recombinant DNA research has prompted international meetings, extensive coverage in the news media, and governmental intervention at the federal level has been perceived by the public as prima facie evidence that this research must be more dangerous than all the rest. The scientific community's response has been to establish increasingly elaborate procedures to police itself—but these very acts of scientific caution and responsibility have only served to perpetuate and strengthen the general belief that the hazards under discussion must be clear-cut and imminent in order for such steps to be necessary.

It is worth pointing out that despite predictions of imminent disaster from recombinant DNA experiments, the fact remains that during the past 3½ years, many billions of bacteria containing a wide variety of recombinant DNA molecules have been grown and propagated in the United States and abroad, incorporating DNA from viruses, protozoa, insects, sea urchins, frogs, yeast, mammals, and unrelated bacterial species into *E. coli*, without hazardous consequences so far as I am aware. And the majority of these experiments were carried out prior to the strict containment procedures specified in the current federal guidelines.

Despite the experience thus far, it will always be valid to argue that recombinant DNA molecules that seem safe today may prove hazardous tomorrow. One can no more prove the safety of a particular genetic combination under all imaginable circumstances than one can prove that currently administered vaccines do not contain an undetected self-propagating agent capable of producing cancer in the future, or that a hybrid plant created today will not lead to disastrous consequences some years hence. No matter what evidence is collected to document the safety of a new therapeutic agent, a vaccine, a process, or a particular kind of recombinant DNA molecule, one can always conjure up the possibility of future hazards that cannot be disproved. When one deals with conjecture, the number of possible hazards is unlimited; the experiments that can be done to establish the absence of hazard are finite in number.

Those who argue that we should not use recombinant DNA techniques until or unless we are absolutely certain that there is zero risk fail to recognize that no one will ever be able to guarantee total freedom from risk in any significant human activity. All that we can reasonably expect is a mechanism for dealing responsibly with hazards that are known to exist or which appear likely on the basis of information that is known. Beyond this, we can and should exercise caution in any activity that carries us into previously uncharted territory, whether it is recombinant DNA research, creation of a new drug or vaccine, or bringing a spaceship back to Earth from the moon.

Today, as in the past, there are those who would like to think that there is freedom from risk in the status quo. However, humanity continues to be buffeted by ancient and new diseases, and by malnutrition and pollution; recombinant DNA techniques offer a reasonable expectation for a partial solution to some of these problems. Thus, we must ask whether we can afford to allow preoccupation with and conjecture about hazards that are not known to exist, to limit our ability to deal with hazards that do exist. Is there in fact greater risk in proceeding judiciously, or in not proceeding at all? We must ask whether there is any rational basis for predicting the dire consequences of recombinant DNA research portrayed in the scenarios proposed by some. We must then examine the "benefit" side of the picture and weigh the already realized benefits and the reasonable expectation of additional benefits, against the vague fear of the unknown that has in my opinion been the focal point of this controversy.

References and Notes

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3. If we accept the view that any natural barriers to the propagation of genetic material derived from unrelated species do not owe their existence to the intent of nature, we can reason that evolution has created and maintained such barriers because opportunities for genetic mixing occur in nature. Furthermore, we must conclude that limitations to gene exchange have evolved because the mixing of genes from diverse organisms is biologically undesirable—not in a moral or theological sense as some observers would have us believe—but to those organisms involved.

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NEWS AND COMMENT

Brazil's Nuclear Program: Carter's Nonproliferation Policy Backfires

Brasilia. The Carter Administration's attempt to convince West Germany to renege on its controversial agreement with Brazil for supplying nuclear technology has created a major furor here. Vice President Mondale's discussion of the matter with West German officials on his first foreign mission, before any consultation with Brazil, has fanned an earlier but muted concern into a nationwide outpouring of resentment at what is seen as U.S. interference with Brazil's efforts to become a major world power. The affair seems likely to further damage U.S.-Brazilian relations, which were already deteriorating, and to accelerate a discernible tilt toward Europe and Japan as the favored partners for cooperative development projects and trade deals.

The resentment expressed here is not confined to government officials but comes from many disparate elements of Brazilian society and seems to have had the effect of strengthening political support for President Ernesto Geisel and his authoritarian military regime. Spokesmen for the opposition party, the Brazilian Democratic Movement (MDB), have publicly condemned the U.S. moves and defended the West German agreement. In December a leading MDB figure, Senator Paulo Brossard of Rio Grande do Sul, said in response to then President-elect Carter's call for cancellation of the agreement that while he respected Carter's position, "it is not possible to accept it without protesting the interference in matters that are the exclusive competence of my country and its own interests." The tone of the rhetoric has become harsher in recent weeks. There has been heavy press coverage in Brazil of the Mondale trip, and editorial opinion has been overwhelmingly anti-American. Even university scientists who had been openly critical of the nuclear deal on technical grounds have closed ranks behind the government.

Ironically, President Carter's uncompromising public statements and blunt diplomacy on the nuclear proliferation issue may have had just the opposite of their intended effect. The Brazilian nuclear power program, which was going nowhere fast and might have faltered from its own internal difficulties and high cost, now seems certain to continue. To stop it now would be to appear to bow to U.S. pressure, a posture that would be both politically difficult for the Geisel regime and contrary to the country's growing national pride. Brazilian officials also seem to hope that similar considerations will apply in West Germany and have been talking publicly about that country's reputation for keeping its promises.

Veteran observers recall the earlier and equally blunt efforts of the Johnson Administration, which in 1967 sent U.S. Atomic Energy Commission Chairman Glenn Seaborg to convince Brazil that it should sign the nonproliferation treaty, with much the same result. The political opposition and the academic community rallied behind the government's refusal to sign the treaty.

Yet the West German–Brazilian agreement, under which eight large nuclear reactors and a uranium enrichment facility that could in theory be used to make the material for nuclear weapons are to be built by 1990, will severely tax Brazil's resources. One of the major problems in Brazil, as in other developing countries, is a severe shortage of skilled manpower; and the nuclear program will need thousands of technicians and engineers capable of dealing with a sophisticated technology. These people will have to be trained nearly from scratch—the program calls for training 9000 in 6 years, half with advanced degrees, with West German help—which will make an unprecedented demand on the country's narrow and already strained base of technical expertise. Foreign exchange is also

Will Fertilizers Harm Ozone as Much as SST's?

The Berkeley physical chemist who first proposed that nitrogen oxide exhausts from supersonic transport planes (SST's) might hurt the earth's protective ozone layer now says that nitrogen fertilizer—upon which the world depends for an adequate supply of food—could be just as harmful over a period of 160 years and more.

In an article which has been accepted for publication by the *Journal of Geophysical Research* and which has also been submitted as a chapter in a report of the National Academy of Sciences, Harold S. Johnston, of the University of California at Berkeley, estimates that the ozone layer, which protects life on earth from the hazards of ultraviolet radiation including skin cancer, would be reduced by 12 percent after 160 years as a result of human use of fertilizer. In 1971, Johnston estimated that ozone could be depleted by 3 to 23 percent by a fleet of SST's: the hypothesis was supported by later research and played an important role in the eventual U.S. decision not to build a fleet of SST's.

This new ozone threat has arisen as a result of the ever-increasing use of nitrogen fertilizer worldwide. Nitrogen fertilizer is widely used to increase the yields of crops used for food and livestock fodder. However, when in the soil, the nitrogen in fertilizer undergoes a process called denitrification, in which nitrogen is reduced to gases, mainly nitrous oxide (N_2O). In the atmosphere, N_2O behaves similarly to the controversial, ozone-threatening aerosols from spray cans, the chlorofluorocarbons (CFC's). In the lower atmosphere they are inert, but in the upper atmosphere they become a catalyst for the destruction of ozone.

In a conclusion to his paper which appears in the academy of sciences' version, Johnston goes on to compare nitrogen fertilizer with the two other more widely studied threats to atmospheric ozone: SST's and CFC's. He writes that, if the use of fertilizer continues its exponential increase, it would destroy the ozone layer by 15 percent over a period of a century or more—whereas over a comparable period, a fleet of 500 SST's would destroy it by only 13 percent. And, if fertilizer use were somehow held to 1974 levels, it would still destroy ozone by 6 percent over a 50-year period—or be almost as harmful as CFC's, which at 1974 levels would destroy 7 percent.

Johnston's paper draws attention to the least studied, but most challenging, of the ozone threats scientists have discussed so far—a problem which makes the issues surrounding ozone destruction by SST's and aerosols look simple. Johnston's paper stresses the many uncertainties to be resolved about nitrogen fertilizers, and their role in the environment. But, as he explained to *Science*, his aim was to define all the variables so that soil scientists, agronomists, and other specialists in the various related disciplines are going to have to study. For example, it is not known what fraction of fertilizer undergoes denitrification, how long N_2O remains in the atmosphere, or whether the oceans contribute most of the N_2O found in the atmosphere.

Such a survey of the problem has been hampered by vigorous disputes among those few scientists who have looked at it. Paul Crutzen of the National Center for Atmospheric Research estimates reductions of only a few percent; Michael McElroy of Harvard has estimated reductions of "more than 10 percent." Johnston reviewed these and other supposedly conflicting research findings and concluded that indeed the problem is an important one and that the depletion levels so far estimated by others are "all in the same ball park."

The fertilizer-ozone problem is also going to be politically complicated. It goes without saying that fertilizers are far more integral to civilization than either spray cans or SST's. In 1950, the world consumed only 2 megatons of nitrogen fertilizer; by 1960, world use jumped to 9.7 megatons; thereafter, usage jumped—what with the Green Revolution spreading fertilizer over developing countries and developed, major grain producers such as the Soviet Union increasing their fertilizer use. In 1974, the world was consuming some 40 megatons of nitrogen fertilizer, and by the year 2000, that figure is expected to be anywhere from 120 to 300 megatons. Many scientists, including Johnston, assume that fertilizers will become the single major source—man-made or natural—of atmospheric N_2O within decades.

"Obviously if the choice is between eating and some long-term cancer risk, people are going to choose to eat," he says, noting that recycling of fertilizer and more organic farming might be partial answers. Another partial solution might be to cut back even more on other things that threaten ozone, things Johnston calls "more trivial, like spray cans and SST's."—DEBORAH SHAPLEY in critical supply, so much so that the government has imposed a near-total ban on nonessential imports. Paying for the reactors and other services to be provided by West Germany will clearly prove difficult even if, as was originally contemplated, Brazil is able to discover enough uranium in excess of its own needs to offset part of the price.

The reactor effort also seems to be mismatched with Brazil's real needs, a fact pointed out by many of the country's leading academic energy specialists (*Science*, 11 February, p. 566). Brazil has a huge undeveloped hydroelectric potential, and the projected supply of electricity is sufficiently greater than the demand that schemes abound for fertilizer plants based on electrolytic hydrogen or other ways to use the excess. José Goldemberg, a nuclear physicist who currently heads the Brazilian Physical Society and who believes that nuclear power will eventually be necessary for Brazil, nonetheless characterizes the scale and urgency of the West German deal as "clearly out of context with the present [energy] crisis." He also says, however, that under the present circumstances he would not like to see the government back down.

One of the underlying but often unstated reasons for the nuclear program is the special significance that nuclear power has for Brazil, struggling as it is to become a modern nation. As one Brazilian observer describes this symbolic role, there is "a widespread belief that nuclear energy is a panacea and that if you have it you are a big, developed country—a belief of almost mythological proportions in Brazil."

The Brazilian nuclear program contingent on the West German agreement, however, still exists almost entirely on paper. Construction of reactors has not yet begun and neither have the massive training programs. Originally training was to begin in 1976 and government officials now say it will get under way later this year, but the universities that would presumably be involved in at least part of the effort know nothing of it. In fact, tangible evidence of progress since the agreement was signed in mid-1975 is hard to find. Joint German-Brazilian companies that are to carry out the work have been established, but according to Brazilian observers these are still far from functioning entities. The enrichment company, which is the most controversial aspect of the nuclear deal, is said to consist of an empty office and a president, who promptly went off to Germany for the next 2 years to learn about the process from the ground up. One skeptical Brazilian scientist, who did not want his name used, describes the entire program as "a trade of uranium Brazil does not have for technology Germany does not have," a reference to the uncertain size of the country's uranium resources and the unproved German nozzle technique for enriching uranium.

Brazil has always claimed that it would use the enriching technology strictly to guarantee itself an independent source of energy and not to produce nuclear weapons. Indeed, the lack of an ensured supply of enriched uranium is the reason Brazilian officials give for switching from the United States, which has tight controls on the uranium supplied to U.S.-built reactors, to West Germany as their supplier of nuclear technology. The first Brazilian power reactor, a U.S.-supplied Westinghouse unit capable of delivering 630,000 kilowatts, is nearing completion. The switch also represents a change from buying "turnkey" plants like the Westinghouse unit to attempting to master the technology itself and to build up an indigenous nuclear industry, for which the Germans agreed to provide extensive help. Nonetheless, Brazil has refused to sign the nonproliferation treaty, and the Brazilian military are known to be uneasy about the nuclear plans of neighboring Argentina.

One Brazilian official close to the nuclear program told *Science* that Carter's statements about nuclear proliferation last fall caused real worry within the government at just the time when the difficulties of bringing off the nuclear program were becoming apparent. It is not at all obvious that a less strident or at least less public effort to undo the German-Brazilian agreement would have had any greater success, but the opportunity now seems clearly past. Thus the Carter Administration's first foreign policy venture, as far as Brazil is concerned, seems only to have succeeded in uniting the country in its determination to resist that policy.—ALLEN L. HAMMOND

Science in Europe/A Brookings-Style Think Tank Is Proposed

Britain could have its own version of the Brookings Institution within the next year, if plans now circulating in London are put into effect. Brookings has long been admired by liberal British policy-makers, who feel that if Britain had a similar center for the scholarly analysis of policy options, some of the more glaring blunders made by successive British governments might have been avoided.

Most of the enthusiasm for a "British Brookings" has been generated by a German politician and academic, Ralf Dahrendorf, a former European Economic Community commissioner for research, science, and education who is now settled in Britain as director of the London School of Economics. Dahrendorf, being an intelligent man and—perhaps even more important—a German, is listened to with great respect in London. He is frequently called on to rally the fainthearted in newspaper articles declaring that Britain is not really in so awful a mess as might appear. He does this very well.

Four years at the EEC commission in Brussels and two as director of the London School have taught him caution. When asked to discuss with *Science* the nature of the institution he was trying to set up, he declined on the grounds that it would not be helpful to discuss the plan in public at the moment.

Some clues nonetheless are in a discussion document written by Dahrendorf and circulated through academic and government circles last year. It said that what was needed was "a meeting place which is also a place of scholarship, and one which attracts the best brains in the country as well as those in positions of major responsibility." It would be established within easy reach of Parliament and the Civil Service, cost £1 million a year to run, and at any one time would have up to 80 fellows and visiting fellows in residence. It would be run by a permanent director (Dahrendorf has made it clear that he does not seek the job) and a governing board of ten.

The areas of policy which it might investigate include the use of North Sea oil revenue to reconstruct the British economy, industrial democracy (which would include such questions as worker representation on the boards of com-