Review: Moral Responsibility and the "Galilean Imperative"
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Moral Responsibility and the "Galilean Imperative"*

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"*Sapere aude*!" Now that so many of the advances in knowledge take the form of scientific discoveries, which are often put to practical use before their effects can be fully known or carefully evaluated, should Kant's motto for the Enlightenment be discarded? If to "dare to know" is to undertake inherently risky experiments or to disseminate truths which may be misused, would it be wiser to resist the impulse to satisfy the cravings of curiosity when there is reason to fear that serious harm could result?

For intellectuals whose vocation commits them to the pursuit of truth "even unto its innermost parts" (the psalmist's phrase having become especially apt in the era of subatomic particles and micro-organisms), the question is bound to be troubling. However absorbed they become in their special disciplines, those who inquire into the truths of nature and man are regularly reminded that they also belong to a kind of secular clergy, as Julien Benda first suggested in *La Trahison des clercs*. By one contemporary sociological definition, intellectuals are those "who exhibit in their activities a profound concern with the core values of society," who "seek to provide moral standards and to maintain meaningful general symbols."[1]

* A review of: Clifford Grobstein, *A Double Image of the Double Helix: The Recombinant DNA Debate* (San Francisco: W. H. Freeman & Co., 1979), pp. xi+117; $11.00 (cloth); $5.95 (paper). Keith M. Wulff, ed., *Regulation of Scientific Inquiry: Social Concerns with Research*, American Association for the Advancement of Science Selected Symposium no. 37 (Boulder, Colo.: Westview Press, for the American Association for the Advancement of Science, 1979), pp. xvii+222; $17.00. John Richards, ed., *Recombinant DNA: Science, Ethics, and Politics* (New York: Academic Press, 1978), pp. xiii+368; $19.50. David A. Jackson and Stephen P. Stich, eds., *The Recombinant DNA Debate* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1979), pp. xiv+385; $19.95. Marshall S. Shapo, *A Nation of Guinea Pigs: The Unknown Risks of Chemical Technology* (New York: Free Press, 1979), pp. xvi+300; $12.95. Gerald Holton and Robert S. Morrison, eds., *Limits of Scientific Inquiry* (New York: W. W. Norton & Co., 1979), pp. xviii+254; $3.95 (paper).

1. Lewis A. Coser, *Men of Ideas: A Sociologist's View* (New York: Free Press, 1965), p. vii, cited in J. P. Nettl, "Ideas, Intellectuals, and Structures of Dissent," in *On Intellectuals*, ed. Philip Rieff (Garden City, N.Y.: Doubleday & Co., 1970), pp. 65–66n.

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Should natural scientists be considered intellectuals in this sense of the term? John Dewey, who was among the first to recognize the importance of the question, argued that a separation of what he termed natural and moral science was unwarranted because under modern conditions the natural sciences have acquired moral meaning: "When physics, chemistry, biology, medicine, contribute to the detection of concrete human woes and to the development of plans for remedying them and relieving the human estate, they become moral; they become part of the apparatus of moral inquiry or science."[2]

Many natural scientists would surely be uncomfortable with Dewey's answer if, by accepting it, they would open their work to moral judgment and political intervention. The 1977 Nobel laureate in physiology or medicine, Roger Guillemin, probably spoke for quite a few of his colleagues when he recently objected because a popular magazine had run a story on the development of the cruise missile in its department of science. "What is going on there," he complained in a letter to the editor, "is not science but technology and engineering. . . . The use, including misuse or ill use, of . . . knowledge is the realm of politicans, engineers and technologists."[3]

In effect, Guillemin is claiming that whenever scientific knowledge is put to use the responsibility rests entirely with the practitioners and not with those who simply make the knowledge available. It follows that it would be absurd to expect scientists to refrain from doing fundamental research merely because their findings might later be misapplied by others. To do so would be as wrong as to blame a benefactor for leaving a legacy misused by a profligate heir. In both cases, it is the user, not the donor, who is culpable.

But is the issue really so clear cut? Scientists themselves often point out that basic or fundamental research is increasingly a direct source of technology. Indeed, it is the new dependence of technology upon science which is thought to mark the transition from the industrial to the postindustrial era. The evidences of this dependency are by now familiar to all. The physical and life sciences are the source of a great many of the innovations which have revolutionized our way of life. Whether we make

2. John Dewey, *Reconstruction in Philosophy* (New York: Henry Holt & Co., 1920), p. 173. Dewey's views are cited by Richard McKeon, in "Democracy, Scientific Method, and Action," *Ethics* 55 (1945): 235–86, esp. p. 258, who subjects them to a richly instructive critique. McKeon contends that the efforts of pragmatists and positivists to unify natural science and moral discourse, in order to bring about a unity of science and democracy, is misconceived and potentially dangerous. Instead, he argues for a sharp distinction between social action, including the democratic process, and scientific law (p. 264). According to this reasoning, it would seem that natural scientists would become intellectuals, in Coser's sense, only when they leave the realm of experiment and exactitude and enter that of the uncertain, if still rigorous, discussion of ideals by means of the higher forms of rhetoric.

3. Roger Guillemin, in a letter to the editor, *Time* (September 3, 1979), p. 5.

love or war, whether we use the birth control pill or the atomic bomb, we are making use of the end products of fundamental science.

Unfortunately, the use of many of the products of the laboratory, even those not designed as lethal weapons, may entail significant risk. The list of nasty surprises grows longer by the day, and in an alarming number of instances the risks become evident only well after the product has been put to use. When a thousand new chemical substances are thrown onto the market each year, after safety reviews which are at best incomplete, some are bound to turn out after ten or twenty years to have unanticipated harmful effects. Can the researchers whose work makes these applications possible conscientiously wash their hands of all responsibility for doing whatever can be done to identify the risks in advance? Can they plausibly claim that science is so far removed from technology that the uses made of their discoveries are in no degree their responsibility?

In the paradigmatic instance of science-based technology—the development of atomic energy—some of the scientists engaged in fundamental research have, in fact, expressed moral qualms about their role. At least one eminent researcher claimed that before the atomic bomb was developed it occurred to him to propose that all scientists refrain from contributing to its development. Werner Heisenberg, commonly considered the dean of the German physicists, maintained in an autobiographical memoir that he went to occupied Copenhagen early in the Second World War with the intention of proposing a moratorium on bomb-related research to Niels Bohr, another exceptionally influential physicist whose views were sure to carry weight with scientists working on the Allied side.[4] Whether because he was too circumspect or because in retrospect he put more stress on his intention than it actually had in the conversation (but if so, why the visit?), Heisenberg succeeded only in frightening Bohr, who immediately fled to England where he had no trouble persuading his colleagues that they should develop the atomic bomb before it could be made available to Hitler by the German physicists.

More common among the scientists who took part in the Manhattan Project was an ambivalent attitude drawing them in one direction to the curiosity-driven creed of the scientist and in the other to a sense of moral responsibility. The desire to unleash the energy locked in the atom, and so to prove dramatically the truth of the physical laws of a totally invisible structure, must have been in itself a powerful motivation, judging from the joy of the researchers at the moment of success. Moral motives were

4. Werner Heisenberg, *Physics and Beyond: Encounters and Conversations* (New York: Harper & Row, 1971). The fullest account of the German atomic bomb research is given in David Irving, *The German Atomic Bomb* (New York: Simon & Schuster, 1968). The Heisenberg episode is further discussed in Sanford A. Lakoff, "Science and Conscience," *International Journal* 25 (1970): 754–65.

also evident, especially on the part of those, like Leo Szilard, who first urged that the bomb be developed, lest the war be lost by default, and later, when victory seemed assured, that it not be used, lest a terrible precedent be established.

After the war ended with the atomic bombing of Japan, the leader of the Manhattan Project, and in some ways the personification of American science, J. Robert Oppenheimer, continued to express the same ambivalence. When his security clearance was lifted in 1954, the charge laid against him was that he had been "less than enthusiastic" about the development of the hydrogen bomb. In fact, as chairman of the General Advisory Committee to the Atomic Energy Commission, Oppenheimer had expressed reservations about embarking on a crash program to develop a "super" bomb, both because it did not appear feasible and because it seemed immoral and militarily unnecessary to develop a weapon even more destructive than the fission bomb. Yet, when Edward Teller showed that such a bomb could be made to work, Oppenheimer confided to him that he would never have opposed the crash program if it had been clear earlier that the project was technically sound. As Oppenheimer himself explained, "When you see something that is technically sweet, you go ahead and do it and you argue about what to do about it only after you have had your technical success."[5]

Later, after he had been all but certified a martyr to McCarthyism, Oppenheimer made another public statement which may well have amounted to a principled concession to Teller reaffirming their common commitment to the scientific vocation. In his Columbia bicentennial address, Oppenheimer said: "When a friend tells of a new discovery . . . we may not be able to listen without jeopardizing the work that is ours and closer to us; but we cannot find in book or canon—and we should not seek—grounds for hallowing our ignorance." It may be necessary "to leave the room, from fatigue or trouble; but that is our weakness and our default."[6]

The ambivalence felt by scientists may well be even more widespread. Alvin Weinberg, the former director of the Oak Ridge Laboratory, has suggested that we have all made a "Faustian bargain" to accept the benefits of science and technology in exchange for the risks. The metaphor is unfortunate in suggesting that in the process we have sold our souls to the devil. This is a notion one would expect from such hostile critics as Jacques Ellul, Lewis Mumford, and Theodore Roszak, but not from so devout an apostle of science and technology as Weinberg.

5. Atomic Energy Commission, *In the Matter of J. Robert Oppenheimer: Transcripts of Hearing before Personnel Security Board* (Washington D.C.: Government Printing Office, 1954), p. 81.

6. The text of Oppenheimer's speech was published in the *New York Times* (December 27, 1954), p. 10.

Still, his point is well taken. As the philosopher Michael Ruse points out,[7] we know that we run a certain risk of being killed in an airplane crash, but it is not unreasonable to travel by air, as most of us do. Similarly, although the program of mass immunization aimed at preventing a swine flu pandemic (which never developed) caused a significant number of those immunized to contract a disease, there has been no demand for an end to mass immunization programs. It is well understood that most vaccines are safe and that immunization has freed us from such scourges as smallpox, diphtheria, and polio. The lesson drawn from the swine flu episode is that those responsible for such programs must be more careful in recommending untested vaccines and that they should make more of an effort to explain the balance of risks that each of us must weigh in deciding whether to be immunized.

The need to make such information available is especially serious in campaigns of voluntary immunization, which raise the free-rider problem in one of its most acute forms. If enough people volunteer to be immunized, even those who refuse will probably be protected because the epidemic will not spread. The willingness of enough people to accept immunization, therefore, depends upon their confidence in the recommendations of the public health authorities. If too many come to feel that these officials are apt to mislead them, either about the danger of an epidemic or about the risks of immunization, the maintenance of public health could be jeopardized, unless a compulsory rather than a voluntary program is adopted.

The example of immunization suggests that scientists, along with engineers, bureaucrats, and politicians, all of whom are involved in the interlocking chain that leads from the laboratory to the decision to use a new product or process, have at the very least an obligation to make known any reservations they may have about its safety or benefits. More than this, they may also have an obligation to take the trouble to investigate the possible consequences of their discoveries. In some instances, the discoverer of a piece of knowledge may lack the expertise to assess its consequences. It takes pathologists and epidemiologists to predict the effects of a new drug developed by a pharmaceutical chemist, but even so the chemist is apt to know enough about the drug to participate in an evaluation and to make sure that one is conducted. To fail in either of these responsibilities is to be morally culpable of causing harm by an act of omission. After Thalidomide, no one engaged in the development of "ethical drugs" can plausibly claim that his moral responsibility ends once the product is shown to be effective for the limited purpose claimed. What is true for nuclear physicists and for pharmaceutical chemists holds for all scientists. The right they claim to pursue truth wherever it leads carried with it a responsibility to alert

7. Richard, p. 120.

users of their discoveries to risks and dangers which, in many cases, they are best able to ascertain.

Another, perhaps more obvious, restriction on the right to engage in scientific research arises in connection with the performance of experiments which, unlike theoretical inquiries, do not fall under the general protection accorded in a liberal society to all forms of freedom of thought and expression. As Thomas I. Emerson, the constitutional lawyer, points out,[8] an experiment which may cause harm is not the expression of an idea but the commission of an overt act. As such, it is subject to the same restrictions that apply to all overt acts that may be harmful to others. Another legal scholar, Harold Green, notes that a precedent for such restriction was established in the Atomic Energy Act of 1946, which imposed limitations on experiments and other activities involving the use of fissionable or radioactive materials.[9] Dorothy Nelkin, a student of technical controversies, also points out that the use of psychochemicals in brain research was virtually forbidden in the 1960s.[10]

More recently, in the National Research Act, all research using human subjects has been made subject to prior scrutiny by institutional review boards operating under broad guidelines set forth in the law. The statute was occasioned by the revelation of some particularly disturbing cases. In one, elderly patients at a nursing facility who had been persuaded to participate in an experiment involving the injection of cancer cells into the skin were told only that it was a "skin test." The researchers contended that the experiments posed no significant risk of causing cancer, but that if the patients had been informed that cancer cells were being used, they would have been unduly alarmed. Another oft-cited case involved a group of prisoners with syphilis, some of whom were deliberately not treated in order that the effects of medication could be studied. The law now requires "informed consent."

In cases like these, the breach of ethical standards is blatant and the need for control evident. In others, regulation of research poses harder problems. Research into certain chromosomal abnormalities has been decried as unethical because even the identification of individuals with genetic makeup thought to predispose to deviant or criminal behavior could stigmatize them regardless of their actual conduct. Research into the link between intelligence and genetic characteristics has been denounced because the findings could be used to justify racial discrimination.

Social scientists are fearful that if proposals currently being considered, which would extend the reach of the law and stiffen the standards, should be adopted, they could well have a chilling effect on a

8. Wulff, p. 132.
9. Ibid., p. 116.
10. Holton and Morison, p. 206.

great deal of social research. Marshall Shapo, however, who is a professor of law, argues that the rights of human subjects should be protected against harm from social researchers as much as from medical researchers and drug companies. The social researchers—notably Albert J. Reiss, Jr., Lee N. Robins, and Eliot Freidson—in the Wulff volume point out that the biomedical model of informed consent does not transfer well to social research. In some cases, it would vitiate the research altogether and in others, where indirectly obtained data are used, it would be impossible to administer. In some types of social research, moreover, the "harm" that social research might do to individuals and institutions studied could be socially desirable as, for example, when corruption or inefficiency is exposed.

* * *

The issue of the restriction of research has come to public attention mainly in connection with experiments involving genetics. There already has been much controversy about genetic surgery and cloning, even though the possibilities of such activities on the human scale are still remote, with the exception of screening for genetically transmitted diseases and abnormalities. A more acute controversy has developed over experiments with recombinant DNA. This controversy is the focus of the book by Clifford Grobstein and the essays in the collections edited by John Richards and by David A. Jackson and Stephen P. Stich. It is also an important concern of the three other volumes under review. The book by Shapo probes the question of liability for harm and standards of consumer protection in connection with a variety of experiments and technologies. The collections of essays edited by Keith M. Wulff and by Gerald Holton and Robert S. Morison treat the general question of whether scientific research should ever be restricted.

The recombinant DNA controversy first came to general awareness in 1975 when 150 researchers, including ninety from the United States, met at the Asilomar Conference Center in Pacific Grove, California, and issued a declaration voluntarily imposing restrictions on their own research and asking their colleagues to do the same. This appears to be the first recorded initiative of this sort ever taken by a representative group of researchers.

The experimental technique that troubled the conferees is an ingenious method for isolating bits of DNA, the substance that controls the development of all characteristics of plans and animals, from different organisms and splicing or recombining them to from new, artificial genetic combinations. The technique enables the researchers to study the ways in which DNA controls the development of particular characteristics, and it also has important technological applications. By inserting the DNA controlling for certain substances into bacterial hosts, the substances can be produced in what amounts to a "biofactory."

The researchers who met at Asilomar discussed a number of concerns, including the danger that certain toxic or otherwise life-threatening substances would be produced which would somehow escape from the laboratory. They were particularly troubled because the bacterium in use in most of the experiments is a strain of *Escherichia coli*, a normal inhabitant of the human intestinal tract. This particular strain, however, which is known as K-12, has been in use in laboratories for some fifty years, and its characteristics are well understood. Many of the experimenters contended at Asilomar, and many still contend, that this strain has developed so many adaptations to life in laboratory conditions that, like domesticated animals, it could not survive in the wild or, in this case, in the human gut. Nevertheless, the fear was expressed that, if a bacterium containing some dangerous foreign DNA, such as a cancer-causing virus, were to escape laboratory confinement, it could enter and survive in human beings, where the virus would take effect, either because the *E. coli* would survive for a long enough time or because the foreign DNA would be transmitted to other, hardier bacteria. Certain of the researchers were troubled by the question the biologist George Wald was to raise in another forum: "To do potentially hazardous experiments, why pick an organism that lives in us?"[11]

Concern was also expressed over "shotgun experiments" in which random bits of DNA from a complex disassembled genome (such as the human cell) are propagated through the recombinant technique. It was feared that in these experiments combinations might be formed which would have highly unpredictable consequences for man and the environment.

At Asilomar, however, as Grobstein points out, there were no "maximalists" in favor of a total ban on all research using recombinant DNA.[12] There were some "minimalists" in favor of as little regulation as possible, but the largest group consisted of "moderates" who preferred that the work proceed with caution, since the potential dangers were still too uncertain to assess and because they wanted to reassure laymen that the research community was behaving responsibly, lest an alarmed public demand unnecessarily severe restrictions.

The conferees reached consensus on a recommendation that the research be classified into four different categories depending upon the degree of risk and uncertainty. Projects falling into the first or highest category of risk were not to be performed at all. Others were to be undertaken only with appropriate levels of physical containment, in the form of strict laboratory regulations, and "biological containment," by the use of a bacterial host so genetically "crippled" as to be incapable of surviving in vivo.

11. Jackson and Stich, p. 130.
12. Grobstein, p. 24.

The Asilomar recommendations were adopted by the National Institutes of Health (NIH), which issued a set of guidelines covering research in each of the designated categories. The types of research which were not to be performed at all included cloning of recombinant DNAs derived from certain pathogenic organisms and cancer-causing viruses or from DNA containing genes for the biosynthesis of potent toxins and also the transfer of a drug-resistance trait (such as penicillin) to microorganisms not known to acquire it naturally. The guidelines applied to all research supported by the NIH, which effectively meant all university research but not industrial experiments. To review the standards, the NIH created a scientific advisory panel, the Recombinant DNA Molecule Program Advisory Committee.

These steps did not satisfy the more extreme critics of the research. As the philosopher John Richards rightly observes, "The thoughtful, measured tone of the early stages of the debate soon erupted into a more intense, all-out fight."[13] Erwin Chargaff was one of several eminent biologists who argued that their colleagues were being grossly irresponsible. As Chargaff put it, in a letter to *Science*, "If Dr. Frankenstein must go on producing his little biological monsters—and I deny the urgency and even the compulsion—why pick *E. coli* as the womb?" Any trait the researchers would choose to study, he predicted, "will eventually get into human beings and animals despite the precautions of containment." Chargaff also complained that the researchers had seriously underestimated the risks entailed in the creation of new organisms, risks which could prove irreversible: "You can stop splitting the atom; you can stop visiting the moon; you can stop using aerosols; you may even decide not to kill entire populations by the use of a few bombs. But you cannot recall a new form of life."[14]

Raising a point also made by other critical biologists, notably by Robert Sinsheimer, Chargaff also put a more speculative objection. The researchers were intending to combine relatively primitive life forms, the prokaryotes, with the more advanced eukaryotes, or in other words, organisms that do not have nucleated cells with those that do. The more advanced cells had been developed in the course of hundreds of millions of years of evolution. The research contemplated threatened to breach the barrier that had been created by nature. "Have we the right," Chargaff asked rhetorically, "to counteract, irreversibly, the evolutionary wisdom of millions of years, in order to satisfy the ambition and the curiosity of a few scientists?"[15]

As the controversy heated up, a series of extraordinary public hearings were held, at Ann Arbor, Princeton, Cambridge, and San Diego, where much of the research was underway, and in Washington,

13. Richards, p. 322.
14. Ibid., pp. 324–25.
15. Ibid., p. 326.

where the National Academy of Sciences convened a well-publicized forum. Legislation was introduced in the states of New York and California which was designed to reenforce the NIH guidelines, and another effort was initiated in Congress in order to forestall a proliferation of contradictory local ordinances and extend the reach of the guidelines to industry. The local meetings usually led to the creation of monitoring committees more comprehensive in membership than the NIH advisory panel, which is composed exclusively of research biologists.

As new information has become available, the researchers' estimates have become more reassuring. Most now believe that the strain of *E. coli* in use in the experiments with recombinant DNA is definitely not viable outside the laboratory. To diminish risk still further, another strain has been developed which is even less capable of surviving in the human intestine. Fears that DNA might be exchanged with other more viable hosts have been answered by the observation that such exchanges go on naturally all the time but have a very low probability of producing new organisms capable of surviving. The same argument is raised about the supposed danger of combining prokaryotes with eukaryotes. As to interfering with what Chargaff referred to as "the wisdom of evolution," defenders of the research point out that this wisdom is also responsible for the transmission of disease and pestilence.

Most of the researchers are not ready to claim flatly that there is no risk at all in their experiments. As Grobstein puts it, "it is not self-evident that particular DNA-recombinant organisms escaping laboratory confinement may not propagate in natural populations."[16] It is, rather, that a large number of the researchers now consider the risk of harm too small and too remote to warrant concern. As a result, the pressure for legislative control has died down, and the NIH advisory panel has recommended that the restrictions on all but the highest categories of risk be dropped.

The stories about recombinant DNA that now make the headlines are those that tell of the practical benefits of the research. These are certainly substantial, as indicated by the high level of commercial investment now being made to achieve them. Insulin, somatostatin, and the human growth hormone are expected to be produced by biofacture in the not-too-distant future. The growth hormone is used to prevent dwarfism in children and is currently available only from cadavers. The production of insulin by this process will mean that its supply will no longer be limited by the availability of animal tissue and that it will not be rejected, as insulin derived from animals sometimes is. It is also expected that vaccines and antibiotics will be synthesized (as with interferon recently) by the use of recombinant DNA technology.

16. Grobstein, p. 86.

Enthusiasts like A. M. Chakrabarty also predict that when even more is understood about recombinant DNA it may be possible to increase the yield of plants and reduce the need for chemical fertilizers by creating new hybrids or by implanting in them or in their bacterial symbionts DNA controlling the capacity for fixing nitrogen from the air.[17] Similarly, it may be possible to produce substances usable as fuel, such as methane and alcohol, by biofacture rather than by the more cumbersome and expensive process of growing plants and processing them. Another major medical application would be the ability to remedy genetic diseases by replacing malfunctional cells with normal ones, produced by the insertion of properly coded DNA. Sickle-cell anemia, for which there is no known cure, could one day be treated by inserting in bone-marrow cells DNA which could correct the deficiency causing the disease.

* * *

Although the recombinant DNA controversy seems to have been resolved to the satisfaction of most, though by no means all, of those knowledgeable about the risks, it raises several interrelated issues of principle which remain controversial and will certainly reappear in other contexts. The key question is whether, or under what circumstances, it is morally justifiable to forbid certain types of research, either because the experiments are inherently dangerous or because the findings may be put to harmful use. Related to this central issue is the question of whether it is possible to develop universal criteria that may be applied in making the judgment to restrict research. Finally, there is the question of the process to be used in arriving at the judgment.

As might be expected, there is considerable disagreement on each of these issues, especially the central one. As Grobstein points out, while the scientists engaged in recombinant DNA research have been more than willing to exercise caution, they would not be at all willing to accept a permanent prohibition of research on any particular subject. "The method and habit of thought of science," he observes, do not "in principle accept a permanent *terra incognita*."[18] Gerard Piel, the publisher of *Scientific American*, takes this position even further when he contends that no prohibitions on research are necessary because the "social constitution" of science makes them superfluous. Presumably, the process of peer review and interaction generates a kind of corporate moral responsibility which would inhibit scientists from putting their talents to evil use. The case of Nazi medical experimentation is said to be an anomaly resulting from the political subordination of German science.[19]

17. Jackson and Stich, pp. 62–63.
18. Grobstein, p. 51.
19. Wulff, p. 44.

The Nazi example is a poor one for Piel's case. It is just as plausible to suppose that the very insistence of many natural scientists that they have no responsibility for what engineers and politicians do with their findings makes it easy for them to accept political directives or, at the very least, to make their findings available to the most diabolical of regimes. Of course there are also examples of resistance by scientists to political interference, such as the resistance of Russian geneticists to Stalin's attempt to convert them to Michurinism, but such examples only prove that the social constitution of science protects against fraud and charlatanry, not that it guarantees moral responsibility on any other count.

The contrary argument for subjecting research to tight control is put most vigorously by the philosopher Hans Jonas. With the same Nazi medical atrocities in mind, Jonas contends that it is no longer possible to distinguish between the freedom of pure inquiry and the duty to desist from harmful experimentation. Virtually every field of science, he argues, has practical applicability and, in many cases, the conduct of research requires dangerous experimentation. Experiments on human beings, Jonas argues, are no longer a rarity. He would probably agree with Shapo's characterization of the practice of drug companies in making available new compounds, the effects of which may not be known for decades, as "market experimentation."[20]

For the most part, Jonas asserts, scientists have become the servants of the state. If a scientist claims that what is done with his findings is no responsibility of his, he should be reminded that his work could not have been accomplished without "massive arrangements from outside under whose broader roof his role becomes part of a contractual division of labor." Since support comes only because benefits are expected, "the tasks of science are increasingly defined by extraneous interests rather than its own internal logic or the free curiosity of the investigator." The "ancient alibi" of the scientist is therefore undermined. Now that research is heavily subsidized and its fruits eagerly awaited, what issues from the laboratory is virtually certain to be applied, for better or for worse. In the case of atomic physics, "the world itself has become the laboratory."[21]

Robert Sinsheimer arrives at a similar conclusion. He points out that as early as 1930 an associate of Lord Rutherford warned that research into the structure of the atom might lead to the building of very destructive weapons. At the time, R. A. Millikan, the founder of Cal Tech, was among those who dismissed the possibility as a "hobgoblin." To Sinsheimer, this is an indication of the danger of adhering blindly to what he calls the Galilean imperative," the belief in the need "to explore every domain, unravel every mystery, penetrate every unknown, explain

20. Shapo, p. 92.
21. Richards, pp. 33–39.

every process. Consider not the cost, abide no interference, in the holy pursuit of truth."[22]

The notion that scientific discovery is always beneficent rests, according to Sinsheimer, on an "unspoken, even unrecognized faith—a faith in the resilience, even in the benevolence, of Nature as we have probed it, dissected it, rearranged its components in novel configurations, bent its forms, and diverted its forces to human purpose." It is a faith "that Nature does not set booby traps for unwary species." We have learned, however, sometimes at great cost, that most natural states are quasi equilibria and whenever man intervenes in such states disequilibria are caused which can be restored by natural forces only with great difficulty and over long time periods.[23] Sinsheimer and the physicist Barry Casper point out that sometimes seemingly innocent achievements in science threaten grave consequences.[24] The development of a laser which can be used to separate isotopes will make it possible to separate the isotopes of uranium cheaply and easily. As a result, one of the last technological defenses against nuclear terrorism will have been breached.

Sinsheimer also raises other examples of research that could have harmful consequences, including current work on the biology of aging. Such research, he argues, is irresponsible because if it succeeds in preventing death it will have created an enormous moral and social problem. Research on aging, Sinsheimer argues, is "the wrong research on the wrong problem in the wrong era. We need that talent elsewhere."[25] Robert S. Morison shares this concern, pointing out that if science succeeds in prolonging life, the process of social evolution will be impeded "simply . . . for the selfish advantage of that tiny fraction of humanity that happens to be alive at the time the life-extending technologies become available." The desire to live forever at the expense of "the opportunity of an indefinite number of potential others to live at all" strikes him as "cosmic effrontery" and "unjust."[26]

Sissela Bok, the ethicist, holds a position similar to that of Jonas and Sinsheimer. She argues that, quite apart from the dangers posed by experiments, there is also a danger that knowledge resulting from experimentation can provide "new, more easily acceptable ways of harming people: blueprints for new weapons or for instruments to prey upon individuals and invade their privacy, or means for terrorizing entire populations."[27] Against those who argue, as the philosopher Carl Cohen does,[28] that the burden of proof should rest on those who seek to

22. Ibid., p. 30.
23. Ibid., pp. 23–25.
24. Wulff, p. 17.
25. Ibid., p. 58.
26. Holton and Morison, p. 228.
27. Ibid., p. 121.
28. Jackson and Stich, pp. 313–18.

deny the right to inquire, Bok contends that if this standard is adopted, the threshold would be so high that no precautions would be taken, even where there is such obvious risk as in the case of discoveries with military application. She therefore argues that the burden of proof must be borne by those who propose the experiments.[29]

Jonas, Sinsheimer, and Bok are on solid ground in pointing out that scientists must assume that their work will in fact be put to use, whether for good or evil. It is less persuasive, however, to argue that moral responsibility arises because the source of support is public patronage or because the research is supported for the sake of certain desired applications. The fact that a scientist's equipment is paid for by the National Science Foundation or, for that matter, by the Department of Defense has no more bearing on his responsibility for the uses of his research findings than the fact that some of Newton's work may have been made possible by his sinecure as warden of the mint or Einstein's by the salary he earned in the Swiss patent office. The moral issue arises from the possible use of knowledge, not from the source of patronage.

It is also wrong to extrapolate from certain types of experiments which do indeed have wide effects, such as an atomic test, to the great majority of experiments, the effects of which are confined to the laboratory. Nor is it helpful to concentrate entirely on the ultimate possibilities of research and ignore the more immediate prospects. To complain of gerontological research while the ravages of aging impose premature death and mental senility is to be too much preoccupied with ultimate threats at the expense of proximate needs. There will be time enough for future generations to worry about the implications of immortality; the scientists of this generation must still be asked—indeed, beseeched—to make it possible for people to live out the span that nature presumably intended in sound mind and body.

If the Galilean imperative is to be rejected, what criteria should be used in deciding whether a given line of research should be pursued? It is perilous, as the philosopher Stephen Stich points out, to invoke utilitarianism, for technology that would be beneficial to a majority but harmful to a minority is incompatible with a social commitment to the protection of human rights.[30] Theoretically, at least, a better criterion is the calculation of risks and benefits: Presumably, a line of research which offers more benefits than risks is one that would be generally supported. The trouble with this criterion, however, is that it is sometimes virtually impossible to know precisely what the risks and benefits are. In the case of recombinant DNA research, Carl Cohen points out that "the application of a probability calculus to such states of affairs is spurious."[31] Daniel Callahan argues that in cases such as this consequentialist criteria are

29. Holton and Morison, p. 124.
30. Jackson and Stich, p. 195.
31. Ibid., p. 315.

useless, and the only plausible decision rule is to consider the moral principles at stake. By weighing the value placed on health and safety, we may decide whether or not to permit a line of research.[32] Shapo suggests that the passage of the Delaney amendment, which bans any substance shown to produce cancer in laboratory tests, as well as other expressions of concern, indicate that the American public is becoming more risk aversive.[33] The trouble with this line of analysis, of course, is that it mixes up moral and political criteria. The Delaney amendment, because it is so broad brush, is sometimes honored in the breach, when, as in the case of saccharine, there is public clamor to lift a ban. In any case, the notion that certain moral principles should be selected and applied is also objectionable because, in order to apply the principles, it is still necessary to assess risks and benefits. We cannot escape consequentialism, however rough our guesses of the results must be.

The difficulty of coming to sound criteria leads to a reliance on process. Gerald Holton notes that the late philosopher of science, Imre Lakatos, proposed a set of universal criteria to distinguish "progressive" from "degenerating" research programs. On the blacklist Lakatos included elementary particle physics and environmentalist theories of intelligence. He would have empowered a tribunal of philosophers of science to develop the criteria in order to "overrule the apologetic efforts of degenerating programs" and to make it possible for a lay jury to do the appraisals.[34]

While such a role may hold fascination for philosophers of science, it is not easy to see its appeal to natural scientists. They are apt to prefer either a system in which, in accordance with Piel's views, they are the ones entrusted with such decisions or in which, as in the case of recombinant DNA, their judgment is made subject to political review but is taken very seriously, especially in the adoption of guidelines.

Several social scientists argue that in the case of recombinant DNA the process was flawed, precisely because the political authorities put too much reliance in the judgment of the researchers themselves. Roger Dworkin and Donald N. Michael, in the Jackson and Stich volume, and Susan G. Hadden, in the Richards volume, argue that this is a classic instance of the capture of a regulatory agency by those it is supposed to regulate. Even the president of the National Academy of Sciences, Philip Handler, has admitted that, if he had it to do over again, he would have broadened the membership of the academy review committee, so as to include specialists on the possible effects of the release of harmful organisms, rather than only the researchers themselves.

Harold Green, however, who is particularly sensitive to the problems of adapting scientific controversy to the requirements of a legal

32. Richards, pp. 135–47.
33. Shapo, p. xv.
34. Holton and Morison, p. 240.

adversary process, contends that the recombinant DNA controversy is "a model of responsible public policy decision making for science and technology."[35] There is more than an ample basis for this judgment. This was one of the rare instances in which the scientists engaged in the research took the initiative to discuss restrictions among themselves and to make their recommendations public. Forums were held and committees were appointed involving other scientists and laymen. It is arguable that the NIH advisory committee, like the academy committee, should have been more broadly constituted, perhaps to include laymen as well as natural scientists, but in general the process of review was open and thorough.

Some of the researchers are said to regret having raised the issue in the first place, because it may set a precedent for a broad effort to restrict research and because it provided a platform for opponents of science and technology to gain attention and respectability. Further reflection should persuade them, however, that because they depend upon public confidence, as well as upon public financing, it is essential that they follow the precedent established in the case of recombinant DNA, by taking initiative themselves when there is reason to be apprehensive and inviting carefully framed public inquiry. In the *New Atlantis*, Francis Bacon imagined a more imperious role for the scientific elite: "We haue *Consultations*, which of the *Inuentions*, and *Experiences*, which wee haue discoured, shall be Published, and which not: And take all an *Oath* of *Secrecy*, for the Concealing of those which wee thinke fitt to keepe Secrett: Though some of those we doe reueale sometimes to the *State*, and some not."[36] The fathers of Salomon's House, however, did not have to depend on a congressional appropriations process or on the confidence of a democratic electorate.

Granted that the moral significance of knowledge is a problem that must be raised, it does not follow that scientists alone must bear the responsibility for the uses of knowledge. Since scientists cannot control these uses, the only logical conclusion they could come to, if expected to bear this burden alone, is that no knowledge should be produced, since there is always the possibility that it may be misused and it is difficult, if not impossible, to predict which knowledge may be misused. If they are to pursue their vocation in good conscience, it is essential for scientists to be forthcoming and to invite their fellow citizens to review with them the prospects opened up by their research. To do otherwise is to feed the smoldering fires of irrationalism and anti-intellectualism and thereby threaten the process of inquiry and reflection upon which the human race must depend now more than ever.

35. Wulff, p. 118.

36. Francis Bacon, *The New Atlantis*, ed. A. B. Gough (Oxford: Oxford University Press, 1924), p. 46. Bacon's views are discussed in Sanford A. Lakoff, "The Third Culture: Science in Social Thought," *Knowledge and Power* (New York: Free Press, 1966), pp. 1–61.

Candor and consultation, however, will not resolve the deepest conflicts between a sense of moral responsibility and a commitment to the Galilean imperative. More and more, all of us—not only the natural scientists—will have to ask ourselves whether we can continue to accept the sometimes bitter fruits of the tree of knowledge, especially as scientific inquiry into human nature and the operations of the human mind strips the last veils of vanity from the species. We may well have to decide, as George Steiner has put it, "whether society and the human intellect at their present levels of evolution can survive the next truths."[37]

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Readers interested in pursuing these questions will find some overlap in the books under review. Sinsheimer, for example, is represented in three of the collections of essays. Each of the books, however, has its own special virtues. Grobstein offers an instructive short course on molecular biology which helps the reader understand the nature and significance of the recombinant DNA controversy. The Richards volume contains a good statement of the case against the research by Richard Novick and a well-reasoned reply by the philosopher Michael Ruse. It is also the only volume to reprint the exchange of letters in *Science*, including that of Chargaff. The Wulff collection treats the DNA issue as a part of a larger discussion of the regulation of research, in which natural scientists, social scientists, lawyers, and philosophers are all well represented. The most fully satisfying of the books concentrating on the recombinant DNA controversy is that edited by Jackson and Stich, which contains very good explanations of the scientific issues as well as a nicely balanced debate on the merits of the controversy, including stimulating treatments of the philosophic issues by Stich and Cohen. The Shapo book treats a broad range of legal issues raised by the proliferation of chemical substances as well as by research involving human subjects. It is a useful compendium, but it suffers from tendentious argumentation and a dense and inflated style of writing. The Morison-Holton collection is an issue of *Daedalus* containing thoughtful essays, especially those of Loren Graham, Bok, and Holton.

37. George Steiner, *In Bluebeard's Castle: Some Notes toward the Redefinition of Culture* (New Haven, Conn.: Yale University Press, 1971), p. 136.