant DNA techniques prove as powerful as expected and human nature and hardware as unreliable as they have always been, proliferation is almost certain to have disastrous consequences eventually. But to establish a policy of proliferation by default is not only to uncork the genetic genie in a manner likely to bring about disaster: it is also to deny the public its right to make an informed decision on a matter which vitally affects its interests. In my view, the only way to protect that right is to require an immediate and full moratorium until policy options have been carefully considered and chosen through democratic procedures developed for the purpose. No doubt this course of action would be frustrating to scientists who see the problem in terms of technical solutions to short-term risks or who, in the name of freedom of inquiry, defend their freedom to manufacture novel and potentially harmful organisms. But only in this way can we ensure that a decision to set off down the one-way road of proliferation is not made by default.

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The recent enactment of the Toxic Substances Control Act (Public Law 94–469) may have implications for certain kinds of research on recombinant DNA. In the debate over the risks and benefits of such research, some scientists have stressed that important practical applications, for example, the creation of bacteriological "factories" to produce needed quantities of somatotropin or insulin, could be quickly realized.

The definitions section of the new law may encompass the use of recombinant DNA techniques to produce quantities of these and other important chemicals. According to the law, if the administrator of the Environmental Protection Agency finds that the manufacture of a chemical substance "may present an unreason-

able risk of injury to health or to the environment" and that there are insufficient data to determine the risks, he can require that those who intend to manufacture the substance complete extensive tests to determine the safety of their proposal.

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Those debating the issue of recombinant DNA experiments might do well to consider what *can* be done along with what *should* be done. While I enjoy reading the arguments concerning freedom to do research and the questionable benefit of additional knowledge, I do not find these arguments of much use in plotting a course of action.

More specifically, how do opponents of recombinant DNA experiments propose to enforce a ban on them, and how do proponents of general guidelines expect to achieve adherence to such guidelines? Certainly legislative action cannot be relied upon, and it is obvious that consensus is unlikely. Federal funding policies can influence only the pace at which such experiments are conducted.

Monitoring recombinant DNA research then becomes the crucial issue. One approach for federal surveillance is put forth by Clifford Grobstein (10 Dec. 1976, p. 1133). I suggest, for discussion, an alternative, two-point proposal:

1) Establish a small number (three to five) of "centers for recombinant DNA research," each with an independent control board comprised of members from both the scientific and nonscientific communities and charged with the responsibility of setting, publishing, and reviewing guidelines for experiments. In addition to a permanent staff, each center would provide for a visiting scientist program. Federal funding for recombinant DNA research would be confined to these few centers.

2) Establish a single, independent review board consisting of the director of each center, three members (not associated with biological research) of the National Academy of Sciences, and two members from the scientific press. This board would periodically review the work of each investigator, issue press releases, screen all material submitted for publication, and publish an annual report in language comparable to that in the Research News section of *Science*.

If we can't stop the research, let's attempt to keep abreast of the new knowledge.

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