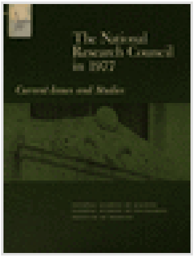

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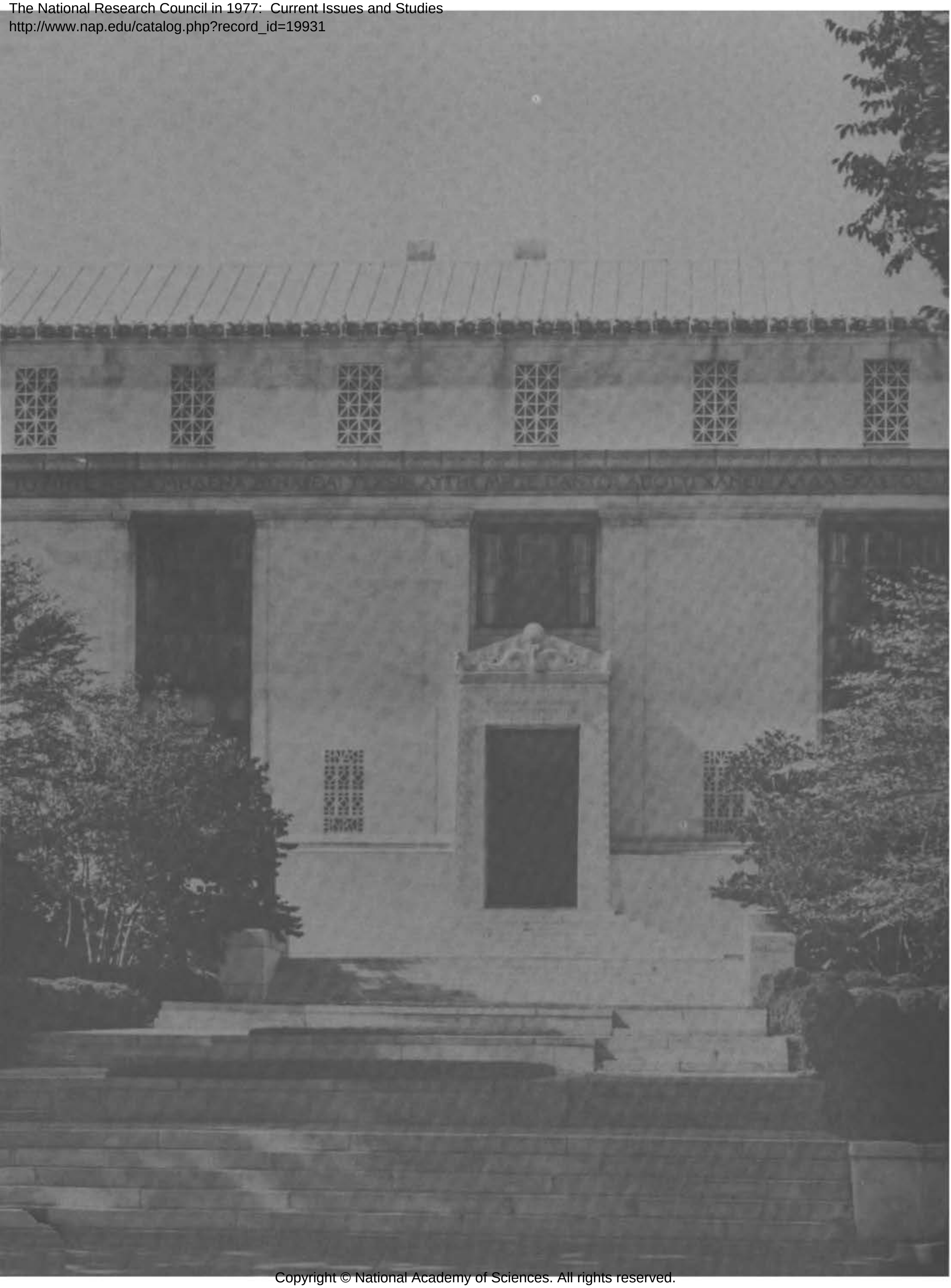

The National Research Council in 1977

Current Issues and Studies

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE

National Academy of Sciences
WASHINGTON, D.C. 1977

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Preface

This second annual report of the National Research Council offers the views of its officers on a variety of national issues as seen from the vantage of the National Research Council, as well as descriptions of a few of the study projects under way. Again, the sampling is highly selective, given the size of the Research Council and the range of its undertakings. And the intention remains the same—to offer a perspective on the concerns and activities of an organization responding to its Presidential charge ". . . to promote research in the mathematical, physical, and biological sciences and in the application of these sciences to engineering, agriculture, medicine, and other useful arts, with the objective of increasing knowledge, strengthening the national defense, and of contributing in other ways to the public welfare. . . ."

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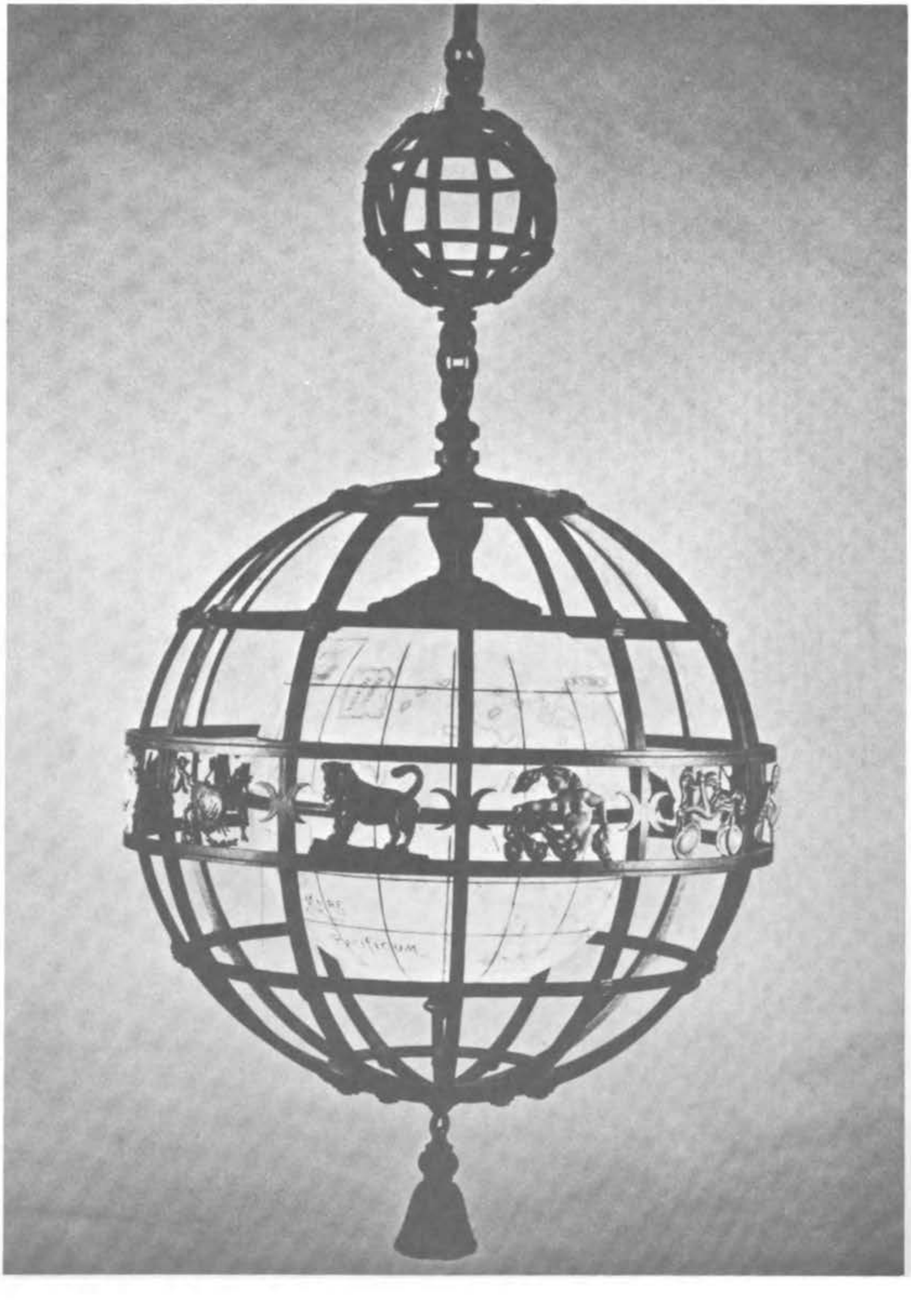
I

NATIONAL RESEARCH COUNCIL



Of Questions and Committees

PHILIP HANDLER

. . . the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art. . . .

Act of Incorporation, National Academy of Sciences, 3 March 1863.

The organizational structure by which this charge is implemented is the National Research Council, as described in the NRC report of 1976.* From this unique enterprise there flows a stream of reports to the government and to the American people, concerning subject matter the diversity of which can best be appreciated from the titles of the reports issued in 1976, listed in Appendix C.

The purpose of this introduction is to indicate the kinds of questions considered by the National Research Council, to describe the mechanisms by which the institution, *qua* institution, takes collective responsibility

* Philip Handler. 1976. Scientific volunteers in the national service. *In* The National Research Council in 1976: Current Issues and Studies. National Academy of Sciences, Washington, D.C., pp. 3–22.

Philip Handler is Chairman of the Governing Board of the National Research Council and President of the National Academy of Sciences.

for "advice" rendered to the government, and to recount some aspects of the life and times of a committee, the working unit of the National Research Council.

The principal business of science is immutable: the quest for truth. It is pursued in gleaming laboratories replete with bizarre glassware, electronic instrumentation, and dancing strip charts; in lonely observatories on mountaintops; in sturdy submersibles at inky depths; on remote plains, deserts, jungles, and at both Poles; in rift valleys; in cultivated greenhouses; and in human habitations. The subjects of these studies are variously found in cores retrieved by deep drilling; in samples found in rocks, bogs, the sea, the atmosphere, the stratosphere, and the moon; in the light reaching us from the outer planets and from the most remote objects in the universe. They embrace the smallest living organisms and ourselves. Innumerable observations and experiments, performed by a multitude of scientists the world over, are codified, analyzed, and correlated until, in the disciplined minds of a relatively small group of creative individuals, there take shape the sweeping generalizations, the laws, and the insights that converge into a coherent understanding of the nature of the physical universe, of the nature of life, and of the human condition. The scientists engaged in these endeavors are of that genre who would enthusiastically reply in the affirmative to the question that Benjamin Franklin posed to those of his friends who would join his "club for mutual improvement," the Junto: "Do you love truth for truth's sake and will you endeavor impartially to find and receive it for yourself and communicate it to others?"

Yet other individuals of slightly different turn of mind—scientists, engineers, physicians, agronomists, and so on—have seized upon each fresh understanding in the effort to employ it for the welfare of mankind. The result has been a rich outpouring of new materials, new devices, new conveniences, easier communication, and longer, healthier, and richer lives for those fortunate enough to have been born in the industrialized nations of the world where such developments proceed apace. In the three and a half centuries since Francis Bacon envisioned the scientific enterprise as consisting of the performance of "experiments of light and experiments of fruit" directed at "the enlarging of the bounds of the Human Empire, through the effecting of all things possible," these two complementary endeavors have proceeded in an elaborate counterpoint, each essential to the other. Together, basic research and its applications transformed our civilization.

NEW GOALS AND PROBLEMS

As the body politic came to appreciate that transformation and began to share the optimism of the scientific community, our nation also expanded its goals. We sought not only to conquer space and increase human longevity, but also to feed the hungry, eliminate disease and poverty, and improve the socioeconomic status of the disadvantaged, while we also undertook to assist "less-developed" nations and to secure a genuine peace. These ambitious goals and the nation's intention to seek distributive justice rested in considerable part on the heightened national confidence engendered by the progress of science and the prospect of an ever richer, more powerful science-based technology.

But we were not long to be permitted to enjoy that mood. A welter of problems old and new, large and small, reasonable and unreasonable, began to clamor for public attention. Ever greater consideration is demanded by the larger questions of our time: population growth, energy supply, adequacy of mineral resources, adequacy of the world food supply, climatic change, national security, and the deadliest arms race in history. And our affluence encourages us also to demand that food and drugs be "safe," that industrial practice injure neither the public health nor the environment, that medical research proceed vigorously but without risk to humans, that privacy be protected. Each issue becomes a matter of public controversy, each demands resolution, and many are brought to the attention of the National Research Council. Thus, it is the changing agenda of the American people that shapes the agenda of the National Research Council.

THE AGENDA OF THE NRC

More specifically, what manner of problems are addressed by the National Research Council?

A consistent thread, naturally, is the concern for science itself. What is the status of each branch of science? What resources will be required in the future to assure the strength of the national effort in each field?

How shall large-scale projects—e.g., the Global Atmospheric Research Program or the Large Space Telescope—be organized and managed? What is the optimal scientific program for NASA? What priorities should be assigned in various fields of science? Are adequate numbers of new young scientists being prepared? Will there be opportunities for them?

And the great problems of the day. Can one outline a plan whereby the scientific and technical resources of this country can be mobilized to enlarge and improve the world's food supply? What should be the place of nuclear energy in the future economy of the United States? What are the prospects for solar energy, fusion, and geothermal energy? How tightly coupled are the growth of the GNP and that of the energy supply? Can one now predict long-term changes in continental and global climate? What effects will these changes have? How reliable is current knowledge of the magnitude and distribution of mineral resources? How well can one predict the rate of depletion of fossil fuels and of the minerals utilized in the economy? Are economically acceptable substitutes available? How can we prepare for such eventualities? To what extent are we compromising the quality of life of future generations? How can one maintain global surveillance of critical situations? Is the Department of Defense efficiently utilizing the capabilities engendered by new scientific understanding?

There are the innumerable problems created by the less-than-perfect functioning of the complex man-made world. Can local and national transportation systems be rationalized and made to operate economically? Can new technology improve and lower the cost of acceptable housing? What are the prospects for coal gasification, or for desulfurizing coal? How can government policy and the government's R&D capability be used to undergird the industrial economy? Can new technology restore the efficiency of the postal service? Can one devise a national policy to assure to all children food, shelter, clothing, education, and a supportive environment, regardless of parental means? Is new public policy required for management of recreational facilities? Are vocational retraining programs effective?

And the problems of health care. What will be required to assure all Americans access to an acceptable level of health care? What is the effect of the research activity within a hospital setting on the quality of its medical care? What are likely to be future manpower requirements for physicians, nurses, technicians, and research personnel? How can health care be provided to those in sparsely settled, impoverished regions? Is it possible to validate the efficacy of clinical procedures in common use?

FACTS AND JUDGMENTS

Public concern for the impact of technology is addressed increasingly to the numerous forms and dimensions of "risk." Such matters have long been considered by the National Research Council, and it was out of that experience that I was led to note to the 1976 General Assembly of the International Council of Scientific Unions that

> . . . latterly, a new and large endeavor has arisen wherein scientific understanding is employed to appraise the risks and benefits which may attend the utilization of diverse technologies in current use. The result is not always a wholesome dialogue. Although much is written concerning the scientific method and the ethical code of science, these concepts reduce rather simply to the imperative of honesty, dispassionate objectivity, and the obligation to publish descriptions of one's procedures and findings in such a way as to permit verification.
>
> But to establish "truth" with respect to technical controversy relevant to matters of public policy, and to do so in full public view, has proved to be a surprisingly difficult challenge to the scientific community. To our simple code must be added one more canon: When describing technological risks and benefits to the non-scientific public, the scientist must be as honest, objective, and dispassionate as he knows he must be in the more conventional, time honored, self-policing scientific endeavor. This additional canon has not always been observed by the individual scientists on the public platform. Witness the chaos that has come with challenges to the use of nuclear power. Witness the cacophony of charge and countercharge concerning the safety of diverse food additives, pesticides, and drugs.
>
> We have learned that the scientist–advocate, on either side of such a debate, may be more advocate than scientist, and this has unfavorably altered the public view of both the nature of the scientific endeavor and the personal attributes of scientists. In turn, that has given yet a greater sense of urgency to the public demand for assurance that the risks attendant upon the uses of technology be appraised and minimized. And what a huge task that is! . . .

The current agenda of the National Research Council affords abundant illustration of the character and dimensions of public risk: What are the relative hazards of vaccines containing live versus attenuated poliomyelitis virus? Are there "hot particles" of plutonium that are more dangerous than the predictions based on the known properties of this element? Are some artificial sweeteners carcinogenic? Do food additives contribute to the hyperkinetic behavior of some children? To what extent do man-made carcinogens contribute to the current incidence of cancer? To what extent do man-made pollutants of the atmosphere and stratosphere endanger the public health?

Frequently, the question requires judgment of risk versus benefit, yet the two are intrinsically incommensurable: Will the electrical and magnetic fields associated with a large antenna to be buried in the earth disorient fish in lakes and streams, or confuse microorganisms that normally move, however slowly, toward the earth's magnetic pole? If so, should that deter construction of an antenna that may be the only means of communication with submerged submarines? Or if it is alleged that genetic manipulation, as by the technique of recombinant DNA, may result in a new organism of highly undesirable properties—even though none has ever been seen—what should be society's response? The question may take other forms. If the calculated odds against the occurrence of a disastrous accident are very large but the possibility of such accident is real and finite, what should society do? For example, how shall one weigh the known risk of 200 deaths per year in coal mine accidents against the statistical chance of perhaps 1 in 10 million of a major accident in a nuclear power plant? If ultrasensitive analytical techniques detect widespread occurrence of extremely minute traces of some industrial chemical known to be injurious in very much larger doses to man or some other inhabitant of the biosphere, how shall one regulate its usage?

Two general challenges recur time and again: If one knows the dose–response, in small experimental animals, of some substance that is injurious to that species, how shall one calculate the extrapolation to humans? For a given noxious material, is there a threshold of exposure below which it may be assumed that there are no effects? All these, and more, now occupy our attention.

DEGREES OF RISK

Recent experience has markedly enhanced the public's perception of risk, and it has become more acutely aware that individuals and societies have always been at risk. The public is slowly coming to understand that the term "safe" has no meaning, that one can only deal with the statistics of risk, and that, usually, to ask that risk be reduced to zero is to ask what is both unnecessary and either impossible or achievable only at unacceptable cost. For example, we can presumably live comfortably with the knowledge that the total solanine in 1 year's intake of potatoes by the average American would be lethal if given in a single dose—or should I not have mentioned it?

Technologies are adopted by society to secure specific benefits. As associated risks are also perceived, public decision must turn on the relative weights assignable, respectively, to the acceptability of the estimated risk and the desirability of the expected benefit. To be sure, rarely can the risks be stated with confidence, and seldom are risks and benefits commensurable. Yet decision is necessary. Such decision must be made by appropriately designated public officials, or, occasionally, by the public itself, guided by an intrinsically unquantifiable value system.

COMMITTEES

The task of an NRC committee is not so much to resolve each dilemma as to reveal its nature, quantify it whenever possible, make evident the reliability of the available information, and display the alternative courses available to American society. It is commonplace to scoff at "committees," to suggest that the most useful committee has but one member, or to propose that some alternative mechanism should be utilized for the analysis and resolution of questions such as those noted above. It has been suggested that formal adversarial procedures would be more suitable than the committee system for the examination and analysis of technical matters that are the subject of public controversy. But neither the hearing procedures of legislative bodies nor the formal procedures of administrative law judges, of hearing commissioners, or of the court system have been demonstrated to be as effective as a well-constructed committee for the analysis and resolution of complex controversy regarding technical matters.

Contrariwise, there is no evidence that the committee system employed by the NRC fails to arrive at the closest approximation of "truth" that the relevant body of evidence will support. In a general way, one might come to the paradoxical conclusion that a formal adversarial process is useful only for answering those questions that are so limited as to make the inquiry unnecessary; that is, those questions where facts can genuinely be separated from values, as, for example, whether artificial sweeteners are carcinogenic under any circumstances. Rarely are such questions the subject of major public controversy.

Moreover, the task of sorting out the valid from the invalid evidence can be accomplished by simpler procedures, as was demonstrated by the nonscientist hearing examiner for the U.S. Environmental Protection Agency who, for months, listened to the evidence offered, pro and con, with respect to the hazards alleged to attend the use of DDT.

For the great majority of problems that come before the National Research Council, the matter of risk is but one aspect of the question. A useful response requires not only an evidentiary examination to establish the relevant facts and degree of confidence in which they may be held, but also a judgment concerning the significance of those facts when human, social, economic, or political values are made explicit. For example, the question would not be simply whether it is true that the agents employed to flameproof children's sleepwear are mutagenic in a specific microbiological essay, but, also, whether the amounts and the manner in which they are employed are likely to occasion cancer and, if so, with what frequency? Also, are there nonmutagenic substitutes available, are there alternative approaches to protection of children against the risk of fire, how great is that risk, how successful has the fireproofing program been, and so forth? Or, to give another example, not only can the runways at Kennedy Airport be extended to lighten the burden on the New York area airports, but what would be the effects on the ecology of Jamaica Bay and on the residents of surrounding neighborhoods? Decisions concerning regulation of the use of nitrate in fertilizer will require analysis of the quantitative relationship between nitrate dosage and crop yields, the consequence of nitrate finding its way into drinking water, its effect on the ecology of lakes and streams, the relationships of nitrate usage to reduction of stratospheric ozone by nitrogen oxides, etc.

In each case, those performing the analysis must not only attempt an evaluation of the relevant body of information, but must also make their values explicit as they portray their findings of fact and their significance. Even well-intentioned scientists who attempt to be objective may give greater weight to those data that tend to support their general views. Controversy rarely consists of dispute concerning the underlying facts, rather it hinges about their interpretation, which is frequently value-laden. Hence, the public is best protected by an analysis conducted by a balanced group and to which those on both sides of a controversy have agreed. To assure that the public interest is held as the foremost objective, no social invention surpasses a well-constructed committee served by a competent professional staff in enabling the decision-making mechanisms of American society to operate in an informed manner.

Most of the questions under consideration in the National Research Council deal with subjects much broader than the specific risks associated with a specific technology. Many, of course, are not concerned with risk, per se. Invariably, however, there is required not only an analysis of the relevant facts, but also a large measure of judgment that may be value-freighted and, hence, must be made explicit. For example, how will we know whether man-made "environmental carcinogens" are occasioning an increased incidence of cancer in our population? Is the current design of a prototype breeder reactor likely to lead ultimately to a commercially successful source of energy? What research programs are most likely to enable capture of solar energy as a major contribution to total national energy requirements? How can the unique flora of the tropics be utilized for local economic development? In what order should new major facilities be provided for research in astronomy? By what procedures should research grant applications be reviewed and grant recipients selected?

Is the staffing pattern of Veterans Administration (VA) hospitals appropriate to their requirements? More to the point, what is the role of the VA hospital system in current American society? Are there measures whereby one might improve the scientific literacy of the general public? And myriad other questions, to be found throughout this report, all of which require not only an incisive analysis of the existing relevant information base, but also a high degree of creativity and professional judgment.

CRAFTING COMMITTEES

When a question is brought to the National Research Council, it is referred to the appropriate Assembly or Commission or to the Institute of Medicine. The executive committee of that unit, most of whom are members of the Academies or of the Institute, will inquire whether the question embraces a meaningful body of scientific or technological information, whether it is appropriate for consideration by that unit, whether it is sufficiently significant to warrant the formal attention requested, and whether there is some prospect that the question can be addressed successfully. If the answers are affirmative and the Governing Board of the National Research Council is in agreement, the matter is then made the subject of the standard modality of the National Research Council—a committee.

Construction of effective committees is an art carefully cultivated by those responsible for the operation of the National Research Council. In so doing, they seek the wisdom of experience, familiarity with the matter in hand, expertise in relevant areas, innovative spirit, a balance of contending interests when these are identifiable, and assurance of objectivity and willingness to devote the time and effort commensurate with the task. When the matter is controversial, an effort is frequently made to include one or more scientists of stature who have had no previous connection with the problem and whose personal expertise lies in a quite remote area but who are known to have good judgment and good scientific "taste."

Initiative in committee selection is the responsibility of the chairman of the cognizant commission or assembly. With the assistance of his professional staff, of the members of his executive committee or commission, and of the records in the files of the National Research Council this task is begun. The search network can expand to include recommendations from the staff and members of other executive committees, members of the Academies and of previous NRC committees, officers of scientific societies, and many others. The final list of potential members and their alternatives is reexamined in the Office of the Chairman of the National Research Council, using much the same criteria, but with particular attention to avoidance of undue bias. Considerations more relevant to the totality of the NRC structure than to any given committee include: affirmative action with respect to appointment of women and members of minority groups, a reasonable geographical balance, and representation by such major sectors of American society as academia, private industry, government, citizens groups, consumer groups, labor, management, scientific and professional societies, and others.

An illustration of this art is afforded by the Committee on Nuclear and Alternative Energy Systems, engaged in the most complex task ever attempted by the National Research Council. It is cochaired by an applied physicist who is a university professor and an industrial engineer whose company manufactures scientific instruments, both of whom had previously chaired major NRC committees with great success. In all, 10 members are from academic institutions, 1 from a government laboratory, 1 from the research arm of an oil company, 1 from an instrument manufacturer, 1 from a utility company, 1 from a bank, and 1 from a law firm. From a disciplinary standpoint, there are 5 engineers, 3 physicists, 1 geophysicist, 2 economists, 1 sociologist, 1 banker, 1 physician–radiobiologist, 1 biological ecologist, and 1 "public interest" lawyer. They live in Arizona (1), California (4), Colorado (1), Illinois (1), Massachusetts (4), New Jersey (1), New York (2), Oregon (1), and Wisconsin (1). In a general way, by my appraisal when the study began, about one-third were negative, perhaps 3 were positive, and the others were genuinely open-minded concerning nuclear energy. At this writing, it is clear that the ideas that have come to be uppermost in the committee's collective thinking were central to the views of few if any of the committee members when they first met.

The evolution of a committee's own dynamics and style begins at its first meeting; no two committees are quite alike. These initial meetings are tentative experiences, where the members of the committee learn something about their fellows. Formal discussion of their responses to the questionnaire concerning "potential sources of bias" reveals to each other much about the background, values, and views of their fellow members. The committee reviews its charge and work statement, not infrequently modifying both, examines the dimensions of the problem before it, and develops its own *modus operandi.* At that first meeting, federal agency staff may present the problem as it appears to the government and provide such relevant information as the government may already have assembled.

With the passage of time, as members begin to know each other, responsibilities for specific assignments, such as preparation of position papers, are agreed upon. The staff, charged with securing all available relevant information, is given more specific instructions by the committee. The committee may request appointment of additional members with expertise in relevant areas as yet unrepresented and develop a list of informed individuals whose views should be gathered, either in writing or in person. A schedule is agreed upon, and the committee is then immersed in an intensive new learning experience. Each member gains close familarity with diverse aspects of the subject material, is surprised by the attitudes of some and by the information provided by others, acquires familiarity with some portion of the material body of law, and increases his or her understanding in previously unfamiliar aspects of science and technology.

In 1976, about two dozen open committee meetings were convened, in conformance with recently adopted institutional policy. This is still a limited experience. In each case, public notice was given and invitations were extended to numerous individuals and groups who, conceivably, might desire to contribute to the specific study. In most instances, the committee gained credibility in the eyes of external interest groups; rarely did the committee gain new information or encounter a new viewpoint, but often it gained a firmer sense of the views held by the interest groups and the nature of public sensitivity to the issues in question.

Slowly, the diversity of backgrounds of the members gives rise to a coherent view of the committee's problem; conclusions and recommendations begin to emerge, almost of themselves, while the deadline appears to be upon the committee before it has hardly begun. Only after members, chairman, and staff have pieced together a rough first draft does the committee begin to see what it has wrought.

For the larger, more complex studies, it is particularly valuable for the committee occasionally to convene in an intensive workshop for several consecutive days in virtual isolation, for example at the Academy's summer studies facility at Woods Hole, Massachusetts.

The final draft takes shape. Inconsistencies, flawed arguments, missing information become evident, are debated and repaired. The logical structure of the report is put in place, and there is a last opportunity for the resolution of controversy. All committees seek for consensus, but not for a compromise in which none believe. When individuals or a minority of the committee dissent or hold views that seriously differ from those of the majority, they are encouraged to prepare a "minority statement" to be included in the report itself. Final assignments are accepted, and polishing begins. Where many have contributed portions of the first draft, all must foreswear pride of authorship if the report is to have a consistent style and avoid repetitiousness. Then, one last pass by the committee staff and the chairman and the manuscript is ready for formal review by an independent panel of reviewers.

In most instances, the review process is helpful and without friction. Almost always, reviewers note small flaws, missing arguments, absence of supporting data that are presumed to be available, minor inconsistencies, irrelevant digressions, poor grammar, verbosity, etc., and their constructive criticism is welcomed. Occasionally, however, the reviewers' comments may strike at the validity of the central findings, conclusions, or recommendations of the report. Then, like as not, the committee will demonstrate the strength of its group dynamic by supporting its report and reaffirming positions arrived at by prolonged and sometimes painful deliberation. The chairmen of the committee and of the review panel then exchange memoranda until the difficulty is resolved, sometimes by adoption of the positions espoused by the reviewers, sometimes by accession of the reviewers to the view of the committee, not infrequently by mutually acceptable compromise.

The report is then ready for public release. It has a style and flavor that is unique to the committee but not of any one member. Its conclusions and recommendations derive from that constructive synergism that makes a good committee other than the mere sum of its parts. The work of the committee is completed. The nation benefits from its collective wisdom and simultaneously gains a cadre of individuals, now extraordinarily knowledgeable with respect to the matters to which they have given intensive examination, prepared to be of assistance in the future.

SOME STATISTICS

In a typical year more than 800 groups—committees, subcommittees, and panels—are at work in the National Research Council. Some are concerned with basic science, some with development problems or engineering applications, and some with the interactions of science and technology with public policy or with far-reaching social questions. They form a pattern that is fluid and ever-changing with the flow of the Council's work. In the listing for fiscal year 1976, for example, there appear 145 groups that were new in that year, while 255 that had been listed in 1975 had been discharged.

In mid-year, these hundreds of committees and similar bodies were populated by more than 7,500 individuals occupying about 8,250 "slots" in the structure. Figure 1 shows that more than 40 percent were in academic life, while 27 percent were divided about equally between industry and federal agencies. Others work in local or state governments, in private research institutes, or in private practice.

Table 1 offers a proximate representation of the disciplinary backgrounds of those who serve. The fact that a significant number of individuals serve on more than one committee is irrelevant to this analysis in that, were such duplication completely avoided, in general, chemists would be replaced by chemists, engineers by engineers, etc. The totals in several disciplinary categories are heavily influenced by the large advisory structure of the Transportation Research Board of the Commission on Sociotechnical Systems, which includes large numbers of engineers, economists, and sociologists, as well as a significant number of attorneys.

Of the 7,500, more than 200 were foreign nationals. Every state was

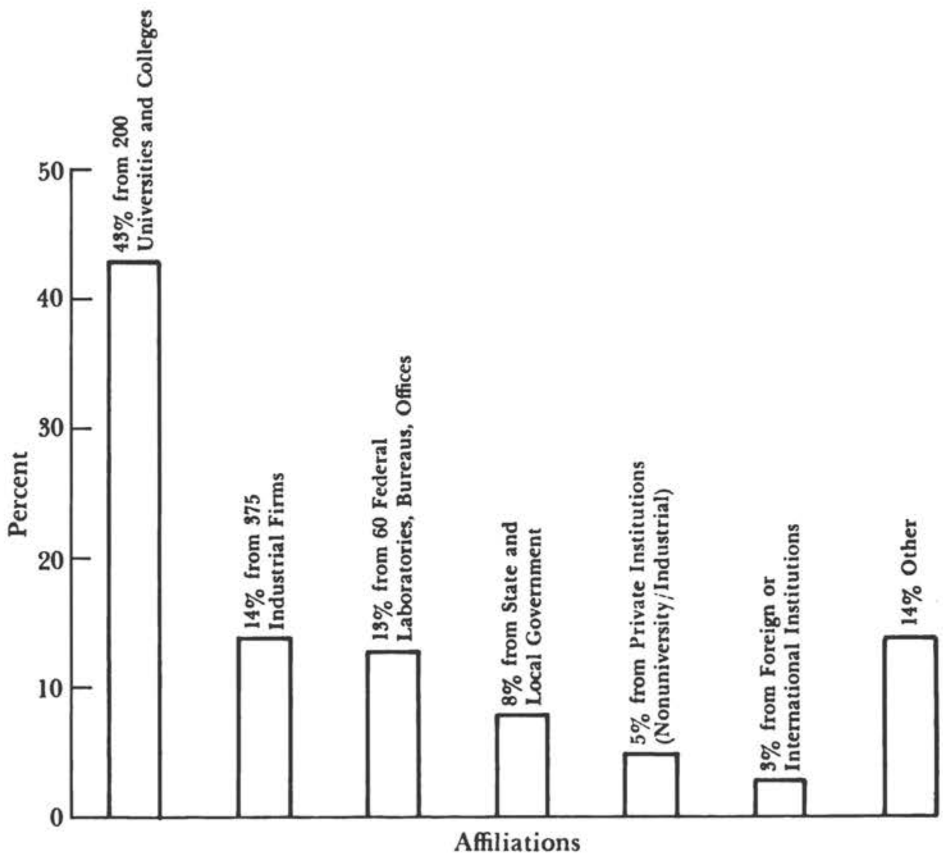


FIGURE 1 What are the "home" affiliations of the 7,500 who serve on NRC committees?

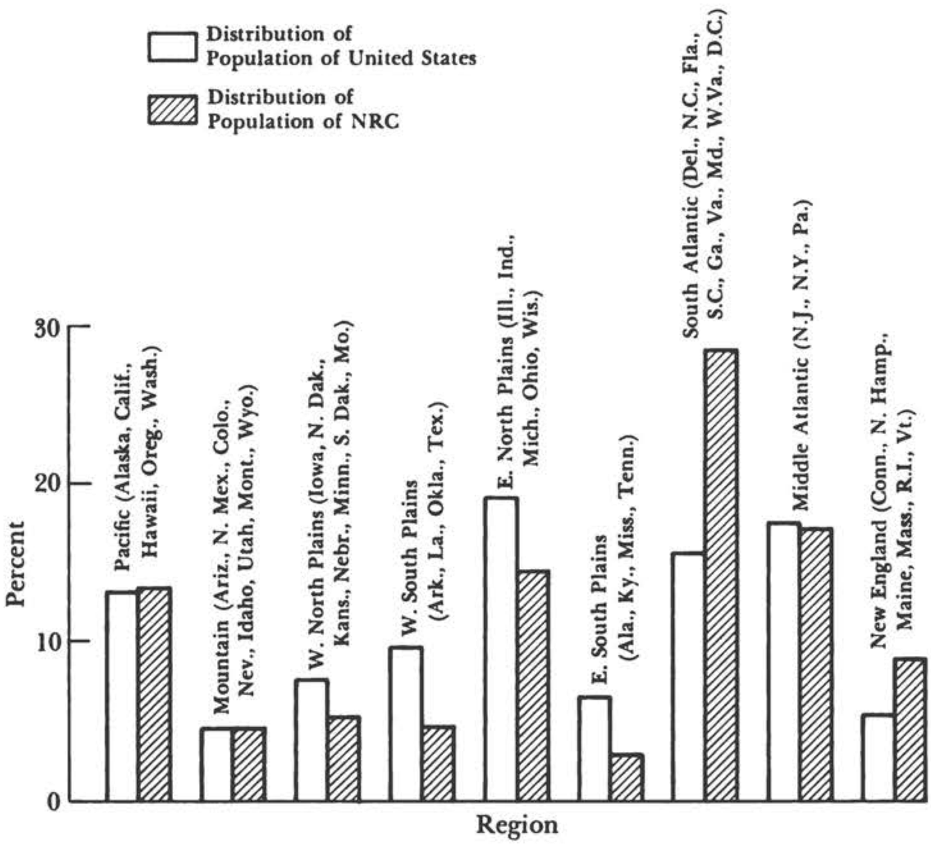


FIGURE 2 Where do members of NRC committees come from? Ninety-seven percent are U.S. citizens.

represented. The distribution by major regions of the country is shown in Figure 2, along with the regional distribution of the nation's population for comparison purposes. In some regions, the proportion of those serving in the NRC was about the same as the proportion of the population; others were larger or smaller. The high ratio for the South Atlantic region is the principal distorting factor. It comes about because the 13 percent, or so, of the members of the Research Council committees who are federal employees are drawn predominantly from the heavy concentration of federal scientific and engineering agencies in the District of Columbia and nearby Maryland and Virginia. In turn, this occasions the seemingly low ratios of the eastern and western Plains regions, while the highly

TABLE 1 Disciplinary Distribution of the Members of the Committees of the National Research Council

	Assemblies				Commissions							
	Behavioral and Social Sciences	Engineering	Life Sciences	Mathematics and Physical Sciences	Human Resources	Natural Resources	International Relations	Sociotechnical Systems		Institute of Medicine	Total	
								TRB [a]	All Other		Number	%
Agriculture	—	—	16	4	—	66	114	14	—	—	214	2.6
Biological Sciences	3	23	150	31	77	31	81	14	1	3	414	5.0
Medical Sciences [b]	12	28	455	41	29	90	43	14	70	65	807	9.8
Chemistry	1	22	33	168	31	38	16	84	17	1	411	5.0
Earth Sciences [c]	—	23	16	332	21	63	33	84	18	—	590	7.1
Physics & Astronomy	8	68	14	290	47	16	27	14	11	—	495	6.0
Mathematics [d]	5	12	12	83	31	9	6	280	10	5	453	5.5
Architecture	—	1	3	6	—	2	—	56	103	—	171	2.1
Engineering [e]	9	341	26	210	48	50	54	1,400	685	2	2,825	34.2
Social Sciences [f]	140	95	29	53	73	34	152	560	69	20	1,225	14.8
Law	6	23	2	6	—	15	6	140	30	9	237	2.9
Other	2	36	5	26	11	—	11	140	134	13	418	5.1
TOTAL	186	672	761	1,250	368	414	543	2,800	1,148	118	8,260	100.0

[a] Transportation Research Board.

[b] Includes all branches of clinical medicine, basic medical science, veterinary medicine, public health, etc.

[c] Includes geology, geophysics, seismology, hydrology, meteorology, mineralogy, etc.

[d] Includes statistics, applied mathematics, systems analysis, etc.

[e] Includes all branches of engineering.

[f] Sociology, psychology, economics, anthropology, geography, political science.

NOTE: In many cases the disciplinary characterizations overlap, e.g., in biological and medical sciences, electronics specialists may be either physicists or engineers, etc. Also, there was no attempt made to eliminate duplicated counts in cases where an individual serves on more than one NRC committee.

developed educational and industrial establishments of the Pacific and Middle Atlantic regions match their large populations. The New England region, with educational and industrial development out of proportion to its fraction of the national population, shows the second highest ratio.

Figure 3 shows that about three-fifths of expenditures are for advisory and research activities. The absolute expenditures in these categories significantly understate the magnitude of this effort. No figure is available to indicate the total number of man and woman days contributed by the 7,500 volunteers who make this activity possible. As a first approximation each contributes about 10 days per year—some much more—for a grand total of no less than 75,000 man-days per year. Were each recompensed according to the consultant's fee schedule of the federal government, to say nothing of consultant fees in the private sector, the direct cost of this enterprise would increase by perhaps one-third.

Sixteen percent of total outlays go for direct support of fellowships and other arrangements for the support of scholars. About four percent of total expenditures are for formal publications and other media and for conferences and symposia. Twenty-one percent of all expenditures are

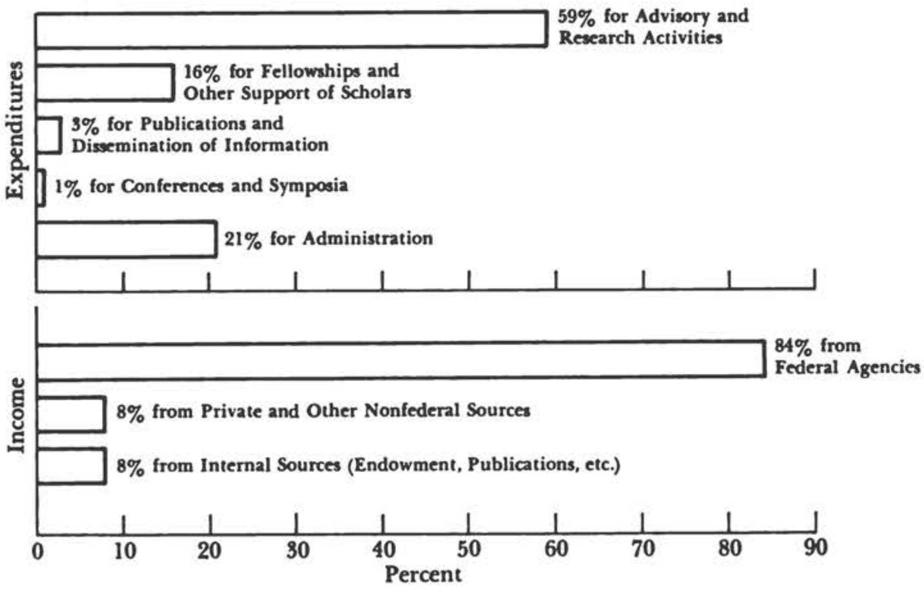


FIGURE 3 The NAS/NAE/IOM/NRC complex. The source and uses of its funds.

for the administrative support of the entire enterprise, including the physical plant.

Funds for the operation of the Research Council come principally, but not entirely, from the federal government. About five-sixths of the supporting funds come from federal contracts and grants; the remainder derives about equally between the institution's own internal resources and funds from outside private sources and from state and local governments. Finally, Figure 4 indicates the major departments and agencies of the federal government from which funds were received during fiscal year 1976. Although this picture also changes with the pattern of requests and with changes in our own perception of needs, Figure 4 may be regarded as typical of the sources of financial support of the National Research Council in recent years.

Thus, the National Research Council is a unique institution. Through it flows a continuing stream of the nation's most highly talented scientists, engineers, physicians, and other professionals. Their professional lives are enriched by an intensive learning experience while, voluntarily, they serve our nation as only they can.

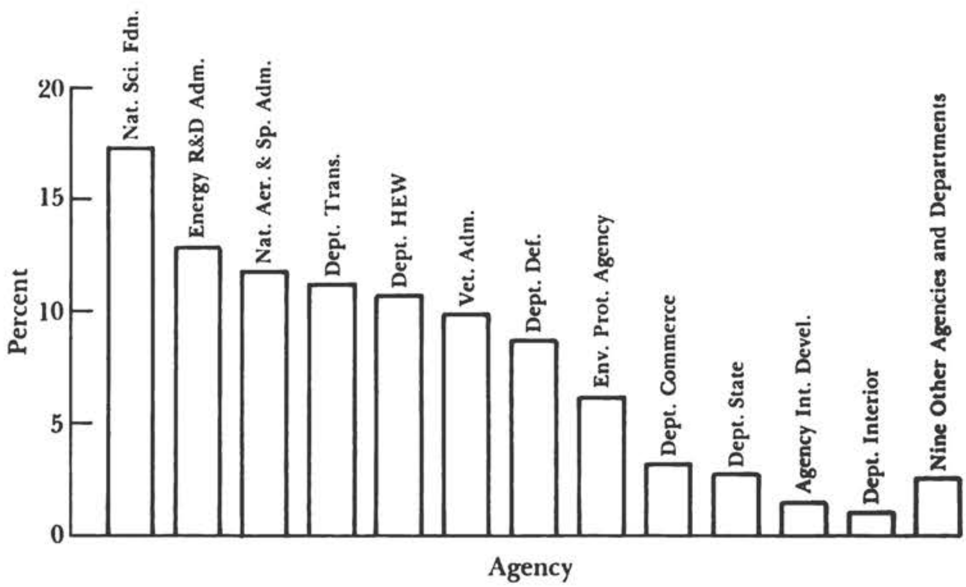
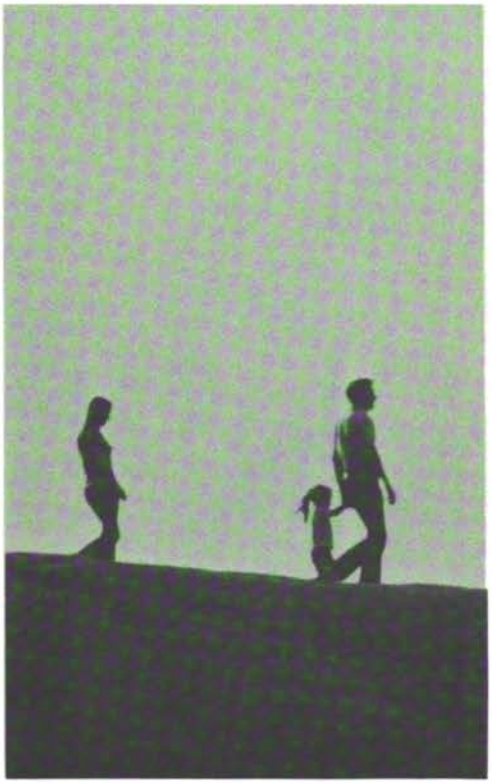
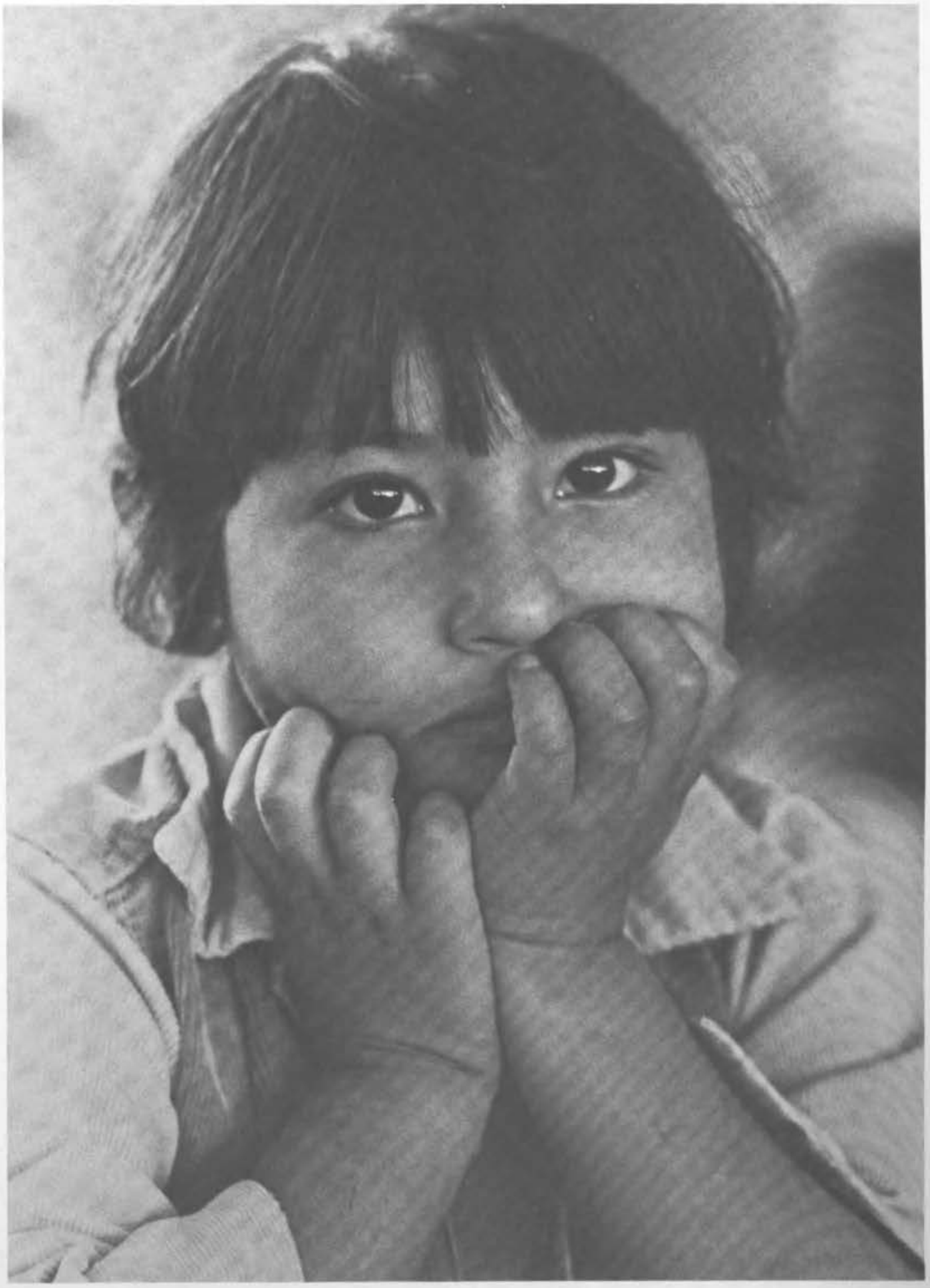


FIGURE 4 Distribution of funds from federal agencies to the NRC—fiscal year 1976. TOTAL: $47.2 million.

Assembly of Behavioral and Social Sciences





Social Research and Development

ROBERT McC. ADAMS

It seems self-evident—to a social scientist—that the natural science and engineering components of policy questions rarely can be divorced from the wider contexts of societal conflicts, compromises, and choices. Personally, I've often thought that the social aspects of many of the policy questions dealt with in NRC studies are among the most crucial. So it is heartening to find a widespread acceptance of this proposition at meetings of the Governing Board, among colleagues in other fields, and in the growing role for social scientists in the activities of several NRC commissions, boards, and committees, quite apart from the continued growth of the program of the Assembly of Behavioral and Social Sciences (ABASS). The social sciences have contributed substantially to three major NRC studies in which ABASS has been only marginally involved—the study of Nuclear and Alternative Energy Systems, the Analytical Studies for the U.S. Environmental Protection Agency, and the study of World Food and

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Nutrition. Senior federal administrators similarly acknowledge the contributions of the social sciences to a broad array of policy questions.*

But are these supportive attitudes, welcome as they are, reflected in the funding policies of federal agencies or in the ways they seek advice from the behavioral and social science community? For that matter, are these attitudes warranted by the research strategies and capabilities for policy analysis of the behavioral and social science community? While I think that the answers are not discouraging and certainly not negative, they do carry some qualifications that should be scrutinized.

SPONSORS OF RESEARCH AND DEVELOPMENT

The Assembly's Study Project on Social Research and Development, discussed in the 1976 NRC report,† provides some useful insights regarding the agencies that are our principal sponsors and "consumers."

1. Major support for social R&D—there are obvious definitional problems, but $1.4 billion in Fiscal Year 1975 is the right order of magnitude—appeared only within the last 10 or 15 years. To be sure, the assumption of federal responsibility for a social R&D component in operational programs is in some respects much older. But it is important to keep in mind the extent of the shift and expansion in emphasis that accompanied the "War on Poverty," health maintenance organizations, revenue sharing, school vouchers, and similar programs. Together they involved not only a direct attack upon major social ills, but also complex organizational reforms and radically altered priorities—all with rapidly accelerating financing providing in its train for a corresponding growth in social research and development. Especially considering the unprecedented scale, novelty, and complexity of a number of these measures, the elapsed time is still relatively brief. This may help to explain why coherent, generally acknowledged results, and even a clear sense of federal purpose, are in many cases still distinguished mainly by their absence.

* Nathan Caplan, Andrea Morrison, and Russell J. Stambaugh. 1975. The Use of Social Science Knowledge in Policy Decisions at the National Level. Institute for Social Research, The University of Michigan, Ann Arbor.

† Study project on social research and development. *In:* The National Research Council in 1976: Current Issues and Studies. National Academy of Sciences, Washington, D.C., 1976, pp. 76–81.

2. The growth in social R&D has been volatile, as reflected in the dramatic downturn in federal support over the past 2 years and also in the current budget. Essentially level dollar amounts over this period imply sharp decreases due to the effects of inflation. (I should add that this pattern does not extend to "basic," largely university-conducted research; as in the natural sciences, funding for this has remained at a relatively static level.)

3. Growth in social R&D, when it occurred, was rapid and uneven. There was a consequent lack of attention to building effective institutions for R&D management and to training and recruiting support personnel below the senior investigator level. Similarly, the paths taken by different agencies were extraordinarily diverse. Few common understandings emerged about how best to deploy social science methods and knowledge in planning, administration, and assessment processes. Little effort was made to control the inevitable overlaps in function and responsibility through coordination, because interagency arbitrators were difficult to identify during a period of mushrooming growth and because of the high rate of flux in personnel at all levels of management. As a result, broad problem areas are at least potentially an object of concern to many independent, noncommunicating agencies. The interests of more than a dozen agencies intersect, for example, in the field of early childhood.

To some, this diversity is a healthy form of pluralism, providing numerous perspectives from which to view problems that in any case almost certainly have no one solution. To others, it seems a hopeless morass, with a duplication of effort that is as unproductive as it is confusing to those seeking either policy guidance or funds for support of research. Yet it is worth noting that our Study Project's investigators found very little evidence of obviously duplicative work. Possibly, most agencies have carved out specialized niches to avoid the practical difficulties of coordination. Also, their programs have developed in interaction with different constituencies, and pressures from the latter are a continuing inducement to proceed independently and in separate directions.

4. At a more substantive level, some important innovations have appeared that are on the way to general acceptance. Several federally initiated, large-scale experiments—such as those associated with income maintenance, health insurance, and housing allowances—on the whole have been well designed and carefully evaluated. More variable in

quality have been numerous smaller activities along similar lines, e.g., those concerned with manpower, reading, and the provision of bail in criminal cases, carried out under federal, state, and even local sponsorship.

It is unlikely that even the best of these experiments will lead to conclusive generalizations not tied to the particular circumstances in which they were conducted. Public attitudes shift, so that the constraints and opportunities of today cannot be considered as permanent. Important fields like education require multifaceted courses of action, subject to institutional and local variables that seldom can be wholly standardized. But the experiments nevertheless provided unprecedentedly solid evidence to use as a basis for policy formulation. And as pilot projects simulating potential national programs, they yielded valuable information on operating and management problems. Therefore, whatever the uncertainties in generalizing from the outcomes of social experiments, it is clear that they constitute an important innovation with an assured place. Hence a national clearinghouse to facilitate access to, and reanalysis of, the data assembled in these experiments may be considered in a forthcoming ABASS planning exercise.

In summary, the dominant characteristics of the programs of support for social science research, and for social R&D more generally, have been their rapid growth, diversity, and volatility. A very large number of agencies have pieces of the action, and it cannot be said that there is any early prospect for the reduction to some more comprehensible order of their highly variable conceptions of the purposes of social R&D, its relationship to ongoing and future policies, or how best to manage the enterprise.

RESEARCHERS

Let me now turn to the researchers in the social and behavioral sciences, whom the Assembly represents, and consider the similarities and linkages between the research community and major characteristics of federal support programs for social R&D.

1. Departmentally organized programs in colleges and universities are the major constituency. Their dominant role is surely a source of intellectual independence and strength. But experience in other fields entitles us to at least question whether the overwhelming preponderance of teaching institutions as places of employment for social researchers is necessary or desirable.

The relatively slow development of other kinds of laboratories and research centers along the university–government interface is in part the result of the funding volatility and lack of attention to infrastructure mentioned earlier. As one consequence, intercommunication and periodic movement of research specialists across this interface has been restricted. Thus, the peer-reviewed programs of the National Science Foundation, the National Institute of Mental Health, and a few other agencies represent less than 10 percent of the social R&D funding, and yet these are the only ones with which a majority of the academic community has any familiarity.

Since graduate training for the most part takes place within individual disciplines, a further consequence of the dominance of the academic component is that durable support structures for continuing interdisciplinary programs are in general lacking. Being relatively underexposed to such programs, new cohorts of Ph.D.'s find few means or incentives to correct tendencies toward hyperspecialization during their own training. Over time, even the term *interdisciplinary* acquires restrictions in its practical significance, coming to mean collaboration among economists, anthropologists, sociologists, and other social scientists and only rarely any involvement with life scientists, physical scientists, or engineers.

2. The fractionation of R&D support among many agencies and a pattern of explosive, somewhat uncritical growth followed by sharp retrenchments militate against the orderly development of the empirical base of the disciplines, particularly against large-scale, longitudinal studies requiring long-term support. The result is a tendency toward short-term, narrowly bounded studies, whose relevance to important general themes is inherent neither in their scope nor in the substance of their findings. Relevance is instead sought in methodological pyrotechnics; theoretical exercises become the fashion, measured neither against definitive tests nor practical applications. Wassily Leontief's presidential address to the American Economic Association made that point—by no means confined to economics—in its title: "Theoretical Assumptions and Non-Observed Facts." *

Large-scale longitudinal studies are not an untested innovation, for they certainly go back at least to the Terman study in the twenties of gifted children. Their potential contribution to social science knowledge is generally recognized, and they would appear to offer resources of information crucial to many policymaking areas. There has been much creative work on their methodology, and some studies are under way, e.g., on high school youth, labor force participation, and income dynamics in relation to poor families. But support for such studies generally remains highly contingent and uncertain, and the institutional settings in which they can be effectively carried forward are still excessively rare.

3. The prevailing isolation of the social science community from government (with economists the significant exception) also means a lack of attention to how government institutions, and the individuals in them, actually behave. An ABASS workshop on regulatory processes made clear, for example, that the Interstate Commerce Commission (ICC) did not conform to the simple stereotype of operating consciously in anyone's

* Wassily Leontief. 1971. Theoretical assumptions and non-observed facts. Am. Econ. Rev. 61(1): 1–7.

"interests"—not even, in the view of most serious students of its decisions, in the interests of the society as a whole. But evidence for the basis of decision making by the ICC and similar regulatory bodies has rarely been systematically sought. To be sure, the subject is a politically sensitive one and one in which subjective elements cannot easily be disentangled in an evaluation. Probably for these reasons a study of regulatory processes is unattractive to funding agencies, although its importance as a theme of policy-relevant research can hardly be disputed.

Consistent with this pattern of isolation is the ambivalent stance of a number of major social science disciplines with regard to studies of government. (There are exceptions to any generalizations, of course, and much of the work outside my own field of anthropology lies in terrain with which I am inadequately familiar to make a personal assessment with any confidence.) One senses a curious absence, at least until fairly recently, of contributions by political science to social policy analysis, with the discipline's main concerns trifurcating instead into political theory, comparative politics, and survey research devoted to subjects such as voting behavior. A similar situation exists in sociology, as Richard Nelson has argued in an incisive critique. Dependent upon uncertain funding and lacking the normative theoretical structure that the market model furnishes for economics, he stated that

> [t]he sociologists studying, for example, medicine, have tended to bend over backwards to describe and theorize about what is, and why it is that way, and to avoid comments on what should be or even serious predictions as to the consequences of well-specified (but presently nonexistent) changes in the structure. Much of what normative structure (in the sense of policy analysis) exists is basically conservative, treating the existence and survival of what is as an indicator of its value to the larger system. . . . As a result, despite the fact that many sociologists have strong feelings about what should be done and feel that their "science" is important to questions of policy, the nature of their analytic structure has ceded the terrain to others.*

4. As already suggested, concern with the relevance of research for social policies and programs is very unevenly distributed within the behavioral and social science community. Such concern is inadequately

* R. R. Nelson. 1974. Intellectualizing about the moon-ghetto metaphor: A study of the current malaise of rational analysis of social problems. Policy Sci. 5(4):391.

represented in political science and sociology, even more limited to certain segments of psychology and geography, almost negligible in anthropology, but heavily concentrated in economics. Yet it is apparent that the observed behavior of firms in a market, for all of the power and parsimony of the model, provides at best a very slender base on which to build an evaluative and policy-relevant research program representing the social sciences as a whole. To quote Nelson again:

> Organization of sectors like education and medical care, issues such as structuring a regulatory system to cope with externalities or to deal with quality control problems, have been hardly touched until recently in the empirical literature. There is thus little empirical work to check whether the conditions that must be met for a market solution to be optimal are in fact met, hence little empirical support behind the proposition that the problems of the ghetto can be resolved by adopting more consumer sovereignty on the demand side and more free enterprise on the supply side. And there are reasons to be deeply skeptical.*

The ABASS child development study, long delayed but now published, exemplifies the difficulties in distinguishing questions of cost and economic efficiency from those of social purpose, strategy, and organization. Committee members engaged in this study shared the common objective of improving the care and education of young children, but economic analysis alone provided no resolution to the simmering debate over whether the goal could best be attained by income redistribution or by building new institutional support structures.

Similar difficulties permeate the continuing national debate over the quality of life, a large, fuzzy issue, but one that cannot be ignored. We have learned from other parts of the NRC about the need to delimit such issues if they are to be worked on effectively. The acceptances of such constraints in order to produce a useful study is at the root of our effort on behalf of the Environmental Protection Agency to assess the Societal Consequences of Transportation Noise Abatement.† That problem is admittedly a limited one, although given current salience by the Concorde debate. But it forces us to deal with the generic, fundamental ques-

* *Ibid.*, pp. 395–396.

† The National Research Council in 1976: Current Issues and Studies, pp. 81–84.

tion of how to make the trade-off of "real" costs for subjective, difficult-to-measure, and yet by no means negligible benefits.

5. Leaving aside impediments to communication and difficulties associated with organization and funding, what can be said of the present capacity of the behavioral and social sciences to contribute effectively to shaping and improving government policy? In some respects, as an ABASS Executive Committee member commented at a recent meeting, the last 10 years or so have seen the narrower specification or even decay of virtually all our explanatory paradigms rather than their growing acceptance. Psychologist Lee Cronbach has recently made an almost equally pessimistic appraisal:

> Social scientists generally, and psychologists in particular, have modeled their work on physical science, aspiring to amass empirical generalizations, to restructure them into more general laws, and to weld scattered laws into coherent theory. That lofty aspiration is far from realization.*

Individual assessments will naturally differ, but I think we must concede the force of these reservations as to the present state of the social sciences as a guide for understanding and action. Out of pragmatic concern for our future credibility, as well as for this principled reason, we should obviously avoid offering unfounded assurances as to the decisive significance and utility of the commodities we purvey. But there are other, partly countervailing, considerations to be kept in mind as the potential contributions of the social sciences to policy, through the social R&D process, are evaluated. Cronbach himself refers to some of them:

> Though enduring systematic theories about man in society are not likely to be achieved, systematic inquiry can realistically hope to make two contributions. One reasonable aspiration is to assess local events accurately, to improve short-run control. . . . The other reasonable aspiration is to develop explanatory concepts, concepts that will help people use their heads.†

Additionally, as I once heard Harvey Brooks comment in response to a passing characterization of the natural sciences as "hard" and the

* Lee Cronbach. 1975. Beyond the two disciplines of scientific psychology. Am. Psychol. 30(2):116–127.
† *Ibid.*, p. 126.

social sciences as "soft," it is a misleading stereotype to suggest that the social sciences are uniquely tinctured by uncertainty. Brooks observed that while prediction and replication of experimental results is frequent in mathematics and physics, that is not the case in meteorology, also a hard science, where the future "disappears into noise" only a few weeks ahead.

6. Another positive consideration qualifies my earlier, generally negative comments on the continuing isolation of much of the behavioral and social science community from most of the policy arena. In spite of a conspicuous lack of continuity and leadership from the R&D program of the Department of Housing and Urban Development and in spite of the decentralization of decision making in the urban field to the point where there is essentially no federal conception of an urban policy, there is a vigorous, largely university-based, discipline of urban studies. Pluralism—implying at least partial insulation of researchers from the wars of attrition between major, conflicting constituencies—clearly can be a source of strength as well as weakness. ABASS proposes to hold a conference on the changing structure of urban areas in 1977, the first such effort in some years. The absence of the urban area from our program probably represents an omission on our part, due partly to funding difficulties. This is precisely the sort of omission that can now be overcome with the Assembly's Program Planning and Development Fund, established with matching grants from The Ford Foundation and the Russell Sage Foundation.

The area of drugs is another in which research seems, finally, to be having an impact. The available scientific evidence has supported the view that marijuana is nonaddictive, but political considerations heretofore have prevented the incorporation into U.S. policy of these research findings. However, it now appears that sporadic and decentralized but cumulative moves toward decriminalization of marijuana are indeed under way. The far greater dangers of alcohol and tobacco can even be explicitly acknowledged by Dr. Robert L. DuPont, Director of the National Institute on Drug Abuse (NIDA). No doubt, larger forces are also at work, but there is at least a suggestion here that research findings can ultimately be effective when they call into question some of the most politically sacrosanct areas of government policy. In this regard, I am encouraged by NIDA's decision to fund a standing committee of the

Assembly to take a broad look at the area of substance abuse and habitual behavior. (Some of the committee's perspectives are described on pp. 45–50 of this report.)

I have discussed in this summary the outstanding promises and constraints of the Assembly's current program, rather than describing all of its many facets in detail. The demand, or at any rate open invitation, of the NRC is to think laterally, across disciplines. Knowledge "producers" and "consumers" find themselves less at odds than is generally the case and more often bound together in a common framework of problems and opportunities. Deep-seated differences are seldom completely erased and may remain salient—in approach, in priorities, in underlying premises. But the effect of linking knowledge to application, of insisting that the field of action of the social and behavioral sciences (and the field of personal responsibility of social scientists) overlaps extensively with the effective range of social policies, is to invigorate and transform both through the R&D process. If the tenor of these remarks at times has been critical, that is partly because improvements are in prospect in which ABASS may well play a crucial role.

Study Projects

ASSEMBLY OF BEHAVIORAL AND SOCIAL SCIENCES

FUNDAMENTAL RESEARCH RELEVANT TO EDUCATION

The scientific movement in American education is well over 150 years old. It began as a cooperative effort of academicians, influential state school superintendents, and university presidents to create a science of education—a science that would professionalize and standardize teaching, make schooling more effective, and free local school systems from the whims of local boards and community fads. A belief in science converged with and supported the emergence of empirically testable theories of learning, tests with measurable predictive validity, and survey techniques.

The National Academy of Sciences (NAS) Committee on Fundamental Research Relevant to Education, with the cooperation of the National Academy of Education (NAE), is now reviewing the progress of scientific research relevant to education. The major purpose of the Committee is to recommend means for strengthening the scientific foundation of education. This is not the first committee to examine the role of science in education, and its questions have been asked before. But recent scientific, social, and governmental changes have created a need for an up-to-date, critical analysis of the health and contributions of fundamental research relevant to education and the proper interest of the federal government in it.

STRENGTHENING THE SCIENTIFIC FOUNDATION OF EDUCATION

The interaction of science and education has been subject to intense criticism for many years. Early in this century, the movement toward universal, comprehensive, and multilevel education brought new legions of teachers and school administrators into state and national education associations. They, and supporters in the schools and colleges of education, began to attack "pure science" for its apparent irrelevance to the immediate needs of the educator. These criticisms, and the growing power of the groups behind them, led to a drifting apart of educational researchers from faculty in disciplinary departments of universities. Educational research functioned increasingly to serve the concerns of educators and to legitimate their practices. Its reputation among basic scientists suffered, and its territory was increasingly identified with university schools of education (or with separate departments of educational psychology, educational sociology, and so forth).

The isolation of educational research remained relatively unbroken until the late 1950's, when the federal government began a major investment in educational R&D after the Soviets launched Sputnik I. Federal interest in R&D to improve science education was followed in the next decade by increased federal involvement in the application of science to social issues. There were also increased federal expenditures for research and development on equality of education, education for the handicapped, improvement of curricula, and other special programs. The optimism represented by these monies was qualified somewhat by the opinion among many scientists and federal officials that basic researchers, particularly in the behavioral, social, and natural sciences, were insufficiently engaged in work on educational problems. The U.S. Office of Education did make an effort to recruit high-quality basic scientists into the field of education.

Perhaps even more significant to education than the search for scientific talent were developmental changes in the 1960's in the social and behavioral sciences that brought them closer to the problems of education. An example was the shift in emphasis in experimental psychology from behaviorism to cognitive processes and from "simple" to "complex" learning. Substantial progress was made toward understanding how people learn and remember information, how children learn to read, and how people solve complicated problems. Parallel developments marked other disciplines, such as anthropology, which moved from a nearly exclusive concern with primitive societies to studies of urban society.

In federal circles, however, qualified optimism had turned to pessimism by the late 1960's, with the major concerns being that the schools were not functioning well and that educational research was not producing "useable" results to help them. (Ironically, research helped to demonstrate the difficulties schools were having.) As criticism mounted, funds were cut or transferred to new programs, development and dissemination were increasingly emphasized, and new demands for evidence of research impact were heard. This decade has been a time of searching—for schools that teach better (and can prove it), that reach everybody, and that meet an increasing variety of social and personal needs. Scientists now face two challenges: to help the schools become better while rebuilding the scientific foundation of education and to provide evidence of results.

The tasks of the Committee on Fundamental Research Relevant to Education reflect these concerns. It will assess the past and potential contributions of fundamental research to educational policy and practice, point out promising areas for federal support, suggest policies or mechanisms for improving that support, and recommend means by which the ties between fundamental research and applied educational research and practice might be strengthened.

SCOPE OF THE PROBLEM

Fundamental research relevant to education could be defined as disciplined inquiry * to pose and answer scientific questions on learning

* L. J. Cronbach and P. Suppes (eds.). 1969. Research for tomorrow's schools: Disciplined inquiry for education. Report of the Committee on Education Research. National Academy of Education, Washington, D.C.

and teaching, as well as the institutions in which these activities take place. This research is conducted primarily by behavioral and social scientists, but is also performed by natural scientists and engineers, and by philosophers and historians. Early in this century, fundamental research on educational processes emphasized the development of learning theory and the measurement of individual differences in intellect. Today, it includes research on physiological processes in the brain, the allocation of community resources, and the development of linguistic structures.

No arbitrary division of purposes, methods, subjects, or results clearly distinguishes fundamental research from applied educational research. For instance, work principally motivated by fundamental issues may develop new technical capabilities, and applied research that presupposes an adequate understanding of some processes may actually produce new theoretical insights. The boundaries are fuzzy. It is probably important, however, to use a working distinction between fundamental

research, whose primary goal is to understand general processes, and applied research and development, whose goal is to alleviate problems or improve practice. One implication of this distinction is a recognition of the need to support research on the substantial gaps and uncertainties of understanding that we have about the cognitive, social, behavioral, and institutional processes involved in education.

The Committee recognizes that fundamental research (as is generally true of R&D) has unpredictable outcomes. Therefore, it is inclined to take a broad view of what is "relevant to education." In mapping the scope of such research, the Committee is considering both developments in science obviously relevant to education and research that might bear on decisions that educators and the public have to make.

THE CONTRIBUTION OF FUNDAMENTAL RESEARCH

In assessing the past and present contributions of fundamental research, the Committee can draw on a number of earlier studies of research in education, including some by the NAS and the NAE. There also exists a set of more general data on how basic knowledge flows into application.

But examining the impact of research on education is still a difficult task, for in education, as in many areas of public concern, new knowledge is not simply used to develop products or to change techniques. It also gradually diffuses among the general population, who read about it in books and magazines and newspapers, hear about it in their classrooms, and talk about it with each other. Research may thus affect how people define educational objectives and problems, how they view the learner and the teacher, and how they evaluate educational practices. The development of computers for classrooms is an example of a product outcome. The use of reward-focused (as compared with punishment-intensive) techniques by teachers is an example of a technique outcome. The increasing recognition and acceptance of variability among children (and the need to vary practice accordingly) is an example of an idea outcome.

The major problem in evaluating the impact of research on popular ideas and conceptions stems from its multidimensional and multidirectional causes and effects. But that does not justify ignoring the issue. In fact, several historians of education suggest that the diffusion model as well or better describes how research has improved schools than does the more direct research, development, and dissemination model. The contrast, according to Clifford,* is between the direct impact of John Dewey on the National Education Association, textbooks, and curricula and the indirect impact of Charles Darwin, Sigmund Freud, and Jean Piaget on conceptions by parent–teacher associations and the general public of the child and his environment. One could make a case that Dewey's work opened up the school curriculum and ended the teaching of trivial material by rote. But one could also argue that, for example, Freud caused parents to think harder about the emotional and social development of their children and henceforth to support more humane schools, whose teachers were friendlier and warmer and whose methods of instruction varied more, were more adjusted to differences among students, and allowed for greater choice.

FEDERAL POLICIES AND SUPPORT

If fundamental research has value, then it is important to examine and remark upon the federal government's role in supporting it. The federal government now supports a modest effort. The Project on Interagency Coordination at George Washington University estimates that in 1975 the Department of Health, Education, and Welfare, including its Office of Education, and other social service agencies supported about $5.3 million in basic research in education. The National Science Foundation obligated in the same year about $31 million for basic research in the behavioral and social sciences, with an examination of project titles suggesting that about $3.1 million of this research is clearly relevant to education. The Department of Defense, primarily in the Office of Naval Research, supports basic research relevant to education and training at a funding level of approximately $1 or $2 million dollars. Relatively little support comes from local, state, or private sources; but it is questionable whether such sources should be heavily involved, since fundamental research has obvious nationwide implications and requirements for high-quality scientific manpower.

* G. J. Clifford. 1973. A history of the impact of research on teaching. *In* R. H. W. Travers (ed.). Second Handbook of Research on Teaching. Rand McNally, Chicago, pp. 1–46.

There are at least eight categories of research supported by federal agencies:

- *Learning—including cognitive processes, memory, and linguistics*
  Supported by: National Science Foundation
  Department of Defense
  National Institute of Education
  National Institute of Mental Health
  National Institute of Child Health and Development
- *Social behavior and attitudes (including the disciplines of social psychology, sociology, and anthropology)*
  Supported by: All the agencies listed above
  Office of Child Development
  Office of Education—Bureau for Education of the Handicapped and Bureau of Occupational and Adult Education
  Department of Agriculture
- *Basic demographic studies in education*
  Supported by: National Science Foundation
  Office of Child Development
  National Institute of Education
  Department of Labor
- *Economics and finance of education*
  Supported by: National Science Foundation
  National Institute of Education
  Department of Labor
- *Organizational processes*
  Supported by: National Science Foundation
  National Institute of Mental Health
  Department of Defense
  National Institute of Education
- *Organic disorders related to education*
  Supported by: National Institute of Mental Health
  National Institute of Child Health and Development
  National Institute of Education

Office of Education—Bureau for Education of the Handicapped and Bureau of Occupational and Adult Education
Department of Agriculture
National Institute of Neurological Diseases and Stroke

- *Education and work*

  Supported by: National Science Foundation
  Department of Labor
  National Institute of Education
  Office of Education—Bureau of Occupational and Adult Education and Office of Career Education

There is also a miscellaneous category (including, for example, studies of diet and education) covered by the Department of Agriculture and the National Institutes of Drug Abuse and Alcohol Abuse and Alcoholism.

The overlap in this listing is more apparent than real. While there is some redundancy, each agency actually covers subareas peculiar to its own interests and mission. Thus, research within the learning category on artificial intelligence is supported by the National Science Foundation, but not by the National Institute of Mental Health. Further, modest overlaps are not necessarily bad or signs of organizational inefficiency, for they can help close gaps in coverage or increase the number of high-quality projects. (Cf. Robert McC. Adams' comments on pp. 24–26 of this report.)

Each of the agencies employs a variety of mechanisms for supporting basic research in education, although typically each favors one or two of the strategies. The National Science Foundation relies almost exclusively on grants awarded after peer review of unsolicited proposals. The National Institute of Mental Health and the National Institute of Child Health and Development also award grants, but the review process is slightly different from that of the National Science Foundation; basic research in specified areas is also supported by grants and contracts. The National Institute of Education is currently using the "grants announcement" to solicit basic research relevant to its interests. In the Department of Defense, basic research is supported through contracts and must be tied to the mission of the agency.

That each agency has a different style should not obscure overall trends in federal policy that have important implications for fundamental research relevant to education. Basic research in recent years has come under close scrutiny and criticism. Reflecting these concerns are changes in policy—some of them a sharp departure from the policies that emerged from World War II and governed research operations to the late 1960's. First should be mentioned a no-growth attitude towards basic research, as illustrated by budget cuts and intense scrutiny by the Office of Management and Budget of questionnaires used in contract research. Second, there is a demand for accountability that has resulted in shifts from continuation grants to new grants and a pulling back from institutional support. Third, we see a reemphasis on centralized direction from Washington, reflected in the trend toward contracts and away from grants. Finally, there is a new emphasis on competition in the *purchase* of research and away from research *support* for what some feel is an elite scientific establishment. This new emphasis (which has nineteenth-century roots) is seen in new requirements for announcing and inviting comment on peer review or advisory panels, and in a general trend toward detailed specification of items and planned activities expected of researchers and agency staff. The Committee will review these overall trends and the variety of support mechanisms now in use, and make recommendations to the National Institute of Education and to other agencies.

A FINAL NOTE

No single committee, however expert, has prescience. No single committee, however open, can represent the whole scientific community. No single committee, however objective, is immune from the pressure of public anxieties. Nevertheless, the Committee on Fundamental Research Relevant to Education has taken at least one active step toward increasing the validity, representativeness, and objectivity of its work by inviting members of over 100 scientific groups and organizations to submit their comments. These comments will not be used as a popularity poll, but each will be carefully considered for its potential contribution to the work of the Committee.

Committee on Fundamental Research Relevant to Education, Assembly of Behavioral and Social Sciences. Committee Chairman, Sheldon H. White of Harvard University; Study Director, Sara B. Kiesler.

SUBSTANCE ABUSE AND HABITUAL BEHAVIOR

Heroin addiction and alcoholism are both examples of substance abuse. But society tends to deal with them differently, jailing the heroin user and treating the alcoholic as a victim of disease, despite considerable evidence that both problems are rooted in common patterns of habit formation. Moreover, habitual use of heroin, alcohol and other drugs appears to be similar to other, less dramatic forms of habitual behavior, such as smoking, overeating, overwork, and obsession with sports.

A recognition of such similarities is not yet embedded in societal attitudes toward different types of substance abuse and habitual behavior, in social policies, or in research priorities. To examine these and related issues, the Committee on Substance Abuse and Habitual Behavior has been established, under contract to the National Institute of Drug Abuse, a unit of the Alcohol, Drug Abuse, and Mental Health Administration. The Committee in its first year will

- Examine ways to analyze common elements in the formation of habits that lead to substance abuse and other damaging patterns of behavior
- Determine whether it is indeed practicable and advantageous to focus attention on common underlying factors in substance abuse and habitual behavior
- Identify research priorities and policy issues flowing from this integrated approach

COMMONALITIES

The evidence of underlying links in behavior patterns that lead to substance abuse and addictive behavior is now considerable and includes the fact that an end to one abuse often means the start of another: a significant number of returned Vietnam veterans who were rehabilitated from heroin addiction became alcoholics, heavy smokers trying to break their habit may begin overeating, and teenagers often increase their sexual activities when they stop smoking marijuana. But, in spite of such indicative data, there is no general theory or concept to explain these behaviors

and therefore no general model of behavior that can clarify the common patterns that characterize damaging habits. Information is still partial, and research is needed to probe the physiological, psychological, and social interrelationships that determine how habits form, are maintained, and end.

This problem was discussed at a 1975 *ad hoc* conference convened by the Assembly of Behavioral and Social Sciences. Several questions emerged; for example:

- Do science and social policy agree on the criteria by which different forms of abuse and addiction are labeled harmful, abusive, addictive, or compulsive? Does the labeling depend on the direct personal and social costs or rather on the effects of society's response, e.g., crackdowns on heroin supply resulting in more burglaries and muggings?
- What kind of person is the addict, whatever the form of addiction: compulsive, self-willed, criminal, or ill?
- What are the actual distinctions among habit, abuse, and addiction, terms encompassing several types of behaviors, including those that are strongly motivated, apparently uncontrollable by conscious effort, difficult to understand through traditional learning theory, and often impairing a person's ability to function effectively?

AMBIGUITIES

Abuse can be classified as behavior that causes physiological, neurological, or psychological damage. It can also be classified as behavior beyond socially accepted criteria that are only loosely related to bodily harm; for example, the different approaches and attitudes to the abuse of substances such as heroin as opposed to more socially acceptable substances, such as tobacco, alcohol, and caffeine.

Social tolerance is also shaped by individual histories; witness the different attitudes toward the "social drinker" and the alcoholic. And social tolerance is also modulated by social mood. That is illustrated by the changing attitudes toward marijuana possession and use in many parts of the United States and by the decreasing tolerance toward tobacco smoking since it is "hazardous to your health."

Tolerance can also be changed by government actions. For example, social attitudes toward aspirin and similar medicines may be changed by Food and Drug Administration panels questioning their safety and efficacy. Similar changes in social attitudes may occur with products that contain caffeine, such as coffee, tea, or cola.

CRIMINAL AND PATIENT

Substance abuse is regarded as hostile behavior in many parts of the world because it is associated with criminality and potential disruption of social environments, including family and economy. But in more technologically advanced countries, acts traditionally regarded as criminal are increasingly considered as health problems, in part due to the contemporary view of health as not only the absence of disease, but also as a state of social and emotional well-being.

That attitude, coupled with the mass of evidence that various forms of substance abuse and addictive behaviors share common roots, has intensified the need to answer fundamental questions on the formation of habits:

- How do social forces and individual needs interact to form habits?
- What are the social mechanisms that determine whether a type

of habitual behavior is labelled a moral or individual failure rather than a health problem?

- Is there a theoretically sound way to gauge whether societal shortcomings are the cause of various forms of substance abuse among different groups: increased alcoholism among teenagers or more women smoking, for example?

The most fundamental question is why and how do habits form. It's a truism that patterns of behavior—in eating, in taking drugs, in work, or in play—reflect a person's style of life. The patterns may be protective, essential to coping with daily routines of life. But habits can also lead to problems: to cancer or heart disease; to interpersonal problems with family, with colleagues at work, and with other social groups; to social problems such as chronic unemployment.

Many behavior patterns may be shaped by societal and peer group pressures; those that fit societal norms are easily accepted, while those that do not may be considered subcultural or deviant. In effect, habit formation can be viewed as social influences modulating individual motivations—a form of environmental determinism.

But there are other ways to think about how habits are shaped. One is that habits may be formed neither by social stimuli nor by cognitive learning, but by physiological responses to emotional, or affective, events. Opiate addiction perhaps illustrates this view. The opiate user experiences pleasurable moods and a euphoric rush after the first intravenous injection—an affective response, but one determined by altered physiology. Repeated use—the forming of habitual behavior—does not bring back the original euphoria, but only a relief from the withdrawal symptoms. If the user abstains, even for a short time, intense craving and withdrawal agony return, and if the drug is taken again, it is not to gain pleasure, but for relief.

This pattern of habit formation is generalized as the opponent-process theory; that is, an individual's reaction to a stimulus, be it pleasant or aversive, is opposed by central nervous system mechanisms so as to both reduce the intensity of the reaction and convert it to its opposite form.

Most affective stimuli that lead to addiction seem to work by some variant of the opponent-process theory, with the actual intensity of the physiological or psychological response depending on the duration and frequency of the stimulus. Opponent-process theory is useful in analyzing various forms of addiction—to opiates; to hallucinogens; to legal drugs such as alcohol and tobacco; or to work, sports, and bringing up children.

Whatever theory—or combination of theories—is applied, its value will be measured by insights gained in understanding the underlying causes of habit formation that produce the varied forms of substance abuse and addiction. But weaving together into a comprehensive theory the physiological, psychological, social, and economic elements that enter into people's lives is palpably difficult. Moreover, the importance of these elements varies according to a person's actual experience with addiction and his contact with others, both addicts and nonaddicts.

To establish sound theories on the causes of habit formation requires interdisciplinary research efforts to answer basic questions, including:

- Do different substances attract people at different ages, for example, teenagers turning to smoking, drugs, and alcohol?
- When do patterns of overwork and overeating develop and in response to what factors?
- What factors—whether physiological, psychological, cultural, social, legal, or economic—are common to the forms of substance abuse and behaviors traditionally frowned upon by society, such as drug addiction and alcoholism? Which of these factors, and in what combinations, also apply to behaviors traditionally viewed as addictive but nevertheless socially approved—work, child-rearing, sports, and the like?
- To what extent are various addictions expressions of a particular culture or subculture, and to what extent do they express purely individual variations in behavior? How does substance abuse relate to the concepts of free will and cultural determinism? Are people really free to decide whether or not to be addicted and what the form of addiction is to be? Is there some form of addiction in every society, and, if so, what does this say about human nature? Are aversive habits best proscribed through child-rearing or through social institutions outside the home?
- Are some people genetically predisposed to addiction to specific substances—to tobacco, alcohol, and other drugs? Why are there different rates of alcoholism in different ethnic groups, even after discounting social

class and economic differences? What are the respective influences of genetics and environment upon habit formation?

- What are the various biochemical pathways for abused substances? Is one form of abuse or addiction more hazardous than another —food versus alcohol, for example?
- Can we find and apply better measures of the social costs of substance and behavioral abuse? What are the monetary costs to society of abuse and addiction?

To date, the approach in research and in the delivery of services has been fragmented, with different research strategies and different forms of prevention and treatment applied to different forms of abuse and addiction. Are different, perhaps more unified approaches, possible, given new concepts? How can an emphasis on the commonalities in different types of abuse and addiction aid program planning and evaluation? These and other similar issues will be part of the interdisciplinary concerns of the Committee on Substance Abuse and Habitual Behavior.

Committee on Substance Abuse and Habitual Behavior, Assembly of Behavioral and Social Sciences. Committee Chairman, Richard L. Solomon of the University of Pennsylvania; Executive Secretary, Jerome E. Singer; Research Associate, Arlene Fonaroff.

TRANSITION TO DECENTRALIZED MANPOWER PROGRAMS: SOCIAL, POLITICAL, AND ECONOMIC IMPLICATIONS

Changes in the programs of administrative agencies of the federal government, and of state and local governments, tend to be mostly quantitative and incremental—marginal modifications of the existing scope of operations or funding level. Qualitative changes—for example, major redistributions of authority for delivering services from one level of government to another—occur far less frequently. Such changes are, however, of considerable political significance. They have figured prominently in discussions of national domestic policy in areas such as health, law enforcement, and community development, and are perhaps the more controversial because expectations concerning their effects tend to be somewhat speculative and not completely understood.

Manpower programs—designed to foster employability of and employment opportunities for the unemployed and underemployed—underwent such a major change when manpower became the first special revenue-sharing measure to be enacted into law in 1973. Special revenue sharing embodies the principles of "New Federalism"—returning federal revenues for use by state and local governments, but earmarking them for specific broad program areas. Thus, the Comprehensive Employment and Training Act of 1973 (CETA) shifted control over a multibillion dollar program from federal to local officials (decentralization) and gave local authorities greater flexibility in the use of these resources (decategorization). Although this block grant system was perceived in some quarters as an expression of political conservatism, even "liberal" critics of the decentralization of government services recognized the need for pulling together into some sort of integrated local system the score or more of categorical manpower programs that had accumulated, helter-skelter, through the social legislation of the 1960's.

The rationale was that state and local governments would be able, with a broad range of citizen input, to plan and operate programs more responsive to unique local needs and to do it more efficiently and effectively. Thus, CETA instructed the Department of Labor to designate "prime sponsors"—state or local government jurisdictions with populations of 100,000 or more—and to vest them with the responsibility to plan and operate programs of comprehensive manpower services. However, the Act placed some limits on local autonomy by making prime sponsor plans and operations subject to federal review and approval.

The National Research Council is examining the impact of this change and its implications in a 3-year study supported by the Ford Foundation. The methodology attempts to combine the advantages of both case study and survey approaches to an analysis of 28 prime sponsor locations. In each of these sites, interviews with local program staff and other key persons have been conducted by resident experts with professional qualifications in such fields as economics, political science, education, management, and social welfare. The information obtained in these interviews, supplemented by the insights of these field research associates, provides a basis for assessing the impact of CETA on local institutions and programs.

This study, begun in 1975, is still in progress. An interim report covering the early transition period was published in 1976.* The final report, now in process, will monitor the experiences of the second year. Although two years is not long enough for a major institutional realignment to achieve its full impact, it has been long enough to bring many of the critical questions about the basic CETA rationale into sharp focus. The questions concern social, political, and economic issues that have relevance not only for manpower, but also for other block grant programs for which the degree of decentralization is under debate.

SOCIAL ISSUES

Manpower training and employability development programs are an expression of domestic social policy that prescribes government assistance for persons who lack skills or are otherwise at a disadvantage in the competitive job market. These programs originated in the "Great Society" legislation of the 1960's as an effort to address the problems of those who subsisted on the rough edges of a generally affluent society—

* William Mirengoff and Lester Rindler. 1976. The Comprehensive Employment and Training Act: Impact on People, Places, Programs, Interim Report. National Academy of Sciences, Washington, D.C.

the hard-core unemployed, the underemployed, the poor, and, particularly, youth and minority groups.

Under CETA (and, by extension, other forms of special revenue sharing), the question is whether decentralization of authority will tend to weaken or dilute what has been perceived as a national commitment to assist these target groups. Certainly general revenue sharing—the return of federal revenues to state and local governments with very little restriction of their use—has not been outstanding in providing services or other benefits to those most in need.

The CETA legislation offered considerable latitude in this regard. Congress expressed its concern for the constituency served by the social programs of the 1960's, but a need for serving a broader spectrum of the population was also recognized. In the end, while a number of target groups were cited as deserving of special consideration, the operative sections of the Act establishing eligibility for service emerged as very broad indeed.

The opening provided by Congress was widened by a number of other pressures, such as the recession, that put many well-qualified but unemployed persons in competition with the disadvantaged for manpower services. In addition, the spread of manpower resources to the suburbs under allocation formulas, and the response of local elected officials to a wider constituency than just the disadvantaged, tended to change the clientele served. Although local sponsors appear to have generally continued and accepted the programs and clientele they inherited, the effect of those developments has been that a somewhat lower proportion of the disadvantaged are being served under CETA than in comparable pre-CETA programs.

Soon after the enactment of CETA, Congress and the administration, reacting to spiralling unemployment, adopted a program of federally subsidized jobs in the public sector. This essentially anticyclical program was then grafted on to the existing manpower system, whose original intent was to redress longer-term, "structural" labor market problems. The legislation addressed these problems separately, with separate funds and guidelines for each, but packaged them together under the CETA umbrella in the expectation that both anticyclical and structural objectives would benefit from coordination and a wider range of service options. The NRC study found that this did not happen: The program

ended up serving two largely disparate and discrete populations. Moreover, public service programs came to occupy perhaps more than their fair share of the time and attention of local officials. The NRC findings suggest the operation of a kind of Gresham's law, in which the more immediate, short-term objectives appear to elbow aside serious consideration of longer-term, more fundamental problems.

POLITICAL ISSUES

The CETA experience illuminates the political issue of the federal/local balance, an essential element of the block grant approach in public administration. Perspectives on this issue have varied with the times and with political alignments. The federal presence has been viewed as either repressive and overbearing, or as a bastion of social justice; local governments have been viewed as hotbeds of corruption or as embodying the American essence of the New England town-meeting style of local decision making.

Not surprisingly, the CETA legislation did not make a clear-cut choice. It provided a reasonably clear statement of local autonomy and accountability, yet circumscribed it through requirements such as federal review and approval of prime sponsor plans. It set forth what had been national priorities in terms of groups to be served, but required that these be observed only "to the maximum extent feasible." The Act left unresolved the basic question of how congruence would be achieved between national policies or priorities and the individual decisions of 400 local and state prime sponsors.

After 2 years of CETA operation, some prime sponsors believe that the Department of Labor (DOL) has extended the federal reach—through regulations, guidelines, reporting requirements, and assessment—to a point that threatens their freedom to develop local policy. However, the DOL is convinced that these activities are necessary to discharge its mandated oversight responsibilities. Federal presence, the Department contends, is necessary to keep local sponsors from drifting toward the expedient and the politically desirable. The perception of federal presence, like beauty, would seem to lie in the eyes of the beholder.

A related political issue is the locus of decision making. Who at the local level actually decides on the allocation of resources among programs and target populations? Is it the elected officials, the professionals, or the people? This is important from the standpoint of local accountability, and CETA experience has provided some interesting insights. The Act provides for a broad base of community participation through advisory planning councils and the designation of specific community sectors to be represented on these councils. The Act also provides mechanisms for public review and comment on prime sponsor plans.

The NRC study found, first, that the elected officials and local manpower professionals hold the key to the decision-making process. Their attitudes and philosophies determine whether the decision-making process will be open or closed, participatory or authoritarian, technical or "political." Second, community participation in program planning other than through the councils was virtually nonexistent. The councils emerged as a potentially significant vehicle for community inputs into the planning process, but one which has had a significant impact in only a relatively small number of communities.

The shift of control over the multibillion dollar manpower program, even with its constraints, disrupted existing networks of interorganizational relations among federal, state, and, particularly, local institutions. The CETA legislation provided to prime sponsors freedom to choose those local program operators that would be most effective in delivering services, but also constrained them somewhat by stipulating that consideration must be given to existing delivery agencies of "demonstrated effectiveness." What followed was an intense struggle over "turf," which is not yet over.

One of the most significant outcomes of this struggle is the diminished role of the public employment service system. Prior to CETA, and indeed since the enactment of the Wagner–Peyser law in 1933, the federal/state employment service agencies had a virtual monopoly over manpower planning and operations in the public sector. The CETA legislation has in effect established a parallel manpower network and provided to prime sponsors the option of using the public employment service (ES) or choosing alternative agencies.

During the first 2 years of CETA, the ES influence in manpower programs and its proportionate share of total manpower funds dropped significantly. This development posed two problems for DOL. As the federal partner of the state employment service agencies, it was difficult to sit idly by and watch the erosion of the ES role in CETA; and, as the funding agency for both CETA and ES, it was anxious to relate the capabilities of one to the needs of the other.

The Department of Labor made efforts to nudge the ES into offering its job placement services to the prime sponsors and to require sponsors to accept the proffered services. These efforts were resisted by some sponsors as an intrusion on their autonomy.

Other agencies that previously delivered manpower services have also experienced change. Private nonprofit community agencies such as Opportunities Industrialization Center, Jobs for Progress, and the Urban League, nationally funded in the sixties to serve specific racial and ethnic constituencies, have fared well under CETA in terms of money. Nevertheless, their influence and independence are diminished—an inevitable consequence of the mandated role of the prime sponsors.

ECONOMIC ISSUES

Finally, we turn to the underlying economic issue—whether program results or achievements appear to be "worth" the resources expended on them. For antirecession or anticyclical programs, the key question is whether unemployment has been reduced. For structural manpower programs, designed to enhance the competitive position of the individual in the job market, there is less agreement as to how program results should be measured. Placement into unsubsidized employment is the most commonly used indicator of program effectiveness, but there have always been complaints by those accountable for programs that this measure is too narrow and superficial and that the emphasis placed upon it by DOL may lead to rushing people into low-wage, unstable employment just for the sake of marking them "placed." The critics argue that the long-range thrust should be an increase in the "human capital" of those served, sufficient to enable individuals to succeed independently in obtaining adequate and appropriate employment.

In any event, the overriding factor affecting the postprogram employment experience of persons who have been in CETA programs has been the recession, which makes analysis of program input–output relationships or comparisons with pre-CETA programs very difficult or inappropriate in many cases.

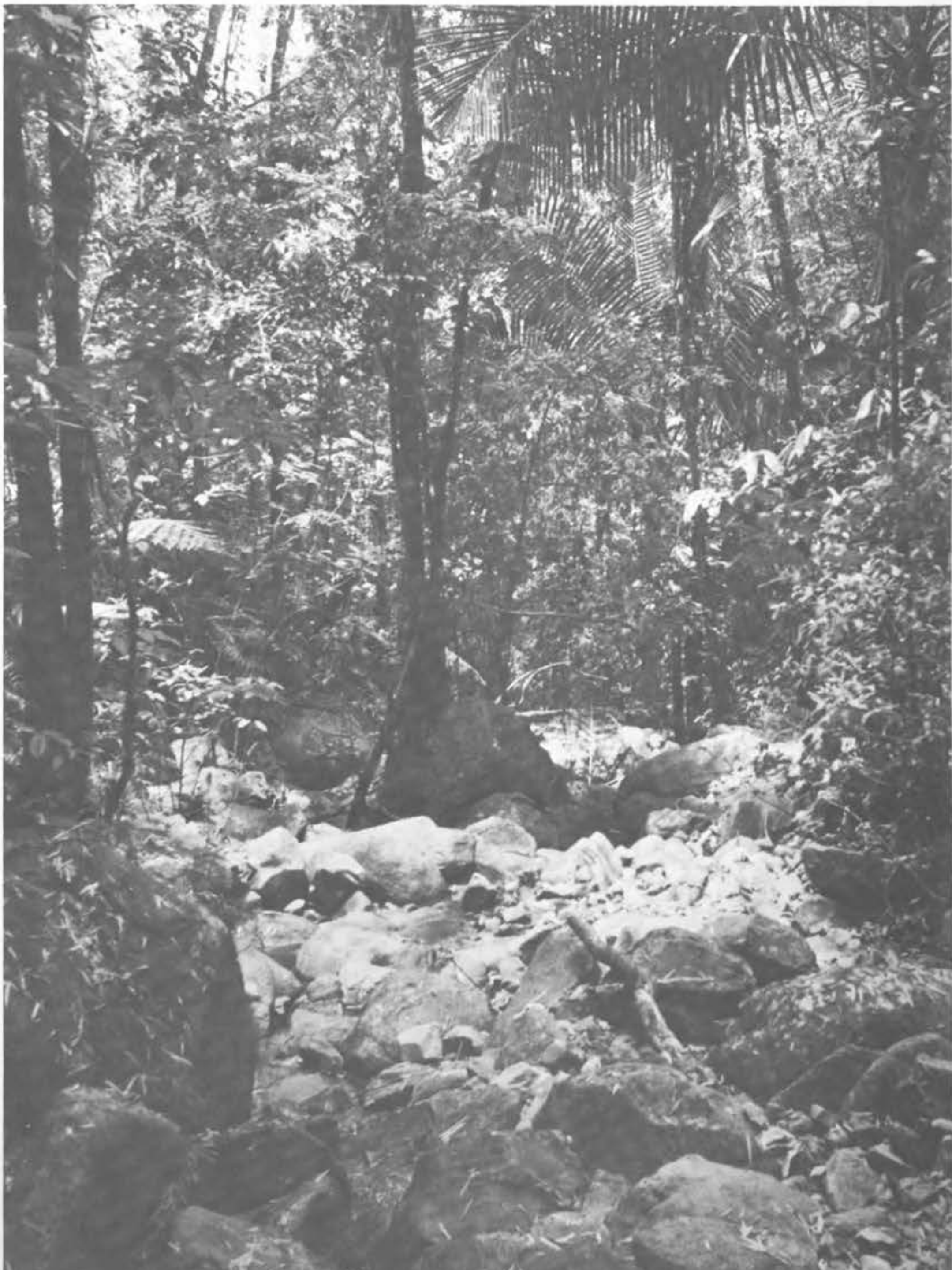
The CETA experience does appear to shed some light on the other major economic question: the impact on unemployment rates of job creation in the public sector. Previous studies have indicated that the substitution effect—the propensity of local governments to simply substitute federal funds for local funds in jobs that they would have supported anyway, rather than to create new jobs—probably diminishes by about half the economic impact of these funds. Analysis of CETA data suggests that the impact is diminished still further—perhaps by another 30 percent—by the selection of some participants from among employed individuals or from those not previously in the labor force rather than from the ranks of the unemployed. Thus the level of "macro" economic benefits appears highly questionable where it is not possible to ensure against substitution.

On the basis of evidence to date, it appears that the circumscribed decentralization of federal authority under CETA is not a panacea, but neither is it a failure. To some extent certain social priorities seem to have suffered both from the latitude encouraged by the legislation and a faltering by some localities. Politically, new actors appear in the long-running pageant of federal–local relations, but the tensions and conflicts appear to be, if not creative, at least balanced. What has developed is an area of responsibility—murky at times—in which the reach of the federal authorities contends with the grasp of the prime sponsors.

The bottom line has yet to be written. The first 2 years of CETA have been devoted by local sponsors and federal program overseers alike to putting the new delivery system into place, and attention is only now turning to what is being delivered. Similarly, the NRC study has focused to date upon the process side rather than the product and has found many positive aspects in the CETA process: greater accountability, closer monitoring, improved coordination, broader community involvement. In a few places, however, CETA appears to have created new layers of administration without any visible evidence of program improvement. The second stage of the study will seek to determine whether the new structure of program responsibility and decision making provides program outcomes commensurate with the level of funds and of effort being put forth.

Committee on Evaluation of Employment and Training Programs, Assembly of Behavioral and Social Sciences. Committee Chairman, Philip J. Rutledge of the National Institute of Public Management; Study Director, William Mirengoff.

Assembly of Life Sciences



Luquillo Experimental Forest, Puerto Rico.

Research Resources*

DONALD KENNEDY

Basic biology has often had difficulty in finding its exact place between the applied disciplines of agriculture and medicine. Within the National Research Council, biology was historically embedded in the Division of Biology and Agriculture. In the reorganization of the NRC, the problem of a place for biology was met by forming the Division of Biological Sciences and coupling it to the Division of Medical Sciences to form the new Assembly of Life Sciences (ALS).

The realignment brought with it new problems and opportunities. The main problem is that the explantation of biology from its old Division left it with an assortment of enterprises that was neither sufficient to stand alone nor a natural complement for its new partner, the Division of Medical Sciences. The opportunity is in dealing with that problem to create a more useful Division. Over the past 2 years, we have been discussing ways in which the Division could fill out its structure and extend

* It is a pleasure to acknowledge the help of Russell B. Stevens, Veronica I. Pye, Norman Metzger, and Carrie Hunter in the preparation of this report.

Donald Kennedy is former Chairman, Division of Biological Sciences, Assembly of Life Sciences. He is currently U.S. Commissioner of Food and Drugs.

its role in supporting the biological sciences; "we" in this case refers to the Executive Secretary of the Division, Russell B. Stevens; his able associates on the Division staff; and my colleagues on the ALS Executive Committee, who began the task long before I appeared on the scene.

We recognize that at any given instant the responsibility of our Division is much larger than its program. We carry little standing committee baggage and are not ambitious to increase our load. Instead, we normally create *ad hoc* structures to carry out initiatives that develop elsewhere in the federal structure or as a result of our own view of developing problems. This *modus vivendi* yields a kaleidoscopic array of projects, superimposed on a core of ongoing responsibility. We have come to see that core as comprising four different areas: (1) the health of the basic research disciplines generally; (2) the adequacy of those aspects of biology necessary for adequate progress in agriculture and medicine; (3) the human resources necessary to carry out the work, i.e., manpower and education; and (4) the necessary tools, i.e., research resources.

It is to this last category that we have decided to give an initial major emphasis. Of course, the term *resources* really includes the capital resources—equipment and financial support—that are so crucial to the health of the disciplines. While recognizing that these may often be limiting, we believe that their allocation will normally depend upon processes that take place at other levels. Our primary concern is therefore with the biological resources themselves.

This concern is unique to biology; chemists hardly need make major efforts to assure the availability of reagents, nor physicists of matter. The most reductionist approaches are concerned least with experimental *objects* and most with *tools*. But biologists are concerned with unique events, and therefore a special part of biology is diversity itself. And as we learn more about diversity and its sources, the variety of research resources demanded tends to increase; new organisms are found that represent new challenges for understanding evolutionary processes, offer special opportunities for analyzing particular problems, or provide especially good models because in some respect they show functional resemblances to human systems. The evolutionary process, by producing a range of solutions to particular challenges, requires us to validate experimental conclusions over a range of species; and the evolutionary process also guarantees that each combination of properties is at least potentially labile. Thus the documentation and analysis of diversity itself is a main business of biology.

RESEARCH RESOURCE NEEDS

There are strong trends both toward the continual diversification of the research resources used and the need to conserve them. The following list gives an idea of the range of activities associated with these forces: systematic collections in museums and herbaria, and their curation; breeding and selection of new laboratory plants, animals, and microorganisms for research (in the past century more mammalian species have been domesticated for scientific purposes than were domesticated for other reasons in the rest of human history); maintenance and propagation of bacteria and protists in type-culture collections; collection or capture of wild squid, sea urchins, electric fish, or macaques for experimental use; maintenance of seeds of cultivated plants with known genetic composition; and preservation of natural ecosystems. Each activity in this limited sample represents a multimillion dollar effort by the scientific community, yet in each case there are signals that our present efforts are both scattered and inadequate to meet the demand.

REQUIREMENTS

Besides diversity, investigators have two other requirements for research resources: quality and dependability. Quality, especially critical to genetic stocks of laboratory organisms, means that the worker is sure of the genetic background and physiological health of the living material with which he deals. This concern led to the establishment more than two decades ago of our Institute of Laboratory Animal Resources, which has been a major force in the improvement of the quality of laboratory animals and their care and use. A second requirement is dependability. Investigators want continuing access to a system of reliable biological identity, in the same sense that users of electricity require continuous ("firm") power. It is no good to invest time and effort in analyzing an ecosystem if it may suddenly be turned into a parking lot; it is equally unwise to begin long-term studies on identified cells in a nervous system if the species may be endangered before the circuit is complete.

CURRENT ACTIVITIES

These needs are already represented by efforts under way in the Division of Biological Sciences. The Institute of Laboratory Animal Resources (ILAR) is a good beginning. Its committees have addressed themselves to particular genetic stocks, to diets and housing, to other aspects of care, and to the training and standards of the supporting professions. ILAR's taxonomic range of attention has been extended from mammals to birds and very recently to amphibians and marine invertebrates. These latter additions, although they may at first sound a bit capricious, reflect special concerns generated by overexploitation of wild stocks. For example, the common "laboratory frog" (primarily the grass frog, *Rana pipiens*) is becoming difficult to obtain for research purposes, partly because of heavy commercial harvesting for use in secondary-school teaching laboratories. The large cells typically found in amphibians, compared to other vertebrates, have made them highly desirable for various experimental purposes—from classical embryological studies to work on the visual system to the biophysics of the neuromuscular junction.

More recently, the availability of genetic stocks of the African clawed toad, *Xenopus laevis*, has been critical to dramatic advances in several areas of molecular genetics—chromosomal organization, mechanisms of gene amplification, and recombination of procaryote and eucaryote deoxyribonucleic acid (DNA). Without *Xenopus* stocks, progress would have been slow or impossible, and the lesson is that progress in research demands the availability of a diversity of stocks of known genetic background.

The Division's new efforts on amphibians, if successfully launched, will emphasize both the laboratory culturing of amphibians to curtail dependence on wild-caught species and the need to work with a variety of organisms having known genetic backgrounds.

In his essay for the 1976 NRC report, James Ebert, Chairman of the Assembly, pointed to the threat posed to supplies of experimentally useful marine animals by the activities of American and foreign fishermen.*

* James Ebert. 1976. The Assembly of Life Sciences: An operational definition. *In* The National Research Council in 1976: Current Issues and Studies. National Academy of Sciences, Washington, D.C., p. 49.

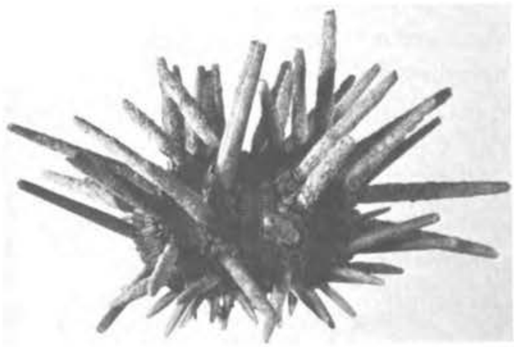
Similar threats may now, or in the future, be posed by overexploitation for scientific purposes alone. Among the endangered resources are squid, needed for neurobiological research but fast disappearing from the northeastern fisheries, and sea urchins, essential for studies on fertilization and early development, but dropping in numbers on the West Coast. As an initial response, ILAR has set up the Committee on Marine Invertebrates to work out laboratory breeding and culture methods for widely studied species. Other committees within ILAR will keep watch on availability problems and attempt to identify new species with potential as research models.

PRIMATES

When it first became apparent that several kinds of wild primates that are heavily relied upon in biomedical research were soon to become endangered species, ILAR established the Committee on Conservation of Nonhuman Primates. Since 1970, this group has been conducting studies, including field surveys, to measure harvesting rates and to examine ways to establish breeding colonies as an alternative to continued importation. The Committee has often cautioned against overexploitation and has examined proposed regulatory bans to ensure that such bans do not inadvertently hasten the disappearance of species, as, for example, when a regulatory ban may lead to black markets for species in short commercial supply.

GERMPLASM RESOURCES

All of the efforts just described are designed to improve the quality or the reliability of supplies of experimental organisms to the investigator. At the same time, they collectively have something of the quality of a call to arms; each is an effort to deal with an impending crisis, usually the availability of some wild organism. We hope to do much better; it ought to be possible to generalize the problem and then create programs that will meet emerging crises before they are upon us. To that end we have tried to broaden the definition of biological resources and to develop a scope of activities that matches this new range. The real leader of this effort has been Dr. Elizabeth Russell of the Jackson Laboratory and a



member of the Executive Committee of the Assembly of Life Sciences. Her concern with the quality and genetic identity of experimental material has animated the rest of us for several years; and, at her initiative, the ALS Executive Committee devoted a day in 1975 to a symposium on germplasm resources, at which a number of specialists in the federal government spoke about their own agencies' concerns. After some delay, modest funding is now in hand for a first step in the overall study.

This effort should give us a better idea of the shape of the problem. But from the beginning we must realize that it will be much larger than the sum of *ad hoc* activities in which the Division has so far engaged. In its broadest sense, the term *germplasm resources* comprises crop plants, livestock, research plants and animals, microorganisms, animal and human cell lines, and natural ecosystems. While in the recent past our emphasis has been on endangered resources of experimental animals obtained from the wild, the program on germplasm resources in the future must work along a much broader front and should, for example, include the development of strains of laboratory animals and the preservation of threatened ecosystems, such as tropical forests.

SPECIAL STRAINS OF LABORATORY ORGANISMS

Ready supplies of animals with a wide range of known genetic backgrounds are invaluable for studies on neurobiology, physiology, biochemistry, and genetics. To most investigators, this need for genetic stocks brings to mind such well-organized efforts as the Jackson Laboratory or the American Type Culture Collection. These programs have the size and staff to provide experimental material to researchers without serious limit. Concern for the health of these institutions is broadly diffused in the scientific community, and there seems no pressing reason to worry about their immediate future.

But not all research is done with mice and microbes, and many taxonomic groups of more limited but still critical value to biomedical investigation have not benefitted from similar efforts. Instead, an individual specialist or a small group has built up a collection of strains constituting an invaluable resource but subject to no protective scrutiny whatever. Such collections are vulnerable to the death or retirement of their curator/protectors, to changes in campus building requirements, or to shifts in scientific fashion that curtail their funding. The scholars who depend on these resources need and deserve the protective overview of science as a whole.

MAINTENANCE OF DEFINED STOCKS

We also should pay attention to alternative ways of maintaining genetic stocks. Breeding colonies of laboratory animals are expensive—in time, money, and space. Where possible, a central agency responsible for germplasm resources should be looking at ways of saving all three. A number of avenues appear to offer hope. For many purposes, cultured cell lines are an alternative to whole-animal experiments—and cells can be preserved by freezing. Some multicellular organisms can now be grown from single cultured somatic cells. This is true of half a dozen or so plant species, and the technology is expanding rapidly. Plants—including many cultivars—that must be propagated vegetatively can also be conserved by frozen storage.

For certain needs, it is important to have animals that are defined both genetically and in terms of health; germ-free or defined-flora collections are seeing increasing use. These requirements amplify the storage problem, as does the expanding need to conserve germplasm of endangered species. New advances in the frozen storage of early embryonic stages and of gametes have been made, but they require extension.

CROP PLANTS

A special problem is presented by major varieties of crops. Studies, including several by NRC groups, have noted the dangers associated with a narrowed genetic base in cereal and other crops.* Resistance to pests and pathogens is sometimes lost under selective regimes in which yield and uniformity are the main objectives of the genetic program. This kind of vulnerability was dramatized in the 1970 corn-leaf-blight epidemic, in which a strain of *Helminthosporium* caused heavy losses because of the uniform (and inadequately recognized) susceptibility of T-cytoplasm to

* Genetic Vulnerability of Major Crops. 1972. National Academy of Sciences, Washington, D.C.

this pathogen. To prevent such occurrences, it will regularly be necessary to return to the ancestral germplasm of these important crops in order to retrieve the natural sources of resistance. Efforts to retain these sources for U.S. crops are concentrated in the U.S. Department of Agriculture's National Seed Laboratory at Fort Collins, Colorado, but their effectiveness is disputed within the agricultural scientific community.* Furthermore, the most serious problems may be in the developing countries rather than the United States. New varieties in these countries are rapidly replacing earlier cultivars and, in some cases, the ancestral landforms from which the crop species evolved. For example, modern corn owes its phylogenetic origin to native races of maize in Mexico and to teosinte, with which a maize congener hybridized in the past. Wild populations of teosinte are undergoing rapid extinction because of grazing activities and genetic swamping by nearby fields of commercial maize. The ancient races of maize are similarly being eliminated because farmers understandably prefer to plant modern hybrid seed or to substitute cash crops such as strawberries.†

Thus, we need ways to collect and store a much larger inventory of genetic material, including crops. Several new developments make this a more sensible—and attainable—project. There may, for example, be more incentive to hold a wider range of variants in the field; in particular, the traditional custom of planting complementary crop genotypes to insure stability in the harvest is getting renewed attention. And resource collections may be miniaturized by coupling storage of cell cultures (some of them frozen) with new techniques of quickly screening useful variants.

PUBLIC ATTITUDES

No treatment of the problem of research organisms would be complete without some reference to changing public attitudes on the use of animals for scientific purposes. Biologists have been inclined to maintain a tactful silence on this subject, perhaps because they have become so sensitized to irrational outcries. However, I think it probable that a more serious set of questions about the experimental treatment of animals will arise,

* For example, J. R. Harlan. 1975. Our vanishing genetic resources. Science 188:618.
†H. Garrison Wilkes. 1972. Maize and its wild relatives. Science 177:1077.

Bamboo. Institute of Tropical Forestry, Rio Piedras, San Juan, Puerto Rico.

prompted by two events: (1) the public debate about the treatment of human subjects, especially in connection with the establishment of guidelines for research on human subjects by the National Commission on the Protection of Human Subjects; and (2) the growing concern over humane treatment of animals in other than a research context, particularly in the area of harvesting of food. A nascent debate over the rights of nonhuman organisms has drawn the attention of several serious legal scholars.

With respect to the more traditional matter of kind and merciful treatment, I believe the record of the biomedical research community is a good one. But as particular species become rare and as new kinds of experiments become possible, the emphasis is likely to fall on new issues. Do scientists have *priority* access to a living resource valued by other groups for different reasons? If so, on what grounds? What kinds of possible outcomes, if any, legitimize endangering the survival of rare organisms for scientific purposes? What purposes permit us to cause pain to expand knowledge—of pain itself and of other matters? Are the procedures for setting regulations within the science, and the sanctions that can be brought to bear on violators, adequate? These questions are going to be asked by others, and we will be in poor shape if we have avoided the subjects so as not to arouse the antivivisectionists. It is my belief, possibly a minority one, that serious attention to these problems will be useful as well as necessary. The experience of the National Commission on the Protection of Human Subjects suggests that the participation of ethicists and others from outside the research community will have a positive effect. Because the ultimate resolution of these questions will involve broad public participation, it will be necessary for those of us who do the work to explain its importance to others.

ECOSYSTEMS

Natural communities of plants and animals in themselves represent critically important biological resources, because a full range of them will be required for ecological studies and because they contain the species resources with which we will want to work. It is unthinkable to preserve such resources only in zoos, botanical gardens, or laboratory cultures; the majority must survive as parts of their natural communities.

The list of ecosystem types under stress is a long one. Rare montane communities associated with particular combinations of latitude and altitude are of concern simply because there are so few of them. Intertidal and estuarine zones are similarly rare and suffer from intense pressures of human activity. However, much of our current worry centers on mature tropical communities, particularly those of the humid tropics. Regeneration of tropical forests is a slow process and may require hundreds of years, with clear signs of disturbance possibly surviving for several centuries in some areas. And tropical ecosystems are unusually rich resources because of their unparalleled species diversity; hence their destruction carries with it a heavy additional risk. There may also be serious practical consequences, because so many medicinally important plants and agricultural crops had their evolutionary origin in the tropics.

The prognosis is deeply disturbing. The average doubling time for the human populations of the tropical Third World countries is less than 30 years; the pressure on their natural ecosystems is enormous. In assessing the situation in 1974, a group of about 30 distinguished systematists, ecologists, and others, at a workshop at the Missouri Botanical Garden in St. Louis, estimated that, of the 2 to 4 million species of organisms that inhabit the world's lowland tropical forests, half may be extinct by the end of the century.* Of the 250,000 named species of higher plants, roughly 50,000 are in danger of extinction or reduction to inviable levels by the year 2000. The main pressure against tropical forests comes not from agriculture, although the inroads made by increasing populations of shifting cultivators are significant, but rather from increased demand for timber, both for hardwood lumber exports and for wood fuel. The former is a significant element in Southeast Asia, particularly the Philippines and Malaysia, where exports of timber products produce important cash flows. The latter is probably more significant in the less-developed countries; according to estimates by the United Nations Food and Agricultural Organization, 85 percent of the annual wood consumption for such nations is attributable to fuel uses.

Obviously, the pressures on tropical forests should be of the highest concern to policymakers in the United States and other nations. The United States and the other Western developed countries are contributing heavily to the stress on tropical ecosystems. American, Japanese, and multinational corporations are extensively involved in tropical forest harvesting and conversion both in Southeast Asia and Central America.† The scientific community cannot (and probably should not) take the central role in determining U.S. policy in this area, because a wide variety of interests are at stake. But we can and must state as precisely as possible the value of species diversity as a scientific resource and emphasize the likelihood that different strategies for preserving it will succeed.

The Division of Biological Sciences did not discover this problem. The Organization for Tropical Studies, a consortium of university scientists that maintains field stations in Costa Rica, has been active in training a small number of U.S. and other scientists in tropical biology. The Man and Biosphere Program has several activities relating to tropical ecology, as does the Institute of Ecology. Both organizations stress the establishment and maintenance of preserve areas on an international basis. The Division recognizes the need to approach the problem multinationally, and our own efforts will continue to stress the mobilization and coordina-

* Trends, priorities, and needs in systematic and evolutionary biology. 1974. Syst. Zool. 23:416.

† N. Myers. 1976. An expanded approach to the problem of disappearing species. Science 193:198.

tion of efforts in the U.S. scientific community to support these activities and to provide the best possible scientific definition of objectives. If funding can be obtained, we will establish a committee to study priorities in tropical biology. This effort, growing out of the St. Louis meeting referred to on page 71, will undertake a closer analysis of the rates of ecosystem destruction in the world's humid tropics, rate the kinds of scientific question that can be asked best or exclusively in the tropics, and determine what modern population biology can tell us about the choices available in the tropics, both for research and conservation. We also intend to launch a program on the biology of indigenous tropical agricultural ecosystems, recognizing that the burgeoning population of the tropics requires attention to managed, as well as to unmanaged, ecosystems and that the same kinds of knowledge may be useful in both cases. These efforts will, of course, also require our attention to the development of appropriate international organizations.

I believe there is a special opportunity to harness new scientific knowledge more effectively in planning for ecosystem resource protection. Modern population biology has made dramatic progress in understanding the structure of natural communities and the way resources are divided up among their members. New explanations of diversity and of the necessary conditions for survival have been offered; and, although these are not yet universally subscribed to by ecologists, there is a real need to consider their significance for a strategy of germplasm resource management. To cite a simple example, shifting cultivation often leaves only small refugia of primary forest; but, since the forests of the humid tropics are so complex and so diverse, a large segregate is necessary to preserve a truly comprehensive sample. This has been forcefully demonstrated by studies of island biogeography, such as those by MacArthur and Wilson,* and also by analyses of specific ecosystem dynamics in the tropical forests. These results establish a minimum limit on sizes of units set aside as part of a preservation strategy.

Can we develop further information? Apart from their size, where should refugia be located? What shape should they have, and what kinds of terrain and biota should they contain? Studies on the distribution of

* R. MacArthur and E. O. Wilson. 1963. An equilibrium theory of island biogeography. Evolution 17:373.

Tuna. Hawaiian Island waters.

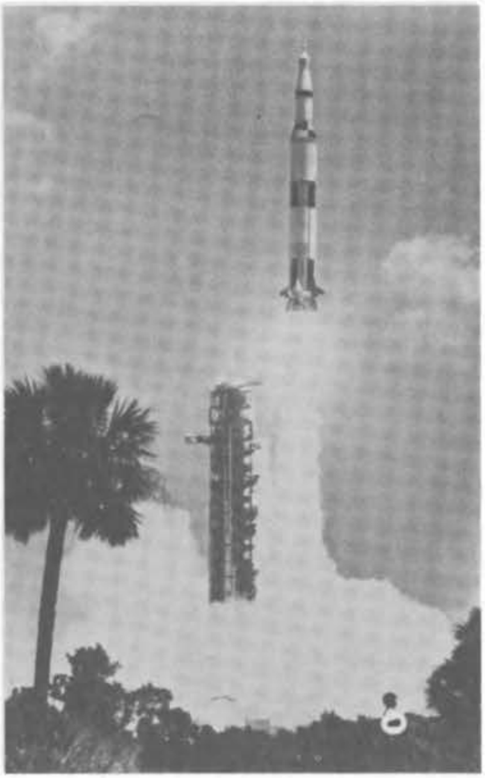
birds on montane "islands" in New Guinea by Diamond * and of patterns of extinction on Barro Colorado Island, in Central America, analyzed by Terborgh † have supported the general requirement for large areas and have also suggested detailed designs for a preservation strategy. The Division is sponsoring a planning workshop of population biologists who are able to contribute other elements, and we hope that from this exercise will come a sustained effort to shape the development of a scientific plan for preserving for future study ecosystems and their contained species resources. The time has come for a vigorous, well-argued case for society's scientific stake in a plan of this kind. Terborgh states the future in chillingly accurate terms:

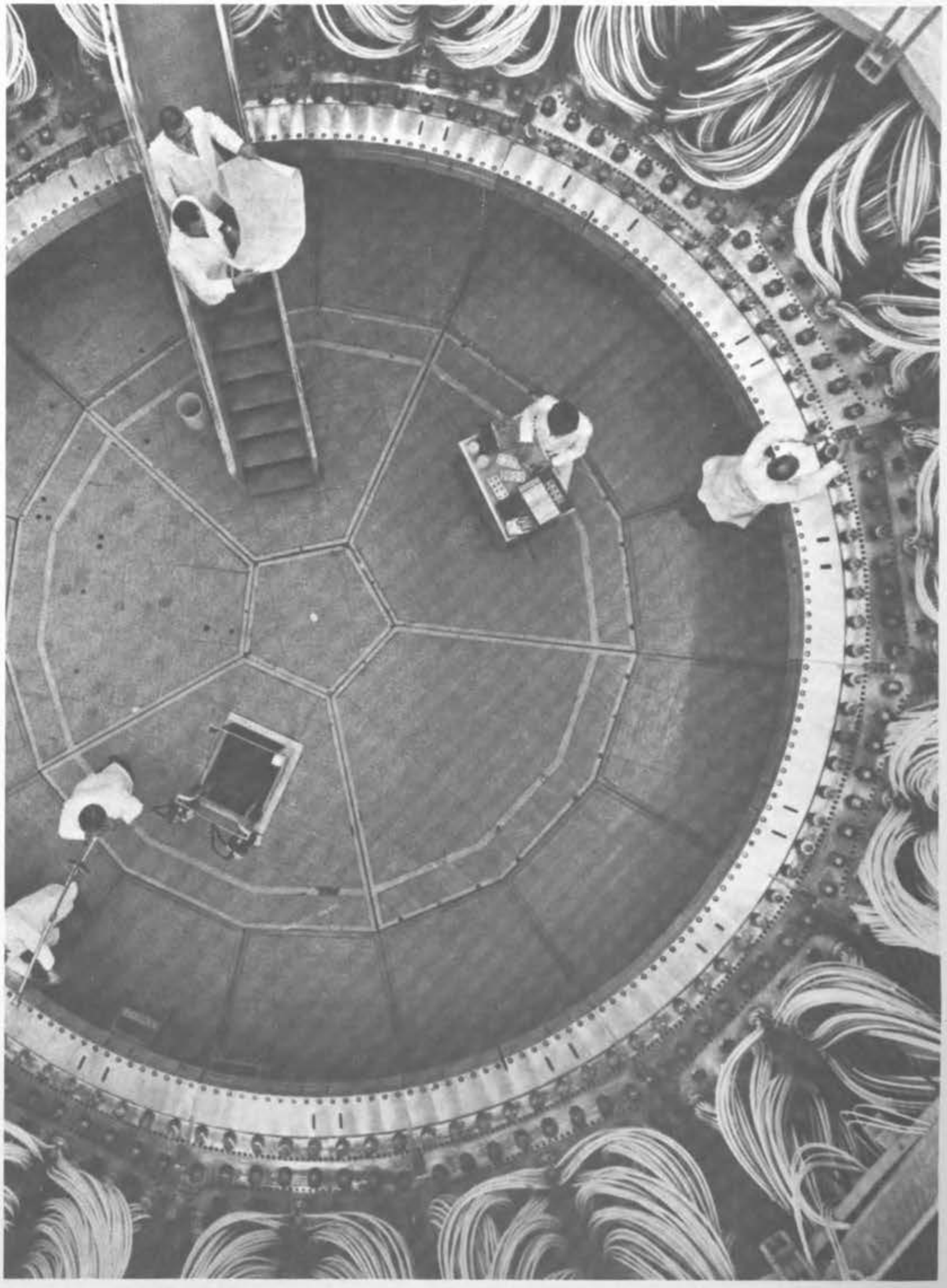
> The day is rapidly approaching when the remnants of the natural environment will be contained in a patchwork of parks and reserves. Much of the world's biological endowment will then be locked into insular refugia that are surrounded by an inhospitable landscape, through which dispersal to the next refuge is slow or nonexistent.‡

If this is to be the shape of the world, and there is every reason to believe it is, then biologists must at the very least see to the maximization of the endowment.

* J. Diamond. 1973. Distributional ecology of New Guinea birds. Science 179:759.
† J. Terborgh. 1974. Preservation of natural diversity: The problem of extinction-prone species. Bioscience 24:715.
‡ *Ibid.*, p. 715.

Assembly of Engineering





Scyllac fusion experiment. Los Alamos, New Mexico.

Changing Engineering Requirements

COURTLAND D. PERKINS

The intricate relationship among science, technology, and engineering is now understood by most of those closely involved with those fields. Unfortunately, most of the public, which is to some degree scientifically and technically illiterate, does not understand the various shadings of disciplinary interests and is often confused by them. We have today a spectrum of scientific and technical disciplines ranging from the pure scientist to the applied scientist, to the applied mathematician, to the engineering scientist, and to the engineer.

I think the largest misconception by the public is with the highly visible large national technical programs. For example, the recent remarkable success of NASA's Viking expedition to Mars has been referred to by nearly all the media as a great scientific achievement. Of course, it was basically an engineering triumph requiring little scientific support except for the experiments carried out by the Viking Lander on the surface of Mars. When the Lander made its first successful landing on Mars, an engineer of the Viking team turned to his scientific colleague and said, "O.K., we got it here, now you do something about it," and they did too!

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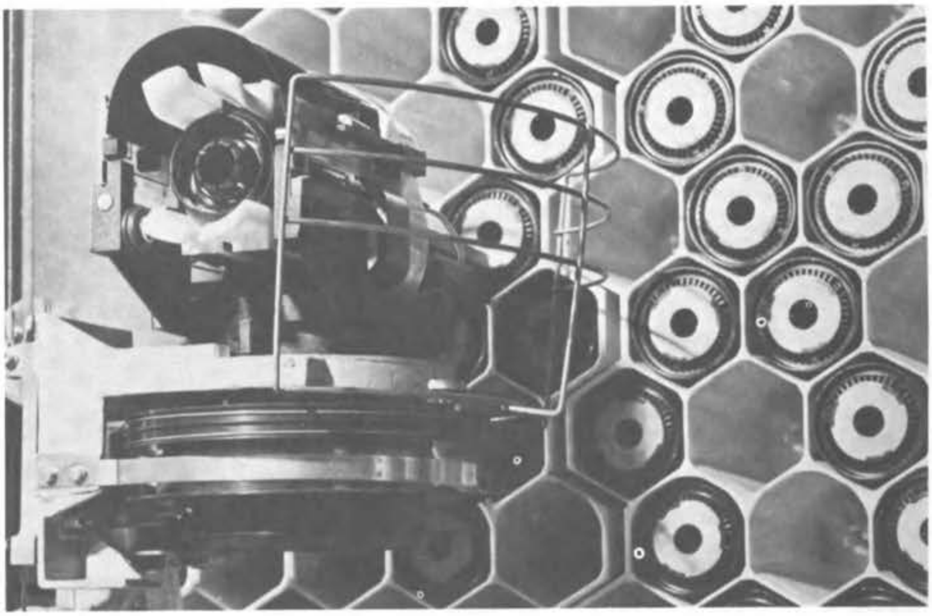


Data cartridges in mass storage system.

TINKERERS

In the early years of the scientific and technological revolution, most of the inventors or engineers had only the most rudimentary background in science or mathematics. They were great empiricists with a remarkable sense of experimenting towards a solution. Certainly, Wilbur and Orville Wright, two bicycle mechanics who opened the Air Age in 1903, worked independently of the scientific establishment and were ignorant of many of the theories of basic science. Henry Bessemer, who developed the open-hearth furnace for making steel, knew little of the work of Henry Sorby on metallurgical properties. Thomas Edison, the genius who devised the electric light, the electric generating station, the motion picture, and the gramophone, had little knowledge of science and less of mathematics. The work of the Wrights, Bessemer, and Edison, like so many of the engineer–inventors of the period—talented tinkerers perhaps—characterizes much of the technology up to World War II.

Prior to World War II, many scientists made a fetish out of maintaining a "pure" posture with respect to their work. One scientist made the rather silly remark to me in the late 1930's that, if he were shown that there was any practical use for his work, he would drop it immediately. On the other end of the spectrum, engineers were largely illiterate in science and mathematics and pushed forward their technical interests and designs through tedious development of handbooks and guidelines. These engineers were referred to with some disdain by scientists and others as "cook-book engineers."

All of this changed very rapidly during World War II, when great national technical programs required competence in science, mathematics, and engineering for rapid solutions. These programs—the building of the atomic bomb, radar developments by the MIT Radiation Laboratory, proximity fuses, analog and the digital computing devices, inertial guidance, rocketry, and others—burst on the scene and generated one of the most productive eras in technical history.

During this period, scientists and engineers learned to work together in depth. The scientists left their ivory towers. The engineers, in turn, realized that to contribute to these sophisticated programs they would have to understand science and scientists, and learn to work with them. The technologies engineers dealt with were soon identified as "high technology." New capabilities were required, including the reworking of engineering education programs. The undergraduate curricula called for more science and mathematics. Furthermore, the education of engineers, which up to World War II usually ended with a B.S. degree, now increasingly called for master's level and even doctoral programs. A successful engineer had to be well grounded in science and mathematics and be able to use these capabilities in his search for new concepts and their application.

ENGINEERS AND SOCIETY

The role of the engineer in today's world has become even more complex. Not only must he be able to deal comfortably with scientists and scientific ideas when developing new technology, but he also now must be concerned with the impact of the new concept on society.

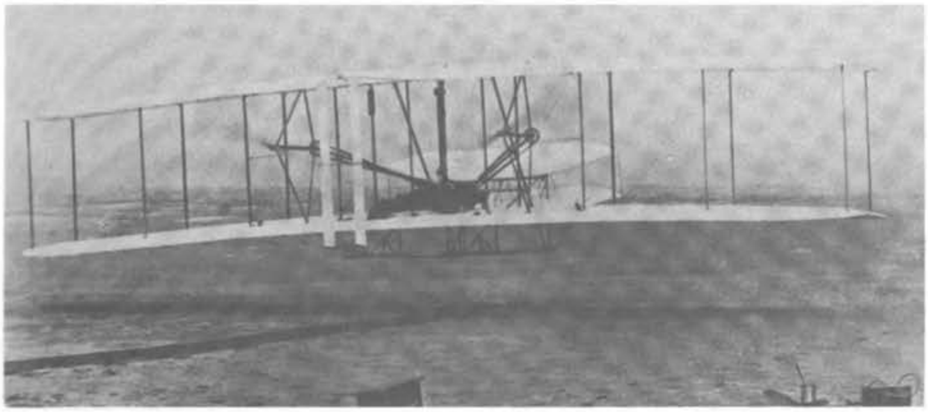
Until recently, the engineer could assume that society could and would use and absorb all new technical developments as they emerged and that he could concentrate his efforts on his particular high-technology interest. But he has now discovered that society has advanced to a point where what the engineer can invent, or provide, although magnificent in concept, may be of little or no interest to society, whether for commercial or military uses. Some advanced technology devices and systems have no payoffs and, in some instances, may only increase cost and environmental pollution. This has come as a profound shock to many of our modern technologists. For example, we can do many things in space today that are either too costly or unimportant to society. Although we can build a Supersonic Transport, society may not want it. The same can be said of Vertical Take-Off and Landing aircraft, 300-mph trains, and so on. The acceptance of these and other high technologies is no longer simply a matter of time, but rather dependent on other, often new, elements—societal perceptions of risk, possible environmental pollution, lifetime costs, impact on resources, and so on.

The modern engineer must understand the changing needs of society and the variety of often conflicting viewpoints. To be successful, the engineer must be alert to the broad spectrum of knowledge and its possible application to societal need and acceptance and be able to innovate acceptable new technology and systems that will improve life on this planet.

These greatly expanded requirements on today's engineer pose a difficult task for engineering education. How can an undergraduate program be designed to educate and motivate young students toward new horizons of high technology and at the same time satisfy the new requirements that they be able to handle the difficult trade-offs involving technological possibilities *and* societal constraints. The National Academy of Engineering and the Assembly of Engineering have established several new programs that focus on this concern, and in January 1977 they conducted a 2-day conference on this subject, with the aim of sharpening the national viewpoint.

One major view to emerge at the joint NAE–AE conference was the importance of engineers studying physical science, mathematics, economics, the social sciences, and the liberal arts in parallel with their technical engineering programs. According to this view of preparing for professional practice, engineering is a multidisciplinary profession. That contrasts, to a large extent, with the emphasis of most engineering colleges today on a specialized technical education. But, increasingly, at schools such as MIT and Cal Tech, freshmen already know as much or more of science and the humanities than most practicing engineers did 30 years ago. The underlying principle of this multidisciplinary education is that—whether as practitioner, advisor, manager, or decision maker—the future engineer will have to understand the total technical–societal system involved in a specific situation and shape his contribution to meet the special demands and constraints of society. The engineer must be able to deal with the socioeconomic and political dynamics of the time—or, more popularly, the "real world" in its broadest sense.

The engineers of today and tomorrow, therefore, must be persons with exceedingly broad viewpoints, having wide-ranging interests and capabilities. The problems engineers face in the future represent a great challenge to their profession, but the challenge will be accepted and met with relish.



TECHNOLOGY AND HEALTH CARE

The major causes of death in 1900 and 1970 were:

1900	1970
Influenza and pneumonia	Heart disease
Tuberculosis	Cancer
Gastroenteritis	Cerebrovascular lesions
Heart disease	Accidents
Cerebrovascular lesions	Other circulatory diseases
Chronic nephritis	Influenza and pneumonia
Accidents	Diseases of infancy
Cancer	Diabetes mellitus
Diseases of infancy	Cirrhosis of the liver
Diphtheria	Bronchitis, emphysema, and asthma

The only infectious diseases on the 1970 list are influenza, pneumonia, and some children's diseases, but the mortality rates for these are far below what they were in 1900.* The list today is dominated by dis-

* William H. Glazier. 1973. The task of medicine. Sci. Am. 228(4):15.

eases not caused by an identifiable microbe, their cause is unknown, and their treatment in the main is palliative and not preventive.

This dramatic change in the taxonomy of diseases from 1900 to 1970 is due in good part to technology, with technology here defined as tools and strategies applied to a purpose: to wit, the improvement and maintenance of health of the American population. Examples include vaccines and antitoxins; bacterial antibiotics; anesthetics and analgesics; gains in the science of hematology, including improved skills in blood transfusions, that widened the range and safety of surgery; new insecticides and their effective use; improvements in nutritional science and their application; and new sanitary systems to assure clean water and to carry away wastes, reducing the risk of sepsis.

There are more examples. But the catholicity of the list is less important than the point that improvements in health have come not simply from medical technology, but also—and, in the opinion of some observers, much more potently—from a variety of public health and sanitary measures, accompanied by and symptomatic of changes in living standards. Successful health-care technology was not only the product of Sir Alexander Fleming looking at his petri dishes, but also of the ripping up of streets of American cities to construct sewer lines.

Contemporary technology is even vaster, more sophisticated, more laden with promise; but, paradoxically, its ability to significantly improve health care, however measured, appears uncertain. Technology faces a daunting future in satisfying several emergent priorities in health care:

- A shift in emphasis from acute to chronic illnesses, necessitated by the rise in average age of the American population
- More emphasis in medicine on prevention rather than simply remedial treatment
- More long-term ambulatory care, supplementing the classical mode of short-term confinements in a hospital

Countering these pressures for change and exacerbating the difficulties of introducing technology is a health-care structure that has remained relatively static. As one writer put it:

> The technology and medical procedures for coping with the diseases that afflict the population have expanded and improved, but the structure of the system

that deploys the technology and resources has tended to remain fixed in a mold determined by medical and social circumstances that are quite different from those that exist today. The result is a mismatch between the technology of medicine and the apparatus that delivers care.*

COSTS

For policymakers, the crunching concern is with the immense costs of health care—now some 8.5 percent of the Gross National Product. As Donald S. Fredrickson, former President of the Institute of Medicine and now Director of the National Institutes of Health, has pointed out:

> The real national dissatisfaction with health care is with its soaring costs, a cost that increases faster than the general rate of inflation. To economists, the cost spiral seems particularly ominous because, if it is measured by changes in mortality rates or in longevity, there appears to be a steadily declining ratio of benefits to cost.†

Technology, which, as a first approximation, should lower costs in a field as labor-intensive as health care, is a logical tool for dealing with these climbing costs. But many observers see technology not as a solution but as part of the problem. "The more advanced and the more effective the technology, the greater the overall costs of health." ‡

The reasons for the anomalous linkages between costs and technology in health care are predictably complex. They certainly include the nature of the health-care system; or, perhaps closer to the mark, a *nonsystem* that's been described as "a bewildering, essentially scatter-brained kind of business, expanding steadily without being planned or run by anyone in particular." § Economies of scale are not at all obvious or easily accessible in health-care systems. In part because of the various third-party payment mechanisms, there is an absence of the usual forces that regulate market costs and prices; and there is typically little or no

* *Ibid.*, p. 15.

† Donald S. Fredrickson. 1976. Toward a national health policy. *In* The National Research Council in 1976: Current Issues and Studies. National Academy of Sciences, Washington, D.C., p. 195.

‡ Anne R. Somers. 1972. Health care and the political system: The sorcerer's apprentice revisited. *In* Technology and Health Care Systems in the 1980's. National Center for Health Services Research and Development, Washington, D.C., p. 39.

§ Lews Thomas. 1972. Aspects of Biomedical Science Policy. Occasional Paper. Institute of Medicine, Washington, D.C., p. 1.

pressure on the principal actors in the health-care system to reduce or even stabilize costs.

As two policy analysts have pointed out,

> [i]ncreasingly . . . the effect of government policies is to reduce the constraints that market forces place upon the introduction of new technologies and, therefore, upon the development of new technologies. The reimbursement procedures that were followed by the government's Medicare and Medicaid programs, for example, guarantee that health care institutions need not have the slightest hesitancy in purchasing the latest in medical technologies, no matter how marginal the health benefit.*

However, it must be said that federal efforts have been made to stem the tide of uncontrolled capital expenditures in health care. Thus, the 1972 amendments to the Social Security Act (PL 92–603) established

- A mechanism for reviews by health-planning agencies of capital expenditures by hospitals, nominally to assure that federal funds support only those proposed health-care facilities actually needed by a community
- Experiments in reimbursement that, among other effects, have moved many state Medicaid programs and Blue Cross plans to the concept of "prospective reimbursement," to give a hospital more incentive to control costs

The National Health Planning and Resources Development Act of 1974 (PL 93–641) was also intended to reduce costs by creating regional and state health-planning agencies with the power to use a "certification of need" mechanism to regulate the introduction of new health services by hospitals and other health-care institutions.

Thus, there have been efforts at the federal level, although there is as yet no compelling evidence that they are loosening the constraints on market mechanisms described by Lambright and Sapolsky.

Other troubling elements in articulating policy in health-care technology, particularly in dampening rising costs, is simply lack of knowledge of the basis of many of our chronic or noninfectious diseases, forcing the medical system to resort to expensive "half-way technology," defined by Lewis Thomas as "efforts to compensate for the incapacitating effects of certain diseases whose course we are unable to do very much about. It

* W. Henry Lambright and Harvey M. Sapolsky. 1976. Terminating federal research and development programs. Policy Sci. 7(2):210.

is a technology designed to make up for disease, or to postpone death." * And there is also increased pressure on the health-care system to deal with problems that are unique and often intractable to conventional procedures: occupational diseases, particularly those involving exposures to chemicals; the resolution of problems in social adaptation and living styles that may relate to health; and the provision of comfort and relief of pain in addition to or in lieu of prevention or cure.

INTENTIONS AND REALITIES

None of these difficulties are necessarily undesirable. But they do influence the benefits and costs of technology and they do underline the point that self-evident perceptions of the role and potential of technology may be fallacious when actually applied to real settings and needs. Victor Fuchs pointed out that "[a] change in technology that is capital saving and labor intensive may be more valuable than one that is not, and a change that permits the substitution of two relatively unskilled workers for one very highly skilled worker may be more valuable . . ." †

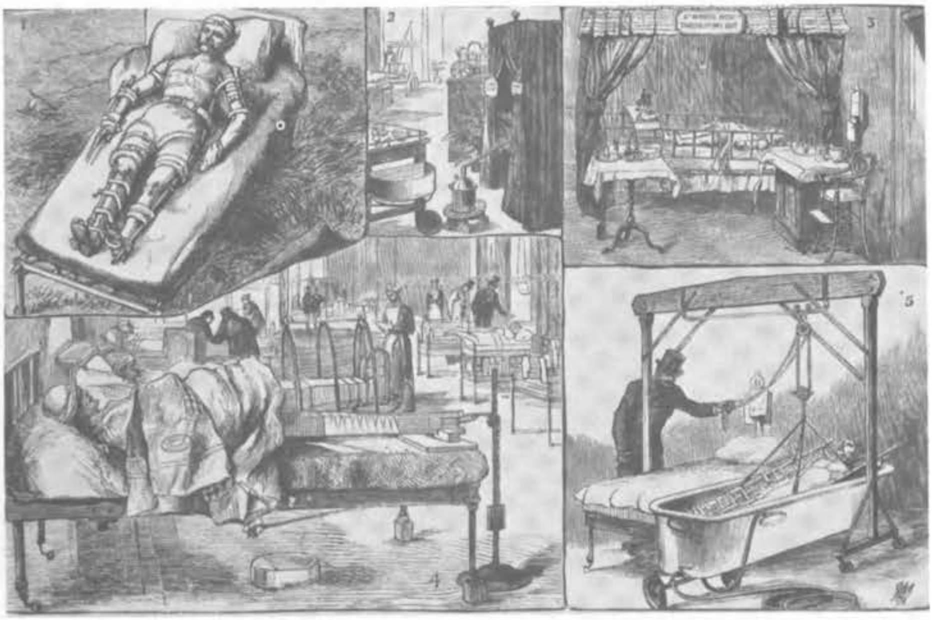
A useful example of the problems that come up and of the difficulties that confront policymakers is that of automated multiphasic screening. Robert J. Glaser has described some of the difficulties:

> Above and beyond the initial capital costs, there is the question of the relative operating costs of multiphasic screening compared to the same procedures carries out by more conventional techniques. But even if the use of automated devices offers a more economical means of making a given set of measurements than other methods, one must still determine whether the market will bear the cost. Consumers are not always willing to pay even a little more to obtain relatively greater value. Here an additional factor, the patient load, comes into play. For as [Morris F.] Collen has shown, the unit costs may increase twofold or more when the patient load drops by 50 percent. Conversely, an increasing patient load may lessen the unit cost by a significant margin. Clearly, planning calls for a very detailed economic analysis.‡

* Thomas, p. 12.

† Victor R. Fuchs. 1972. Health care and the U.S. economic system. *In* Technology and Health Care Systems in the 1980's. National Center for Health Services Research and Development, Washington, D.C., p. 57.

‡ Robert J. Glaser. 1973. Health care and education. *In* Technology and Health Care Systems in the 1980's. National Center for Health Services Research and Development, Washington, D.C., p. 90.



Such considerations of costs in realistic settings apply to multiphasic screening and other health-care technologies, including the much-bruited powers of information systems, and are at the heart of the study on technology and health care undertaken jointly by the NRC Assembly of Engineering and the Institute of Medicine. In addressing the questions raised by multiphasic screening and similar "equipment-oriented" technologies, the study, to cite its own proposal, must deal with the fact that in health care "the application of technology often results in a paradox of increasing costs with negligible effects on productivity. At present it is difficult for health-care policymakers to reconcile the views of the champions of technological applications as a means of increasing the productivity of the system with the skeptics who question the cost–benefit relationship of such applications."

Committee on the Relationship of Technology to Improvements in the Productivity and Effectiveness of Health Care Systems, Assembly of Engineering and the Institute of Medicine. Committee Chairman, Jordan J. Baruch of the Amos Tuck School of Public Administration, Dartmouth College; Study Director, Judith Wagner.

THE POTOMAC AND THE SUPPLY OF WATER

The Potomac River still has many of the same pastoral and wilderness qualities that Capt. John Smith first saw in 1608—just 1 year after he founded Jamestown, Virginia. Its productive estuaries, natural harbors, and easily traversed waterways were exploited by the early explorers and settlers.

Farms and forest–wildlands still account for more than 75 percent of the 14,670 square miles in West Virginia, Virginia, Pennsylvania, Maryland, and the District of Columbia that are drained by the Potomac and its tributaries. Majestic trees line the river in its 383-mile run from the Appalachian Mountains to the Chesapeake Bay. Historical sites—Harper's Ferry, Mount Vernon, the Antietam battlefield, Fort Washington—attract millions of tourists annually. The Chesapeake and Ohio Canal, which parallels a portion of the Potomac, has become an important avenue for bicyclists and joggers, and a cause for naturalists.

A visitor to Mount Vernon looking out over the Potomac might see a sight much like that viewed by George Washington 200 years ago. A 1,500-acre strip on the eastern shore of the river is preserved in its eighteenth-century state as a national park. Sailboats glide by. The river and its tributaries still flow largely uninterrupted by man.

That view is, of course, deceptive. A great city—Washington, D.C.—with sprawling suburbs has grown up by the banks of the Potomac on what was once largely swampland. Strip mining in West Virginia and Pennsylvania has increased the amount of sediments carried by the river and the acidity of its water. Industrial wastes, municipal sewage, and agricultural runoff have changed the ecological balance of the river. Motorboats now outnumber sailboats. And air pollution, primarily from auto exhausts, often drapes the river and city.

ENOUGH WATER?

These environmental concerns are now joined by another problem—water supply. Normally plentiful, drinking water could become scarce if the droughts similar to those that have recently swept across much of sub-Saharan Africa, Western Europe, and, recently, the Western United States, again strike the Potomac River basin, as they did in the early 1930's and the mid-1960's. The District of Columbia's 750,000 residents might then find themselves lined up with buckets in hand waiting for their daily ration of drinking water.

While that scenario is extreme and unlikely, the problem is real. Rapid population growth in the last two decades in the Washington metropolitan area, in which about 2.8 million persons now live, has increased the demand for drinking water close to capacity. The average water flow of the Potomac at Great Falls is 7,100 million gallons per day (mgd). The highest recorded flow was 310,080 mgd in 1936. But the salient figure is the recorded low flow of 388 mgd in 1966, or less than the maximum demand of 448 mgd in 1974.* Should a record low flow and

* The low flow of the Potomac came at the end of a 5-year drought that afflicted the entire northeastern United States. As pointed out in the *Potomac Basin Reporter* (32:8, August 1976), published by the Interstate Commission on the Potomac River Basin, little was actually done during the drought to conserve water. The reasoning was that "since the river was the only source, and there was no way to store large volumes of water, the population might as well use everything going by Washington anyway."

"As a consequence, a greater percentage of the Potomac was channelled into the pipes of a thirsty city—and, one day in the Washington area, the supply was more than 60 percent of the entire flow of the river."

maximum demand occur simultaneously, a water deficit of 60 mgd or more would exist.

Future projections don't brighten the picture. The highest of the many population projections for the Washington area predicts 4.1 million persons by 1980, 6.75 million by 2000, and 8 million by 2020. Further, the U.S. Army Corps of Engineers has projected the maximum daily demand for water from the Potomac in the Washington area as 530 mgd by 1980, 813 mgd by 2000, and 1,096 mgd by 2020. Thus, the potential drinking-water deficit produced by a combination of low flow and high demand is growing and could reach calamitous proportions in the twenty-first century.

The District itself, parts of suburban Maryland, and Arlington County and Falls Church, Virginia, draw their drinking water exclusively from the Potomac, which currently has no dams or reservoirs and thus no reserve capacity to counter extended dry periods. Most other metropolitan centers in the northeastern United States, such as New York and Boston, have sizeable water-storage systems. Suburban Maryland gets most of its water from two dams on the Patuxent River, while most of Northern Virginia is supplied from the Occoquan Reservoir.

REMEDIES

A number of possible solutions to Washington's potential drinking-water problems have been floating around Congress and the administration in recent years. These include:

- The construction of a series of dams and reservoirs on the Potomac and its tributaries
- High-flow water-storage facilities
- Importation of water from other watersheds, such as the Susquehanna, Rappahannock, and Patuxent rivers
- Recycling wastewater
- Using available groundwater sources
- Tapping the Potomac estuary
- Restrictions on water use

Reservoir construction, high-flow storage facilities, importation, and recycling wastewater would cost a great deal and take 10 years or more to fully implement. Restricting the use of water would require action by local governments, the effects of which and public compliance with are now uncertain. The use of groundwater sources would require separate wells for each area and at least double the cost per million gallons of water compared to dams and reservoirs.

The Corps of Engineers, which operates the District's 112-year-old water-supply system, has recommended to Congress since 1963 the construction of a series of dams—originally 16, reduced to 6 in 1969, and now 3—on the Potomac and its tributaries. These dams would raise the average daily flow of water in the Potomac and give Washington a reserve capacity. The one dam now under construction on the North Branch of the Potomac near Bloomington, Maryland, will add 135 mgd to the river. A second dam on a tributary of the South Fork of the Shenandoah River near Verona, Virginia, is on the drawing boards. The third dam—the Sixes Bridge project on the Monocacy River in Maryland—is not yet in the design stage.

But environmentalists vehemently oppose any further change in the natural state of the Potomac and its tributaries. They have forced the Corps to reduce the number of its proposed dams and successfully blocked any further construction of dams and reservoirs in the Potomac River basin.

TAPPING THE ESTUARY

An alternative to the dams is to tap the Potomac estuary—the 110-mile stretch of the river from Little Falls to the Chesapeake Bay, where the ocean tide meets the river current. The estuary has three segments: an upper reach extending from Little Falls to Indian Head (about 40 miles); a middle reach from Indian Head to the Route 301 bridge at Morgantown, Maryland (about 25 miles); and a lower reach from Morgantown to Point Lookout, Maryland, at the mouth of the river (about 45 miles). The upper estuary, which includes that part of the Potomac in the Washington area, is essentially a large freshwater reservoir (containing about 10 billion gallons of water between Little Falls and Blue Plains alone). The middle estuary dilutes the tidal salt water in its daily ebb and flow and keeps the upper estuary waters fresh except during droughts.

Congress authorized the Corps of Engineers in 1974 to study the feasibility of using the Potomac estuary as a source of water for the Washington area. The Corps's study of this alternative to ultimately solving Washington's drinking-water supply problem involves a proposed water-treatment plant that would be located on the Potomac estuary. A pilot plant to test the feasibility of treating the estuarine water for drinking purposes will be built on the estuary in southeast Washington. Construction will begin in 1977 and take two years to complete. The pilot plant will cost $8 million to build, $2 million per year to operate (although inflation may push that figure up), and will have a 1-mgd capacity.

THE STUDY

Congress required the Corps of Engineers, as part of the authorization for the estuary study, to request the National Academy of Sciences and the National Academy of Engineering to review and evaluate the design, operation, and test results of the pilot plant. The National Research Council has established a technical committee under the Assembly of Engineering to conduct that review.

The committee will evaluate the engineering, environmental, economic, and public health bases for the conclusions reached by the Corps. It will not consider the political, legal, or jurisdictional aspects of the problem. The review will result in a final report due 1 year after the Corps completes its own study. Interim reports may be issued as the Corps completes each phase of the study. The study is planned as a 7-year effort at a cost of $535,750.

The committee will work closely with the Committee on Safe Drinking Water of the Assembly of Life Sciences (ALS) and the Committee on Scientific and Technical Assessments of Environmental Pollutants of the Commission on Natural Resources (CNR). The ALS committee is studying the effects of the many kinds and classes of pollutants, including viruses, on drinking-water supplies and will recommend guidelines that the Environmental Protection Agency will use to help them establish drinking water standards. The CNR committee is studying the effects of hydrocarbon pollutants, particularly in water, where their greatest accumulation and exposure to man occur.

In addition to the pilot plant study, the Corps of Engineers will conduct a study of the long-range water needs and resources for the Washington area. A second NRC committee, with overlapping membership and a joint staff with the pilot plant committee, will review and evaluate the Corps' water-supply study. The Corps and this committee will consider socioeconomic means to reduce water demand in addition to the traditional engineering focus on water resources planning. The water-supply study will also consider improved methods and approaches for adjusting to possible water shortages and will make use of the pilot plant study in evaluating the potential of the Potomac estuary for supplying water to the Washington area.

NATIONAL PERSPECTIVES

The possibility of tapping river esturaries for drinking purposes has excited national and engineering interest. Many cities are faced with similar demands on their water supplies and would like to use estuarine water, but cannot afford the cost of research and demonstration projects necessary to overcome the fears of the public health profession and a skeptical public.

The congressional mandate to the Corps requires the pilot plant to evaluate known methods of treating water rather than experimenting with new ones. Initially, the plant was to evaluate every known method. But one method (ion exchange for the removal of ammonia from the water) was dropped from the experimental design because of cost considerations. The plant will test different combinations of methods to determine which give the best results under different conditions.

The design of the plant will assume the worst possible conditions in the estuary—record low water flows in the Potomac because of drought (low water levels reduce the natural cleansing action of and the percentage of fresh water in the river) and the worst quality wastewater resulting from the probable growth in population in the Washington area by 2020.

PILOT PLANT

The pilot plant is designed to recycle wastewater both directly and indirectly. Direct recycling would pump wastewater from the Blue Plains treatment plant, which currently dumps 285 mgd of effluent into the

Potomac to the pilot plant without prior discharge into the river. Indirect recycling occurs when treated wastewater is discharged into the estuary, where it undergoes further natural cleansing action, and then is taken into the pilot plant. Only 20 to 60 percent of the estuary water taken into the pilot plant might then be recycled wastewater. The Corps may eliminate direct recycling because of the high cost of the extra treatment equipment required. In any case, no Washingtonian will drink the recycled water from the pilot plant. The water will remain inside the plant, where it will be tested to determine the effectiveness of the various treatment processes. Some tests on experimental animals may be undertaken at the National Institutes of Health in Bethesda, Maryland.

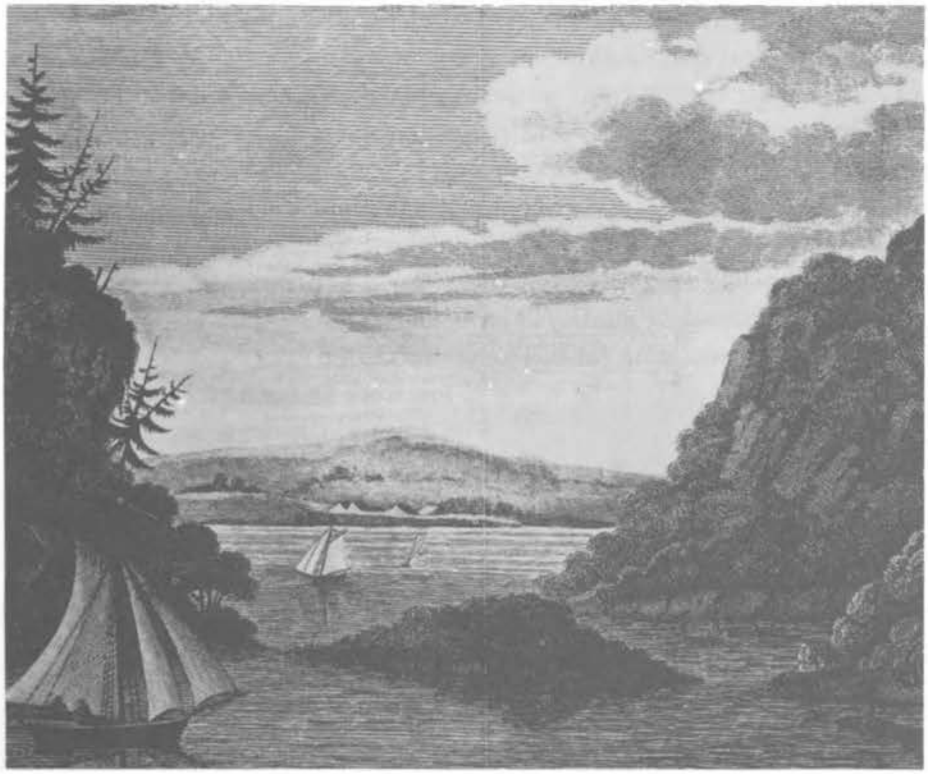
VIRUSES AND CHLORINE

Two major needs in recycling wastewater are to ensure the elimination of human pathogenic viruses and to avoid overchlorination of the water. Viruses can survive present treatment methods and persist for several months in the water. The pilot plant will treat the water with a combination of techniques, including microscreening, coagulation, flocculation, sedimentation, filtration, activated carbon adsorption, and disinfection. New applications will be made of old methods, such as pasteurization (although, again, it may cost too much to be included), used to kill viruses and bacteria by heat and radiation.

Chlorine treatment is now the single most effective means of destroying viruses in water, and has been used to disinfect water (for bacteria) in the United States for more than 50 years. Very high doses of chlorine can kill 99.9 percent of the viruses, but at the price of high cost, toxicity to higher forms of life if the effluents are discharged, and the production of possibly carcinogenic substances resulting from the action of chlorine on naturally occurring or industrial organic wastes.*

The pilot plant will combine ozonation with chlorine treatment in an attempt to improve disinfection. The water will be disinfected both before

* The possibility that large doses of chlorine may produce carcinogenic substances in water is a complex and unsettled issue. These substances, such as carbon tetrachloride and chloroform, are carcinogenic in very large doses, but cannot be proved to be carcinogenic in the small doses found in drinking water. A second problem is that where and how the carcinogenic substances are produced—in the treatment plant as a result of the action of chlorine on industrial wastes or as a natural process in the river itself—are still not known.



View of the Potomac River from Mt. Vernon, 1798.

filtration and just prior to release into the clearwell. Also, under appropriate conditions, viruses are readily absorbed to a wide variety of surfaces, including activated carbon, diatomaceous earth, membrane filters, colloidal organic matter, clays, and soils.

TREATING THE WATER

A large blend tank in the pilot plant will mix water from the estuary with ordinary city water and (possibly) effluent discharged from the Blue Plains treatment plan. Before the estuarine water enters the blend tank, it will pass through two microscreens to remove suspended solids and microorganisms, such as algae, common in estuarine water.

Oxygen will be added to the blended water to increase its palatability and to remove certain metals. Coagulants will also be added, since—next to chemical disinfection—coagulation is perhaps the most effective way to remove viruses from water. Alum (aluminium sulfate), lime (calcium hydroxide), iron salts, and polyelectrolytes can remove up to 99.9 percent of the viruses suspended in water.

After oxygenation and coagulation, the water goes to a flocculation basin where the suspended and dissolved solids and coagulants are brought into contact with each other by a gentle agitation process to increase their size and density. The dense particles then settle out of the water in a sedimentation tank. The water next flows into a recarbonation tank in which the pH of the water is lowered, as needed, to stabilize the water before entering the filters. The filtration process separates finely suspended particles from the water. Dual and mixed-media rapid sand filters will be evaluated at several rates of filtration. The water will then be treated by a carbon adsorption process to remove dissolved organic material and taste and odor-causing substances.

Finally, reverse osmosis, electrodialysis, and ion exchange will be used to remove the remaining dissolved solids from a side-stream flow. Reverse osmosis removes dissolved particles by forcing the water through a semipermeable membrane. Electrodialysis uses a rectifier with positive and negative electrodes to separate the undesirable ions from the water. The ion-exchange process passes water through an exchange vessel first and then through an anion exchanger, where H^+ ions are removed.

If the pilot plant successfully proves estuary water acceptable for drinking, a full-scale regional plant may be built on the Potomac estuary to provide Washingtonians of the next century with a reliable and safe source of water. The plant would probably be located near Little Falls and would only indirectly recycle wastewater. By itself, such a plant will not solve all of Washington's drinking-water problems, but it may obviate the need for an extensive series of dams and reservoirs on the Potomac and its tributaries. In that case, environmentalists and other Washingtonians may be able to quench their thirst and also have a free-flowing river.

Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project, Assembly of Engineering. Committee Chairman, Gerard A. Rohlich of the University of Texas at Austin; Staff Officer, Charles R. Malone.

Assembly of Mathematical and Physical Sciences

"Horsehead" Nebula

Chemistry in a Jiffy*

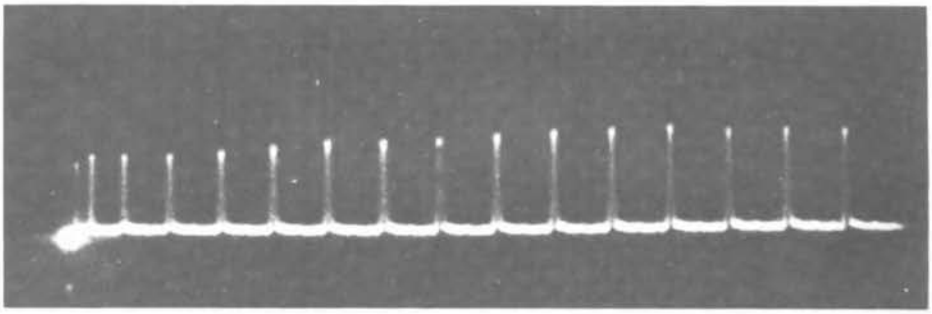
JACOB BIGELEISEN

Thirty-six years ago I had the privilege of spending 2 years in close association with Gilbert N. Lewis, both as a graduate student and as a research assistant. Lewis had broad scientific interests, as evidenced by his work on the electron-pair bond, chemical thermodynamics, acids and bases, and the interaction of radiation with conjugated molecules. He was a wit who often coined delightful phrases, such as the jiffy—the time needed for a photon to travel 1 centimeter, or 33 picoseconds.

The jiffy was far ahead of its time. When the phrase was coined in the twenties, chemistry was done on a time scale some hundred million times slower than a jiffy. In a picosecond—10^{-12} or a million millionth of a second—a light beam travels one-third of a millimeter and a gas molecule at room temperature moves one or two molecular diameters, or rotates several times at most. In 1941, the fastest processes studied in the

* It is a pleasure to acknowledge the participation of Mr. Norman Metzger and Dr. Martin A. Paul in the preparation of this article.

Jacob Bigeleisen is Chairman, Assembly of Mathematical and Physical Sciences, and Tracy H. Harris Professor of Mathematics and Natural Philosophy at the University of Rochester.



Oscilloscope trace showing train of picosecond pulses from a mode locked Nd^{+3} glass laser.

laboratory were on a millisecond scale—10^{-3} second—and were generally limited to analyzing gas kinetics in flowing systems and the lifetimes of slow electronic transitions in molecules.

My association with Lewis coincided with the time when he was actively pursuing organic photochemistry, particularly fluorescence and phosphorescence. His studies of the latter led eventually to his discovery, with Michael Kasha, of the triplet state, in which two valence electrons have unpaired spins. Much has been learned since then about how large organic molecules return from an excited singlet electronic state to the ground state, either directly or through an intermediate triplet state (see Figure 1). Some of the details of this intricate process are now being unraveled by picosecond spectroscopy, a new tool in the hands of the chemical physicist.

FAST EVENTS

Chemistry in a jiffy is the lineal descendent of a sequence of methods developed over the past quarter century for analyzing fast events in chemical processes. Stopped-flow and continuous-flow techniques were used for decades and indeed are still being used in several exciting areas of chemical research to investigate millisecond processes. In 1949, G. Porter and R. G. W. Norrish of Cambridge University described flash photolysis,[1] which, as its name suggests, uses a fast flash of light to trigger a chemical reaction. This strong flash is followed by a weaker probe flash with a variable delay time, which detects intermediates and reaction products spectrophotometrically (Figure 2). The work by Porter and Norrish extended the range of gas-kinetic measurements from milliseconds to microseconds (10^{-6} second). An example of the application of this technique is the measurement in the early 1950's by Norman Davidson and co-workers [2] of the rate of recombination of iodine atoms (I) generated by flash photolysis of iodine molecules (I_2). The progress of the reaction was followed by photographing the oscilloscope trace of the light transmittance at a wavelength where I_2 strongly absorbs light. The entire reaction time was about 1 millisecond.

Flash photolysis was joined by ingenious relaxation methods developed in the 1950's by Manfred Eigen,[3] then at the Max Planck Institute for Physical Chemistry in Göttingen. These methods are based on the application of a carefully controlled, sudden, but relatively small distur-

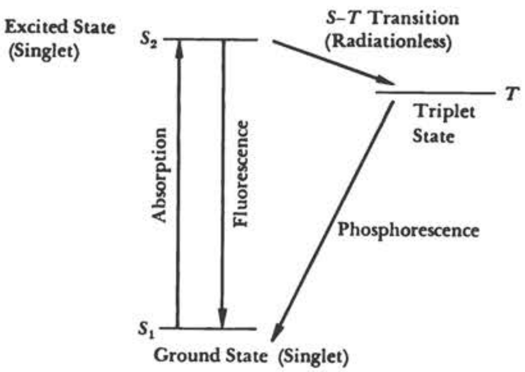


FIGURE 1 Excited States: A molecule can be excited when it absorbs a photon that elevates an electron from the ground or lowest energy state, which is most often a singlet state (S_1). The first energy state in such excitation is usually the excited singlet state (S_2). Its energy is then lost in any one of several ways, including possibly a transition to the triplet state (T), from which it can return to its ground state by emitting light—phosphorescence. In fluorescence, the molecule returns to the ground state directly from an excited singlet state, emitting its energy as light. In a singlet state, the spins of the electrons are all paired; in the triplet state two electrons are unpaired.

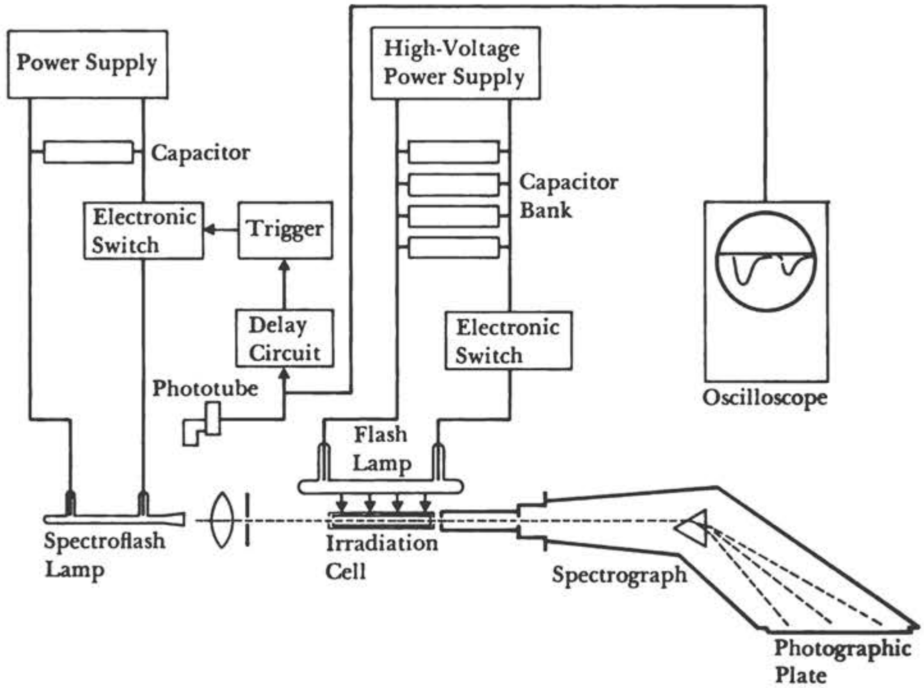


FIGURE 2 A typical flash photolysis arrangement: An intense flash of light triggers a reaction in the irradiation cell, liberating short-lived intermediates. These are then identified spectroscopically, using a second weaker flash from the spectroflash lamp as the probe and the spectrograph as the detector.

bance—an electric field, a temperature jump, or an acoustic shock—of a chemical system originally at equilibrium. The concentrations of reactants and products are monitored spectrophotometrically or conductimetrically as they return or relax to their equilibrium values (Figure 3). Relaxation methods, particularly applicable to liquids and solids, were used to measure the rate of fast chemical reactions in liquid solutions. A classic example is the 1955 measurement by Eigen and Leo De Maeyer of the rate of combination of H^+ and OH^- ions in pure liquid water.[4] They applied a sudden, short, and intense (about 10^5 volts per centimeter) electric field, which temporarily increased the ionic concentration, measured conductimetrically. The observed relaxation time of about 37 microseconds and the known equilibrium concentrations of H^+ and OH^- ions yielded a rate constant for this important reaction. The value of the rate constant indicated that the ions react as frequently as they encounter each other and, therefore, that the reaction is diffusion controlled. Such relaxation methods have been used to probe enzyme-catalyzed reactions, helix-to-random-coil transitions of polypeptides, and other biochemical processes.

The relaxation method of Eigen was extended in the early 1970's to the nanosecond range (10^{-9} second) by J. V. Beitz, G. W. Flynn, D. H. Turner, and N. Sutin in a cooperative project between Columbia University and Brookhaven National Laboratory. They used an infrared laser pulse to induce a temperature jump of several degrees in water.[5] The process studied was the very fast and reversible reaction of an iodine molecule with an iodine ion: $I_2 + I^- \rightleftarrows I_3^-$.[6] From observed relaxation times ranging from 30 to 70 nanoseconds with changes in the initial concentrations, the rate constants for the forward and reverse reactions were determined.

THE PICOSECOND RANGE

Intense light pulses lasting a few picoseconds, generated by mode-locked lasers, were first observed in 1965.[7] Workers in the field immediately recognized that these ultrashort light pulses would permit the study of very rapid physical and chemical processes in liquids and solids. Picosecond spectroscopy was developed by P. M. Rentzepis and his colleagues at Bell Laboratories in the following years.[8]

In a typical experiment, the laser system produces a train of about 100 infrared pulses separated by the round-trip transit time of light through the laser cavity. Each pulse contains about a millijoule of energy and has a full width of between 5 and 10 picoseconds at half its peak intensity. An individual pulse is selected from the train and amplified to about 50 millijoules. This infrared pulse, consisting of some 10^{17} photons, may be used directly to irradiate the sample, or it may be frequency-shifted to longer or shorter wavelengths. Probe pulses derived from the fundamental pulse through calibrated delays provide a clock to time the processes occurring in the sample. When the probe light transmitted through the sample is then put through a spectrophotometer, a complete emission or absorption spectrum as it evolves with time can be obtained from a single laser pulse (Figure 4).

The power density of the picosecond light pulse can exceed a gigawatt (10^9 watts) per square centimeter, and the response of the absorbing system to this intense pulse may be qualitatively quite different from that predicted by linear extrapolation from the system's response to ordinary light intensities. For example, research on time-dependent changes in saturable dyes during the transmission of intense picosecond light pulses shows that it is no longer adequate to consider the dye as a three-level system—ground state, excited singlet state, and triplet state—with only a small population of excited states.[9] Stimulated emission becomes an important deactivating mechanism for the excited state at power densities of gigawatts per square centimeter; and the decay time from the excited singlet state to the ground state—that is, the rate of energy loss—is a thousandfold faster in the laser field than when measured with a conventional monochromatic source. It is noteworthy that stimulated light emission has recently been observed for chlorophylls and certain of their magnesium-free derivatives by J. J. Katz and his associates at Argonne National Laboratory.[10] Certainly, this behavior must be considered when using laser excitation to study the excited electronic states of these biologically important compounds and in interpreting their fluorescence lifetimes.

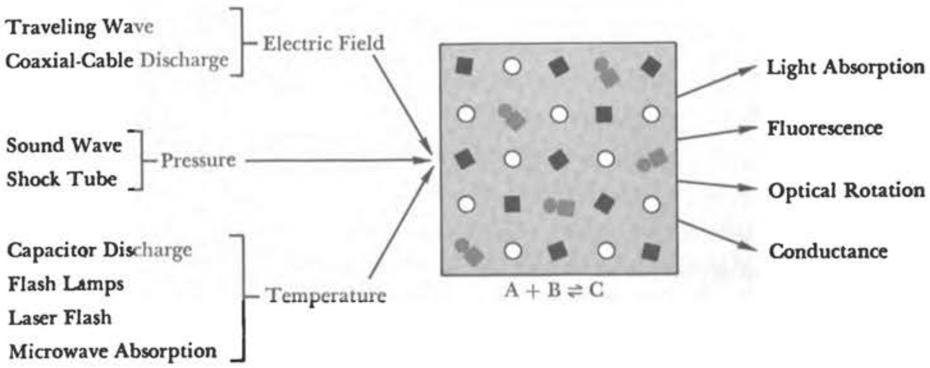


FIGURE 3 In relaxation studies, the equilibrium of a chemical reaction is disturbed by any of several methods and the reaction's return, or relaxation, to equilibrium then observed in various ways.

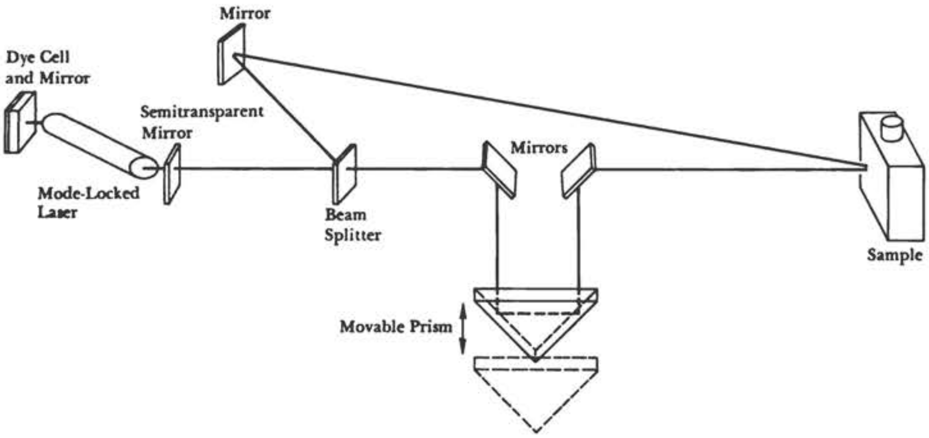


FIGURE 4 An arrangement for a picosecond clock. The pulsed beam from a mode-locked laser is split. By using a movable prism to vary the optical path between laser and sample, one of the split beams is delayed by a calibrated amount.

THE PRIMARY EVENTS OF VISION

Picosecond spectroscopy has been used effectively to study the initial and very rapid photochemical events of vision. We see because light energy is converted into an electrochemical impulse that is then transmitted through neurons to the brain, where signals from all the visual receptors are interpreted. The initial receptor is a pigment called rhodopsin, located in the rods and cones of the retina; it consists of a relatively simple organic compound, retinal (or, in some animal species, a hydrogenated derivative of retinal), in chemical combination with a protein called opsin. George Wald and Ruth Hubbard [11] showed in 1952 that the primary photochemical step in vision is isomerization of the retinal from a *cis* to a *trans* form—a 180° rotation of one of retinal's carbon–carbon double bonds. This change in the shape of the retinal is apparently the signal to opsin to undergo a sequence of thermal or "dark" reactions, one of which is intimately involved in triggering neural excitation.[12]

In what appears to have been the first application of picosecond spectroscopy to a biological system, Rentzepis and his colleagues [13] in 1972 analyzed the mechanism of retinal isomerization by measuring directly the rate of formation and decay of a previously postulated transient intermediate, prelumirhodopsin, formed within 6 picoseconds after the photoexcitation of bovine rhodopsin. The rate of formation found for prelumirhodopsin is so high as to exclude a major structural change from rhodopsin, such as complete geometrical isomerization of the retinal group from a *cis* to *trans* form with concomitant changes in the opsin structure; more probable is a transformation involving only restricted changes in rhodopsin's geometry. However, the thermal decay of prelumirhodopsin, which has a lifetime of about 30 nanoseconds, may involve relaxation to the *trans* isomer. These conclusions are supported by more recent studies of a bacteriorhodopsin [14] containing the same light-absorbing retinal found in vertebrate rhodopsin; here, the photon energy is ultimately converted to chemical energy stored in adenosine triphosphate (ATP).

THE PRIMARY EVENTS OF PHOTOSYNTHESIS

Photosynthesis by plant chloroplasts involves two photosystems and is correspondingly complex. Details of the "dark" reaction—a cycle driven by chemical energy from the "light" reactions stored in triphosphopyridine nucleotide ($TPNH_2$) and adenosine triphosphate (ATP)—were worked out by Melvin Calvin and co-workers at Berkeley, beginning in 1948. Although the "dark" cycle proceeds with surprising rapidity on the scale of ordinary laboratory time, the initiating photochemical processes are far faster and require picosecond measurements for their detailed study.

Photosynthetic bacteria (*Rhodopseudomonas sphaeroides*, in particular) get along with a single photosystem, which has been studied in some detail since 1973 by T. L. Netzel, P. M. Rentzepis, J. S. Leigh, and their associates.[15, 16] A bacteriochlorophyll dimer is the primary electron donor and is bleached within 10 picoseconds after exposure to a laser pulse (wavelength of 530 nm), while simultaneously an electron paramagnetic resonance signal develops indicating the presence of an unpaired electron. However, at the given wavelength, a bacteriopheophytin —a magnesium-free derivative associated with chlorophyll—seems to be the molecule that first absorbs the light radiation. Therefore, energy exchange between bacteriopheophytin and the chlorophyll dimer must be very rapid. The net result of this photochemical process is reduction of an iron–quinone complex, probably the primary electron acceptor.

LIQUID STUDIES

Fast relaxation processes in liquids have also been studied by picosecond spectroscopy. The orientational motions of dye molecules in liquid solutions have been investigated since 1969 by K. B. Eisenthal and his associates.[17]

A picosecond pulse of polarized light preferentially excites those dye molecules having a certain orientation to the plane of polarization. A weak probe pulse then measures how fast these excited molecules return or relax to their original orientations, again with respect to the polarized light field. The times for these orientations are of the order of 10^{-10} second (for rhodamine 6G in methanol) and are proportional to the viscosity of the solution. For large concentrations of dye in highly viscous solvents, the orientational distribution relaxes by way of transfer of energy from excited molecules to neighboring ones; this type of interaction has been studied for rhodamine 6G dissolved in glycerol. Picosecond spectroscopy has extended to nonviscous solvents at room temperature the pioneer work of the Russian school (S. I. Vavilov, V. L. Levshin, and P. P. Feofilov) in viscous media and the Lewis school (G. N. Lewis, D. Lipkin, and myself) in rigid media.

Eisenthal and his associates have also examined the recombination of iodine atoms produced by photodissociation (using a 5-picosecond pulse of a 530-nanometer radiation) of I_2 molecules in carbon tetrachloride or hexadecane.[18] Of particular interest is direct evidence found for the long-postulated Franck–Rabinowitch "cage" effect of the liquid solvent: [19] a tendency for the solvent molecules surrounding a solute to inhibit diffusion. Thus, in the case under study, reassociation of the original partner atoms is favored over random recombination. The strong excitational pulse depopulates most of the original I_2 molecules from their ground state, and their reappearance is monitored by the time dependence of the light absorption from a weaker probe pulse at the same wavelength. Times of 70 picoseconds in hexadecane and 140 picoseconds in carbon tetrachloride were observed for the recombination. Ten thousand pico-

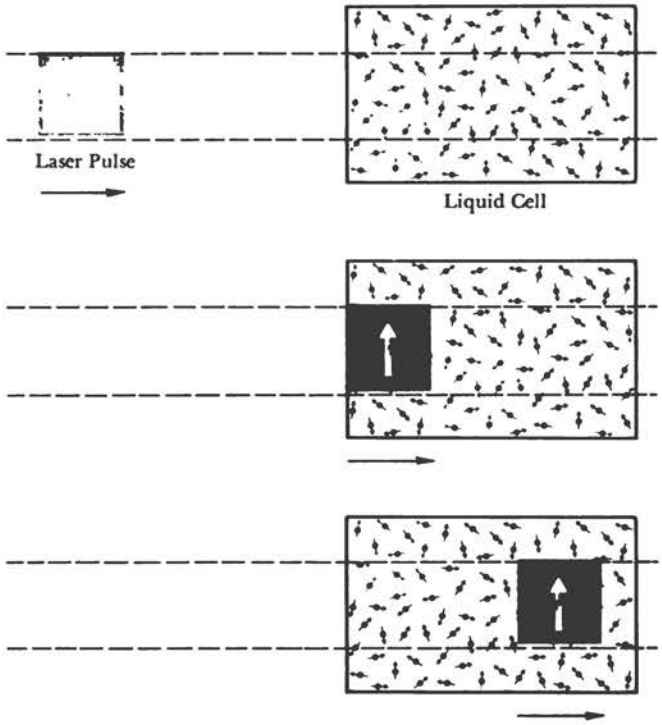


FIGURE 5 A laser pulse can orient liquid molecules in the direction of the pulse's electric field, inducing momentary birefringence. The loss or decay times for this birefringence are characteristic of the liquid.

seconds is the time estimated for recombination of iodine atoms by random diffusional encounters without the cage effect.

In addition, collision-induced predissociation of excited iodine molecules in a liquid was observed for the first time. The phenomenon of predissociation explains the diffuseness of certain band spectra and refers to an event where a bound, excited molecule makes a radiationless transition to another excited state from whence it immediately dissociates. The energy levels at this second excited state are above the dissociation limit, and therefore the spectrum lines are continuous and diffuse. The rate constant for predissociation of iodine molecules in a liquid was found to be 10^5 faster than for spontaneous predissociation of iodine molecules in a low-pressure gas phase.

A problem of considerable interest is the energy relaxation in a liquid of small molecules that are vibrationally, but not electronically, excited. A. Laubereau, D. von der Linde, and W. Kaiser,[20] at the Technical University of Munich, have for the first time measured the relaxation of well-defined molecular vibrations in liquids and have obtained experimental indication of efficient energy transfers between vibrational levels of small molecules in liquids. Laubereau *et al.* have also observed transfer times of vibrational energy from one molecule to another of about 10 picoseconds.[21]

A powerful optical pulse can induce double refraction in liquids whose molecules have anisotropic charge distribution and polarizabilities;[22] that is, the molecules assume a slight orientation in the direction of the electric field (see Figure 5). After the pulse has passed, birefringence decays as the molecules return to the random isotropic orientation. The relaxation time for this effect is characteristic of the substance. Typical values that have been observed are 32 picoseconds for nitrobenzene and 2 picoseconds for carbon disulfide. Optically induced birefringence has been used by M. A. Duguay and J. W. Hansen[23] of Bell Laboratories to design an ultrafast optical gate. A cell containing the liquid is placed between crossed polarizers, which ordinarily block its transmission of light. When an intense light pulse is directed through the cell, the induced birefringence allows a fraction of the gated light to pass through the second polarizer. The shutter opening time is determined by the duration of the exciting pulse and the characteristic orientational relaxation time of the liquid. By using a short pulse to open the gate and short pulses with calibrated time delays as probes, the closing time (the orientational relaxation time) can be directly measured. The light gate itself has found practical application in studying ultrafast processes such as fluorescence of dyes.

PICOSECOND PULSE RADIOLYSIS

In picosecond photochemistry, a pulse of light is used to energize one of the reacting materials. Fast-reacting transient species can also be generated by a pulse of ionizing radiation, such as electrons accelerated to high energies (10 to 50 million electron volts). A technique for using pulse radiolysis to study fast processes was first demonstrated by J. W. Hunt and his colleagues [24] at the University of Toronto in 1970 and has been further developed at Argonne National Laboratory [25] and the University of Notre Dame.[26] Pulses of about 30 picoseconds have been used in typical experiments. Decay of the reacting species generated is observed by a stroboscopic method based on the light pulse induced by the electron pulse as it traverses a suitable medium (Cerenkov radiation). The Argonne investigators use xenon gas contained within a separate cell located between the incident electron beam and the irradiation cell containing the sample. The light pulse, of the same duration as the electron pulse, enters the irradiation cell by a path of controlled, variable length so that it can reach the cell before or various times after the electron pulse. That time is known to within an uncertainty of less than the pulse width (30 picoseconds).

Whereas in flash photolysis the energized reactant is formed from a specific constituent absorbing the light—for example, chlorophyll in the initiation of photosynthesis—pulse radiolysis is less discriminating: The reactant is formed primarily from the constituent present in highest concentration, which in a liquid solution is generally the solvent. For water the result is surprisingly simple: A pulse of ionizing radiation produces within less than a picosecond almost exclusively OH radical, H^+ ion (as H_3O^+ and higher solvated species), and e_{aq}^-, the hydrated electron. If scavengers are used to convert two of these products to inactive states (this can be accomplished within 100 picoseconds), the reactions of the remaining product can be studied almost exclusively. The concentration of hydrated electrons is particularly susceptible to measurement in this way because of their strong absorption in the red region of the visible spectrum (at 720 nanometers).

Among the effects detected by the Argonne investigators is a change in the rate "constant" for fast, diffusion-controlled reactions of the hydrated electron with changing concentration of selected reactants.[27] This result can be understood in terms of the life cycle of the hydrated electron.

Pulse radiolysis studies in a number of liquids have given information about the reactivity of the electron before solvation and about the solvation process itself.[28] Such fast reactions are not just a laboratory curiosity and may be important in the initiation of radiation damage in biological systems. J. W. Hunt and his collaborators [29] have been studying the reactions of hydrated electrons with a broad range of biologically important molecules, including amino acids and nucleotides. The Argonne investigators have studied the rate of the biologically important reaction of the hydrated electron with ferric ion. In sum, pulse radiolysis offers promise for the study of a great variety of fast chemical processes hitherto inaccessible to direct observation.

Much of the research to date on the picosecond time scale has involved the process of absorption and emission of radiation. This is the work of the chemical physicist. It is necessary to understand these primary processes before one can understand the subsequent chemical events. The further development of chemistry in a jiffy will most certainly await the inorganic and organic chemists. It was these chemists who thoroughly explored and exploited the chemistry of the triplet state discovered 30 years ago by Gilbert N. Lewis and Michael Kasha.

FEMTOSECOND SPECTROSCOPY

But even before chemistry in a jiffy is further explored, we may ask: Why stop at a jiffy? Why not venture on to the "millijiffy" or to the femtosecond (10^{-15}) range? One apparent obstacle is that on a femtosecond time scale the limits in energy measurements imposed by the Heisenberg uncertainty principle approach the spacing of vibrational energies in molecules and energy changes in chemical reactions, so any measurements would be negated by their uncertainties. But useful information may still be extracted from femtosecond measurements, for the broadening of signals of femtosecond duration may yield information on new classes of chemical reactions, much in the same way that broadening of resonance signals has provided information on conformational changes in molecules.

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Study Projects

ASSEMBLY OF MATHEMATICAL AND PHYSICAL SCIENCES

GEODESY

The first geodetic triumph is credited to Eratosthenes of Alexandria who, assuming a spherical earth, computed its circumference using three measurements: the time of day the sun shone directly into a well in Syene (now Aswan), the angle of the sun at the same time in Alexandria, and the distance from Syene to Alexandria, allegedly estimated by the time it took a camel moving an average speed to cover the distance. While scholars dispute the matter, Eratosthenes' figure may have come to within 1 percent of the length as now measured with the most refined instruments and methods.

"This was really a fine achievement," according to the British geodesist Desmond King-Hele, "a correct concept being followed by the correct observations, and with great economy of effort if he did use camels instead of stretching tape measures across the desert." •

Perhaps inspired by Eratosthenes' work, geodesy—the name classi-

• Desmond King-Hele. 1976. The shape of the earth. Science 192(4246):1293.

cally means partitioning or dividing the earth and refers to the science of measuring the earth—has made momentous contributions, particularly in the last 2 centuries. It has provided the coordinates (latitude and longitude) of points—horizontal and vertical controls—to serve its major customers, mapmakers and surveyors. The triangulation of India—triangulation being the geodetic technique of determining positions by measuring angles and distances and then computing positions trigonometrically—led to a theory of isostasy; that, most simply, continents of lower density rest on heavier basement rock and that, therefore, the weight of a mountain mass is compensated by a low-density continental root penetrating into the denser, subcontinental rock. Estimates of the viscosity of the earth came from geodetic observations of the uplift of Fennoscandia, the geological area taking in Finland, Sweden, Norway, and Denmark. And an early proponent of continental drift, Alfred Wegener, first inferred the qualitative difference between continents and oceans on the basis of gravity measurements taken by geodesists.

Eratosthenes used an object in space, the sun, for his measurement of the earth's circumference. Similarly, the expanse of modern-day geodesy has been widened enormously by the use of artificial satellites. Changes in the orbit of rotation for Sputnik II were used in 1958 to revise the figure for the flattening of the earth. The first geodetic satellite, Anna-1B, launched in October 1962, carried optical and radio instrumentation for triangulation measurements. From 1964 to 1969, the Secor satellite series was used to fix locations with remarkable accuracy. The most recent geodetic satellite is Lageos, launched May 1976, which is intended, with its extremely heavy weight and small size, to approximate a drag-free satellite, and has the goal of refining measurements of the earth's gravitational field.

These and other satellites have been used in two ways: geometrically, as beacons of known location for triangulation measurements, and dynamically, with their changes in orbit used to infer variation in the earth's gravity field. The goal for these two approaches is the same: to refine the shape of the geoid, the equipotential surface that is adopted as the "figure of the Earth." The geoid is the surface the seas would maintain if not subjected to the tidal attraction of the sun or moon, atmospheric disturbances, variations in water salinity, and the circulatory patterns of the oceans. It is also, in an imaginative sense, the surface to which water would flow in a network of canals cut through and across the continents. The geoid is the basic reference frame on which all geodetic measurements eventually depend. It is not a perfect form when compared to its mathematical approximation as an ellipsoid of revolution, but is rather quite irregular, distorted by the gravitational effects of topography and irregular mass distributions. There is, for example, "a hollow in the Indian Ocean and a hump near New Guinea," * when one compares the geoid with the ellipsoid.

With recent refinements in geodetic measurements and data, the geodetic network for North America was found to be inadequate; and a new adjustment of the horizontal controls—the precise location of over one-half million points—for the North American continent is now in progress. This adjustment was first urged in 1971 by the National Academy of Sciences and is being done by the National Geodetic Survey, with the cooperation and involvement of Mexico, the Central American republics, Canada, and Denmark (since it governs Greenland). The project will cost some $16 million by the time it is completed in 1983.

NEW TECHNIQUES

The satellites themselves and the ability—with cameras, kinetheodilites, and other orbital and radio methods—to track their positions and orbital changes have been the primary geodetic instruments of the last decade.

For example, laser tracking has refined distance measurements between widely separated points to errors in the centimeter range. The technique depends on the accurate measurement, to the billionth of a second, of the time it takes a laser beam to travel to a distant object, whether corner-cube reflectors of a satellite or the reflectors placed on the moon by the astronauts. Other techniques that have expanded the geodetic values of satellites include radio doppler methods, applied to locating positions on the earth's surface and to measuring polar motions; very long-baseline interferometry, used, as has laser tracking, for global geophysical investigations relating to plate tectonics, polar motion, and the earth's rotation; and satellite altimetry, for measuring a satellite's height over the ocean, refining surface measurements, and therefore giving another view of the shape of the geoid.

* *Ibid.*, p. 1298.

Above: Astrolabe, a surveying instrument for establishing astronomical position.

Below: Theodolite, a surveying instrument for measuring horizontal and vertical angles.

New space techniques are emerging, for example, satellite-to-satellite tracking, tested on the Apollo–Soyuz flight and applicable to determining by doppler methods the change in the gravitational field in the space separating the satellites.

Although the space systems have provided the major impetus to geodetic science, the improvement in ground-based laser distance-measuring instruments, in photogrammetric techniques, and in marine geodesy must not be overlooked. The latter is an area of increasing concern as nations move farther and farther out to sea in the search for resources, disposal sites, and offshore installation sites.

But while geodetic science is obviously alive and healthy, the discipline apparently is not. As a geodesist has pointed out,

[T]he phenomenal geodetic fallout from the space program has so obscured the place of the surveyor in the geodetic scheme of things that there is a tendency to downgrade his vital contributions to the science. Hence, more and more the average surveyor finds himself outside the mainstream, relegated to a supporting role as provider of cadastral and lower-order engineering data.*

The problems extend beyond the surveyor, and to the very health of the science, as illustrated by increased difficulty in gaining funding and a lack of students interested in geodesy *per se*. Part of the difficulty may be the proliferation of geodetic research and development among mathematicians, physicists, optical and radio astronomers, space scientists, and even lawyers, each group seeking geodetic information for its own purposes. While geodesists were alert to these new developments, the result is still a discipline that is weak at a time when its potential for significant and necessary advances is being recognized. "The geodesist finds that among many applications he can support the oceanographer in resolving ocean surface problems; the tectonophysicist and the seismologist in measuring continental drift and crustal movement; and the astronomer in determining polar motion and variations in earth rotation."†

Refinement of geodetic data—of gravitational fields and of horizontal and vertical controls, particularly for poorly or nonsurveyed areas such as the oceans—will inevitably have considerable impact. As Desmond King-Hele has pointed out, an

> exact knowledge of the gravitational field . . . will provide a crucial test of the theories about the earth's interior; already the map of tectonic plates has resemblances to the geoid maps. In [the] future, patterns of convection currents or density irregularities within the earth will have to be fitted together to satisfy the observed gravitational field. Together with the satellite altimeter measurements, the gravitational field determinations will give an accurate profile of the geoid surface, including earth tides and ocean tides, which cannot fail to be of great benefit to oceanographers, whose present knowledge of the ocean tides has serious deficiencies.‡

Measurements of polar motions and of changes in the earth's rotation rate may clear up geological puzzles. King-Hele writes that,

> The twitches in the earth's rotation expressed by the polar motions and changes in the earth's rate of rotation may themselves be a source of geophysical events because they make the earth throw its enormous weight around jerkily, perhaps

* Hyman Orlin. 1972. The surveyor geodesist. Trans. Am. Geophys. Union 53(4):295.
† *Ibid.*, p. 295.
‡ King-Hele, p. 1299.

triggering movements of the tectonic plates. The earth is a self-exciting earthquake generator, and it looks as though satellite geodesy may in the end offer the key to the origins of the excitement.*

In the last decade, geodesy has transcended its traditional role as supporter of the land surveyor, the cartographer, and the navigator. These groups remain the prime users of geodetic information, but customers now also include those interested in the precise location of space vehicles, the mapping of bodies in the solar system, and the time-varying aspects of geodetic data—information essential to the modeling or forecasting of horizontal and vertical crustal motions.

Serving this new clientele requires that the training of geodesists be expanded from the classical concentration in mathematics and engineering to geophysics, celestial mechanics, seismology, space and ocean sciences, photogrammetry, and related fields. With these expanded capabilities, the geodesist can help solve problems related to the dynamic aspects of the earth and the entire solar system.

Generally, major geodetic problems to be confronted are divisible into three categories:

- *Geodetic Networks*—maintenance of geodetic control networks—horizontal, vertical, and three-dimensional reference frameworks—for the earth, moon, and planets, including allowance for the changes with time in these frameworks
- *Geodynamics*—the measurement and representation of geodynamic phenomena such as polar motion, earth tides, and horizontal and vertical crustal motion
- *Gravity Fields*—determination of the internal and external gravity fields of the earth, moon, and planets, and their temporal variations

The new NRC Committee on Geodesy will explore these possibilities, including the status of the disciplines. Its particular tasks will be to

- Review scientific and technological advances (such as long-baseline interferometry, satellite altimetry, lunar ranging, satellite navigational systems) to determine when transfer and application is practical

* *Ibid.*

- Identify geodetic research opportunities afforded by new spaceborne instrumentation
- Explore possibilities for achieving more precise horizontal and vertical geodetic control for the oceans
- Review educational opportunities in geodesy and surveying
- Examine the need for a National Plane Coordinate Reference System for mapping, data banks, and property descriptions and for the creation of an official national register of U.S. land as land-use management becomes increasingly necessary
- Review the status of current work in plane surveying and mapping, recommending actions needed to improve its significance with respect to science, technology, and society
- Review the status of current work on traditional geodesy and recommend action to complement the work; included in the review will be the overall need of society for geodetic information and the need for a readjustment of the vertical control network to complement the ongoing readjustment of the horizontal control network
- Provide a Senior Scientist Grants in Geodesy Program under which applicants will be selected by the Committee to undertake specific assignments acceptable to participating agencies for varying periods of from 3 months to 1 year, with the objective being to attract the highest level of talent for research on specific geodetic problems

Committee on Geodesy, Assembly of Mathematical and Physical Sciences. Committee Chairman, William M. Kaula of the University of California at Los Angeles; Staff Officer, Hyman Orlin.

EMERGING

"It is a long dreary winter down here, out of touch with other laboratories and so forth. . . . I think it would be difficult to keep men in Woods Hole for the winter." * The issue was the siting of a new oceanographic institution at Woods Hole, Massachusetts, and the setting was a meeting in August 1928 of members of the newly appointed Committee on Oceanography of the National Academy of Sciences. There were, of course, defenders of Woods Hole: "We are within two hours of the center of light and learning in the United States . . . the eel pond would make an ideal landing place for aeroplanes."

No decision was made, and the Committee—agreeing that a new oceanographic institution should be created, but disagreeing on the site, and aware that some $3 million in initial funding was available from the Rockefeller Foundation—elected to commission a thorough study of the matter. Henry B. Bigelow, the curator of oceanography at the Museum of Comparative Zoology at Harvard University, was asked to prepare the report. Bigelow agreed that Woods Hole "has obvious advantages educationally, but it is a little inaccessible to the deep seas. You have here a miserable harbor with a current running through it like a train of cars. . . ."

Bigelow's effort resulted in the issuance in October 1929 by the NAS Committee on Oceanography of its *Report on the Scope, Problems, and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies.* The report itself is a remarkable document, crisply written and offering a *tour d'horizon*, if not a course, of contemporary oceanography. Bigelow possibly set a model for future reports of its kind by first offering a general argument on largely scientific grounds and then resorting to quite practical matters to particularize it. Thus:

> It may be stated without further argument that the sector from Cape Cod to Halifax, Nova Scotia offers geographic advantages for such an institution that not only make it the logical choice on the American coastline, but which are

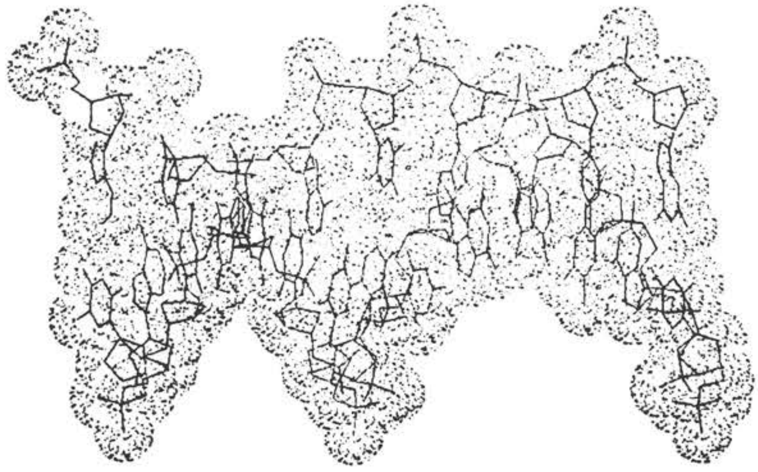
* This quote and two following are taken from: Susan Schlee. 1973. Real men won't winter on Cape Cod—A bit of unofficial W.H.O.I. history. Woods Hole Notes 5(2):2. Published for the Associates of the Woods Hole Oceanographic Institution.

unique for their general illustrative value. This results from the topography of the coastline and of the neighboring parts of the continental shelf, as well as from the fact that in only one other region (around the Grand Banks of Newfoundland) is so sudden transition to be met from cold coastal waters on the one hand, to tropical oceanic on the other, or as great a contrast to be found as along the edge of this sector of the North American continent [p. 158]. . . . The fact that the Marine Biological Laboratory and the Laboratory of the United States Bureau of Fisheries are already located at Woods Hole is strong argument for also locating the proposed institution there. And the great and obvious advantages of close association with these centers of scientific activity seems to us to outweigh the objection to Woods Hole as the site, that might be urged on the score of distance from the open sea, and of isolation in winter [p. 159].

Subsequent to the publication of the report, the Committee on Oceanography became the board of trustees for the nascent Woods Hole Oceanographic Institution, the Rockefeller Foundation indeed did provide initiating funds, and Henry Bigelow was elected the Institution's first director.

That pattern—the Academy serving as a home for converging views agreeing on a goal but not on the maximal routes to it—has been repeated many times and is indeed one of the purposes of the Academy, acting through the National Research Council. For example, a report issued in 1958 by a committee chaired by the late Lloyd V. Berkner and entitled ***Research and Education in Meteorology*** spurred the establishment of the National Center for Atmospheric Research.

Lamenting that "it is a sad commentary on the intellectual maturity of our generation that it is necessary to emphasize the fact that the problems of meterology are scientific problems," the Berkner committee followed Bigelow's example of first making clear the scientific underpinnings for its principal recommendation by assessing "meterological problems of current and potential importance." The committee argued its belief that "[m]ore is required than simple strengthening of institutions," and recommended that a "National Institute of Atmospheric Research should be established." Such an Institute "could serve as the magnet to draw in the outside manpower that will be needed to make the order of magnitude increase in our present research effort, which we believe to be necessary."



DNA, simulated space-filling model of a single turn of the double helix.

More contemporaneous, and offering an example of NRC involvement in aiding the creation of a quite different "institution," was the recommendation of a 1969 report of NRC's Space Science Board for a landing mission to Mars, with its central purpose "to determine the near-surface environment of the planet and, if possible, to determine whether biological activity is present."

These institutional incubation efforts go on. In the summer of 1976, two groups of scientists met in successive weeks at the National Academy of Sciences' Summer Study Center in Woods Hole, one to consider possible scientific work for a proposed National Resource for Computation in Chemistry and the other to recommend an institutional structure for managing the scientific work associated with the Large Space Telescope.

COMPUTATION IN CHEMISTRY

"The whole of chemistry, and with it crystallography, would become a branch of mathematical analysis which, like astronomy, taking its constants from observation, would enable us to predict the character of any new compound." * That comment by Charles Babbage, an English

* Quoted in S. H. Hollingdale and G. C. Tootill. 1975. Electronic Computers. Penguin Books, Baltimore, p. 261.

mathematician whose calculating machines embodied the basic principles of today's electronic computers, was given a modern gloss by P. A. M. Dirac, one of the seminal contributors to the maturation of quantum mechanics. Dirac asserted that with the development of quantum mechanics, all of the problems of chemistry have been solved, in principle.

The operative phrase is "in principle," for aside from the hydrogen and helium atoms—i.e., systems with no more than two electrons—calculations of the energy distribution and electron structures of atoms and molecules are still necessarily semiquantitative, based on various simplifying approximations. The principal stumbling block is that even for very simple structures an immense number of variables must be entered into the differential equations provided by the wave mechanics of Erwin Schrodinger to calculate chemical properties and structure; thus, calculations on a three-atom molecule would require 250 hours on the largest and most powerful computers now extant, a requirement not now granted to researchers.

This is not to gainsay the already impressive accomplishments of theoretical chemistry—"the interpretation of chemistry in terms of the principles of nuclear, atomic and molecular physics." * Perhaps its most telling contribution is its ability on occasion to predict the likely outcome (or outcomes) of an experiment without the experiment actually being done. Thus, theoretical chemistry is of help in analyzing molecular events occurring under conditions of temperature and pressure so extreme they prohibit direct measurement. An example "is the theory of flames, shock waves, and explosions, which requires prediction of diffusion and heat conduction in complex gas mixtures. Theoretical chemists have become adept at this task, and in working at it they acquire information about intermolecular forces, chemical-reaction rates, and molecular structures of species (molecules, free radicals, and ions) not readily observable under less extreme conditions." †

A purely theoretical approach to chemistry, while having already proven its value, remains somewhat of an anomaly in what is still largely an experimental science; and so the philosophical barriers that can divide

* Chemistry: Opportunities and Needs. 1965. National Academy of Sciences–National Research Council, Washington, D.C., p. 73.
† *Ibid.*, p. 74.

experimentalist from theoretician are at times quite palpable. But a number of apparent needs are lowering the barriers. For one, several specific interests—in lasers; in photochemical reactions of atmospheric pollutants; and in solar energy, both its conversion and storage; as well as recent experimental results [cf. Jacob Bigeleisen, pp. 99–112 of this report] on fundamental photochemical and photophysical processes such as photosynthesis and vision—now make it imperative to understand the properties of molecules and atoms in excited states, that is, where electrons are not all in the ground or most stable configuration, but rather have been raised to higher energy levels. The nature of these excited species is poorly understood. They are not easy to study experimentally, and theoretical calculations are difficult and very demanding of computational time and power. But theoretical approaches do offer considerable potential for increased understanding, particularly in estimating and analyzing the possible interactions that excited species may undergo under various conditions. Related to this—and of fundamental necessity to both quantum chemistry and statistical mechanics (one science treating atoms and molecules individually, the other *en masse*)—is the calculation of potential energy functions. These are, most simply, the changes in energy states of incipiently reacting molecules as they approach each other from all possible directions and with all possible orientations; in effect, the detailing of the continual changes in chemical reaction surfaces as the reaction begins and occurs. The calculation of potential energy surface is necesary to fundamental advances in chemical science—for example, in analyzing the chemical bonding process and in predicting binding energies. A quantum chemist, Arnold C. Wahl, illustrated the possibilities by noting that these and similar calculations can make it possible

> to explore fully the changes in the energy and electron distribution as the hydrogen and oxygen molecules approach each other from different angles and pass through a series of intermediate steps to yield the stable water molecule. It is perhaps in this respect of being able to explore slowly and visually a complicated chemical process in terms of both its quantitative features and its conceptual features that such computer experiments offer their most informative potential.*

* Arnold C. Wahl. 1970. Chemistry by computer. Sci. Am. 222(4):63.

These and other possibilities—improved resolution of crystal structures, better understanding of the behavior of macromolecules, more reliable interpretations of spectra—motivated 50 scientists to spend several summer days in a converted garage in Woods Hole debating an illustrative scientific program for the proposed National Resource for Computation in Chemistry (NRCC).

The catholicity of the group—it included not only theoretical chemists adept in quantum mechanics and statistical mechanics, but also physical organic chemists, crystallographers, kineticists, macromolecular scientists and computer scientists—emphasized that the scientific scope of the Resource had broadened considerably from its earlier conception as a facility for theoretical chemistry,* especially quantum chemistry. Previous studies had defined the rationale † for the Resource and suggested an institutional structure ‡ for managing its scientific program. In essence, the facility is to be a

> . . . centralized Resource serving the community by making available the potential to be derived from systematic collaborative attention to software development, documentation, and improvements in computational procedures as applied to chemistry, as well as by making available the benefits of increased computational hardware. . . . The availability of a human resource of computer scientists and chemists working together will permit the documentation, testing, and improvement of existing programs; the development of more efficient algorithms; the generalization of computer programs for recurring chemical problems; the development of new computational methods; the design of specialized hardware, software, and languages particularly suited to use by the chemical community; and the establishment and updating of important data bases.§

The scientists meeting at Woods Hole, while setting forth work to be done with NRCC pertinent to their own subdisciplines,|| did uniformly

* Computational Support for Theoretical Chemistry. 1971. National Academy of Sciences, Washington, D.C.

† A Study of a National Center for Computation in Chemistry. 1974. National Academy of Sciences, Washington, D.C.

‡ The Proposed National Resource for Computation in Chemistry: A User-Oriented Facility. 1975. National Academy of Sciences, Washington, D.C.

§ *Ibid.*, pp. 1–2.

|| The participants were split into seven groups, each charged with producing a menu: chemical kinetics, crystallography, macromolecular science, nonnumerical methods, physical organic chemistry, quantum chemistry, and statistical mechanics.

agree on the need for service functions—aid in writing computer codes or programming directions, verification of the reliability of existing codes, and, in general, assistance to chemists expert in their disciplines but not in the state-of-the-art subtleties of applying computers to important problems in chemistry.

The full results of the meeting have been published,* but a selective sampling of some of the suggestions made should underline the potential importance to chemistry of the computational facility.

For example, macromolecular science—the science of polymers, proteins, nucleic acids, and similar large molecules—saw NRCC as an aid to probing the behavior of macromolecules in solution, particularly concentrated solutions. How do two macromolecules interact with each other in such solutions? What occurs within a single molecule? Or between macromolecules and solvent?

Biology is clearly involved in these questions. Further, the binding process between large and small molecules is of pertinence to understanding antibody–antigen reactions. Calculations of the electronic ground states for proteins in various solutions is a critical need and computationally possible, given access to very large computers. How proteins and polynucleotides unfold and reform is also a problem open to computational approaches. And the most likely route for the assembly of a protein can be similarly traced, likely here meaning the reaction pathway of lowest energy. Moving further into complexities, how do proteins and other large molecules assemble into membranes—information needed to analyze ion transport through cellular membranes? Or how do proteins and ribonucleic acid molecules assemble into ribosomes, the cellular organelles where protein synthesis occurs?

Improved access to computer power and corollary services is expected to assist physical organic chemistry in studying the effects of solvents on rates of reactions, the reactions of excited molecules, and the mechanisms of homogeneous and heterogeneous catalysis, as well as the fitting of experimental data—particularly as regards complex coupled reactions that occur in biology and the environment—to reaction rate expressions. Computers can be used to enhance the already considerable powers of

* Needs and Opportunities for the National Resource for Computation in Chemistry. 1976. National Academy of Sciences, Washington, D.C.

various spectroscopies applied to analyzing the structure of molecules and their reactions—nuclear magnetic resonance, raman, infrared, and so on. As an example, computers can be used to obtain mechanistic details from nuclear magnetic spectra of rapid reactions. Hand or desk calculators are useful in analyzing a number of relatively simple reactions. On-line, high-speed digital computers have extended the capability of high-resolution NMR spectrometers to determining the structures and reactivity of large, biologically important molecules.

The computational needs of quantum chemists goaded the development of NRCC, and predictably quantum chemistry offered a wide-ranging ambitious scientific program as its contribution to NRCC planning. Most simply, the goal of quantum chemistry—and statistical mechanics—is to predict the outcome of an experiment before it is done. That is in effect already possible, but to a limited extent and with reliance on semiquantitative approximations. Theoretical approaches in chemistry can be used to obtain reliable information that simply cannot be gotten experimentally and to unify existing data into a comprehensible pattern.

An essential scientific goal for quantum chemistry is to obtain potential energy surfaces for small molecules as an aid to understanding reaction rates and dynamics and to interpreting spectra. Such information is needed for significant progress in fields such as atmospheric and environmental chemistry, astrochemistry, photochemistry, and combustion chemistry.

Statistical mechanics is in good part concerned with the bulk properties of matter—viscosities, conductivities, diffusion rates, and so on. It has been quite successful in examining the structure and properties of dilute gases and is making headway in similar efforts on dense gases, liquids, and solids. Much of statistical mechanics is directly dependent on quantum mechanical calculations, including the determination of potential energy surfaces. The science can aid in interpreting spectra and solvent and isotope effects and can be used to compare and correlate the results of nominally quite different experiments. NRCC can support and extend this work and can also spur the analysis of the rich trove of information on molecular motions within solids and liquids—molecular dynamics—provided by different techniques such as neutron and light-scattering spectroscopy, infrared absorption, electron spin resonance, and nuclear magnetic resonance. Molecular dynamics is "interpretation-limited," not "equipment-limited," and the problem is to extract from a wealth of data an understanding of the relevancy of molecular dynamics to the properties and structures of different materials. Computer simulations of molecular motions can aid in interpreting existing data, in designing future experiments, and in simplifying otherwise difficult experiments. As an example of the latter, a judicious combining of actual and computer-simulated experiments can be used to acquire information over a larger range of densities, pressures, and temperatures than possible by experimentation alone.

These ideas are again only illustrations of what NRCC can do, not necessarily what it will do. The latter will depend on the needs of the

Artist's conception of Large-Space Telescope.

community, as evinced by the quality of proposals and by judgments of the scientific management of NRCC. However, a project first spawned in 1965 has moved through a difficult process of analyses, criticism, and review by committees of the National Research Council, the Committee on Science and Public Policy of the National Academy of Sciences, members of the chemical community, and pertinent agencies of the federal government, including the National Science Foundation and its National Science Board and the Energy Research and Development Administration. The NRCC has been given a possible structure and has been provided with examples of its initial activities. It is now coming to life: Funds for starting the first phase of NRCC—a 3-year period with a projected budget ranging from $1.3 million in the first year to $2.4 million in the third year—are anticipated, to be provided by NSF in collaboration with ERDA. Proposals to serve as a site have been received from several national laboratories. The facility will begin operation in fiscal year 1977.

THE LARGE SPACE TELESCOPE

The scientists planning chemistry's first venture into "big science" and a partial relinquishing—albeit tenuous—of its cottage industry mode were immediately succeeded at the Woods Hole Study Center by a group concerned with institutional arrangements for the Large Space Telescope (LST). The problems for the LST group were the reverse of those of the NRCC group: The scientific uses of the LST having long been agreed upon,* the problem was now to recommend a structure for its scientific management.

The meeting at Woods Hole was chaired by Donald F. Hornig, a physical chemist, former presidential science advisor and former President of Brown University. Since management, not science, was the theme, the attendees included those versed not only in the uses of optical telescopes but also in the management of large, scientific institutions and projects—the Smithsonian Astrophysical Observatory, the National Center for Atmospheric Research, and so on.†

* See Scientific Uses of the Large Space Telescope. 1969. National Academy of Sciences, Washington, D.C.

† The results of this workshop have been published as Institutional Arrangements for the Space Telescope. 1976. National Research Council, Washington, D.C.

The value of the large space telescope, of course, is that its view is not shuttered by the earth's atmosphere—no spectral absorptions by the atmosphere, thus enabling observation from the ultraviolet to the infrared; no atmospheric blurring; little or no diffusion of light by the night sky. The space telescope will see objects 100 times fainter and 10 times more distant than can be seen by telescopes on the ground. As remarked in an early report on the telescope's potential,

> [m]any astronomers believe that at least the most basic first-order cosmological questions are currently [1969] being answered by ground-based radio and optical studies, especially those using the immense power of the 200-in. telescope. There is strong evidence . . . for this point of view . . . [b]ut the resolution limits set by the earth's atmosphere appear to be well short of permitting ground-based study of details of relatively normal objects and processess in the range . . . where effects of space curvature and of the early history of the universe become pronounced. Indeed, these studies of detail will utilize the resolving power and limiting magnitude of the LST to the very limit. But its ability to achieve more than 100 times the angular information density, and to detect and measure stars and starlike objects at nearly ten times the distance, should prove invaluable for markedly extending the accuracy of the ground-based cosmological studies. If historical experience is a reliable guide, the LST will reveal both unexpected modifications required in our picture and radically new kinds of objects in the universe.*

The report of the 1976 meeting in Woods Hole also commented that

> [e]xtension of observations into the ultraviolet region, where most of the chemical elements have their characteristic spectral signatures, will permit analysis of objects that are hotter than those studied from the ground at optical wavelengths. Similarly, extension into the infrared region, where most molecules have their signatures, will permit analysis of much cooler objects, such as planets and interstellar clouds.†

Viewing astronomical details at a greater distance and with greater resolution of the optical information across the entire spectral range should enable

- Studies of the spatial structures of quasars, including analyses of their spectra and their surroundings

* Scientific Uses of the Large Space Telescope, p. 18.

† Institutional Arrangements for the Space Telescope, p. 5.

• Studies on the structure of galaxies of different ages, enlarging the story of the evolution of galaxies and providing clues to the relationships, if any, of galaxies to quasars

• The clarification of the evolutionary histories of the stars, particularly in their later stages, through observations of the main-sequence stars in the Magellanic clouds

Cosmology will benefit from the LST's ability to peer into the very early history of galaxies. For example,

> the possibility of extending the absolute distance scale ten times further out than is presently attainable means that we shall be able to attack with entirely new precision the classical cosmological problem . . . of defining and tracking back in time the expansion of the universe. The high resolution of the LST will enable such studies to be pushed to greater distance and with greater precision. We can address such questions as: How fast is the expansion decelerating? Is this deceleration uniform in space and time? What is the mean density of matter in the universe that produces this deceleration? How is the matter distributed? What will be the fate of the universe—expansion forever or an eventual collapse into another "primordial fireball" followed by rebirth and eternal recycling?*

That orbiting telescopes do indeed satisfy expectations has already been demonstrated by the orbiting by the National Aeronautics and Space Administration of several smaller space telescopes, with a maximum aperture of 1 meter *vis-à-vis* the 2.4 meters planned for the large space telescope.

The LST—along with other instruments designed to enhance its uses and powers—will be part of a space shuttle payload, perhaps orbited in 1983. It will be deployed from the shuttle, escorted and checked out for several days, and then operated remotely from the ground, with occasional maintenance and servicing from a shuttle flyby, or, if extensive repairs are needed, by a return to earth. Its pointing accuracy should be within 1 second of arc, its lifetime about 10 years or more, and its yield of data enormous. It is in fact the latter result that may in time pose substantial institutional problems; that is, assuring the capability of the

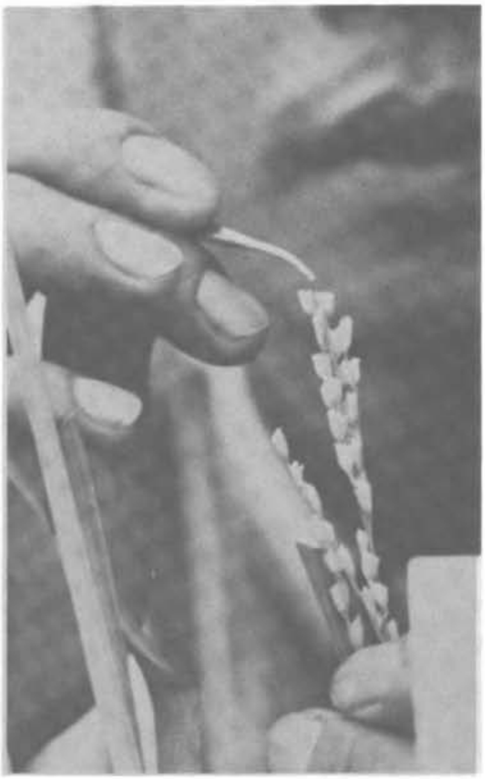
* An International Discussion of Space Observatories. 1976. Report of a Conference at Williamsburg, Va., 26–29 January 1976. National Academy of Sciences–European Science Foundation, p. 6.

institutional management, in whatever form, to receive the data, store it, and then provide it to scientific investigators so that the data can be transformed into information and then into theories and facts about the nature of our universe.

Workshop on a National Resource for Computation in Chemistry, Assembly of Mathematical and Physical Sciences. Chairman of Planning Committee, Jacob Bigeleisen of the University of Rochester; Staff Officer, William Spindel. Workshop on Institutional Arrangements for the Space Telescope, Assembly of Mathematical and Physical Sciences. Workshop Chairman, Donald F. Hornig of Harvard University; Staff Officer, Milton W. Rosen.

NGC 891 spiral galaxy in Andromeda, seen edge on.

Commission on International Relations



Global Relations of the National Research Council

GEORGE S. HAMMOND

The considerable scientific accomplishments of the United States have had a major impact on the rest of the world. Much of our economic strength is derived from the successful use of agricultural and industrial technology, itself largely derived from scientific research. While the United States no longer dominates world technology as it did 25 years ago, it still makes the largest contribution of any country to the global diffusion of technology. That fact implies immense influence and power. It also implies that in this time of changes—in foreign and domestic policy objectives, in the needs and hopes of other countries, and in waning or static global resources for scientific research—American institutions concerned with international scientific and technological matters must look to the concepts that underlie their programs and determine their most urgent goals. Such an effort to evaluate conceptual premises and principal objectives has been started by the Commission on International Relations of the National Research Council.

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PREMISES

International Communication and Cooperation in Science

The Commission is continually attempting to analyze change in science and its social settings and, where necessary, suggest ways of responding to change. For example, for the next several years, there may be little or no increase in the support of science and scientists. Worldwide, this will create difficult problems, which may be ameliorated by consultation among academies of science and engineering. Stable or even declining research support has already stirred a keen interest in collaborative efforts. The Commission is now examining how to best prod international programs of collaboration along productive paths.

The scientific community will be challenged continually to be more frugal by traveling less, by guarding against excessive redundancy in research within and between countries, by purchasing less equipment, and by husbanding resources. These constraints may force scientists to become more insulated within national boundaries—a thoroughly undesirable consequence. At the same time, the Commission is not convinced that money spent on the international aspects of science is always put to uses that are fruitful in generating and dispersing new science, given the heavily political motivations for conducting many international programs. While the Commission does not denigrate political motives, it does believe that scientists should monitor and attempt to maximize the scientific value of international programs.

Technology versus Science?

International relations in regard to technology differ from those of science. Although high technology is largely a product of science, the characteristics of the two differ markedly. People create a technology by choosing ways of making natural phenomena work for them. Consequently, there is no automatic universality of technology as there is in science. "Standard" technologies do develop for various reasons, although it is not at all obvious that this is thoroughly desirable. There is often considerable motivation to keep secret some of the concepts that underlie a particular technology. And technology, unlike science, may be treated as a private, or even national, property, albeit not as successfully as some would like to believe.

But even with these deep differences between technology and science, it is not easy to clearly separate science and technology in our thoughts and actions; indeed, "science and technology" has almost become a single substantive. There is no simple way to delineate between scientific research and technological development, as evidenced by the words "pure and applied" in the titles of two of the largest and most prestigious scientific unions—those of physics and chemistry. And, very often, what people really want from scientific exchanges is access to technology.

The Commission is committed to reducing complexities that often lead to confusion, frustration, and sometimes failure in international "S&T" exchanges.

Science, Technology, and Foreign Policy

The interests of the Commission in international scientific communication and in the differing uses of technology and science converge in another premise underlying its work: that it should be active in understanding the wise and unwise uses of science and scientists and of technology and technological resources for furthering the objectives of U.S. foreign policy. The Department of State and other U.S. government agencies regard "science" as part of the nation's cultural apparatus and therefore usable. But here again the word "science" really is meant to encompass "science and technology." A more sophisticated recognition of the differences between the two should be reflected in the creation of U.S. foreign policy.

The Department of State has negotiated some 24 bilateral scientific and technical agreements in the last few years. The great bulk of these were created to meet presumably otherwise unattainable political objectives or to provide some sort of cosmetically attractive technical assistance. None were devised to benefit U.S. science.

The United States also maintains extensive involvements in international governmental organizations that are both technical and political. Over the years, the Department of State has asked for and received a wide range of advice and comment from the American technical community, some from the National Academy of Sciences, and substantial amounts from hand-picked advisory committees. Currently, the Commission on International Relations maintains well-established technical assistance activities with the Agency for International Development and is intensely involved with the Department of State in Law of the Sea negotiations. The Commission also operates exchange programs with the blessings and support of the Department. However, the Commission does not participate extensively in innovative, evaluative, or analytical activities relating to current or future technological issues in foreign policy—for example, disarmament, communications, nuclear proliferation, fertility limitation, or technological and trade issues. Whether or not it should is open to question in terms of its ability to deal with this admixture of political and technical issues and in terms of the audience it might reach. Nonetheless, it is attempting to find ways in which it can develop an active advisory capacity by which the Department of State and other foreign policy elements of government can seek and find technical expertise willing to provide informal but timely responses within the confines of the foreign policy structure.

A corollary issue is to examine how, why, and to what extent the

National Accelerator Laboratory, Batavia, Illinois.

Commission has (or is likely to) become operationally engaged in governmentally inspired foreign programs. Its exchange programs with the USSR, various Eastern European nations, and the People's Republic of China, and its responsibilities for the International Institute for Applied Systems Analysis, are cases in point.

PRIORITY PROGRAMS

The terms of reference of the Commission on International Relations declare that its functions are:

- To conduct the international affairs of the NRC with individuals and institutions, both domestic and foreign
- To provide consultative services to the agencies of government engaged in international scientific and technical relations
- To provide policy advice and assistance to all elements of the NRC involved in international activities and to suggest needed new international endeavors and desirable changes in current programs
- To initiate programs and projects with the goal of advancing transnational scientific and technical cooperation and facilitating the participation of Americans in all such cooperative activities

These are rather general purposes, but the Commission has agreed to test their applicability by organizing its efforts against a backdrop of eight human needs:

- The creation of population policies compatible with the world's natural restraints
- An increase in and stabilization of food supplies
- An increase in global economic productivity
- Equitable access to the world's natural resources
- More livable human settlements
- Maintenance and improvement in the quality of the environment
- Individual security against natural hazards
- The elimination of war

The NRC can work toward these goals by exploring several considerations:

1. NRC approaches to an effective transfer of technology—whether to developed or, more importantly, to less-developed societies—are still quite primitive. The Commission on International Relations is now tentatively exploring "appropriate technologies," investment patterns, information dissemination, agricultural and population linkages, international organizational capabilities, and country-by-country technical resource evaluations; but the path is long and arduous and experience tells us that successful work with the scientists of one country does not necessarily carry over to another.

2. The formal analysis of scientific exchanges has taken some unique turns in the past year because of the thwarted desire to conduct operational pilot programs while simultaneously developing a rationale for collaborative research. Nonetheless, the analysis of the 17-year exchange program between the National Academy of Sciences and the Soviet Academy of Sciences will be completed and reported in 1977.

3. There appears to be a need for extragovernmental advice to the U.S. Department of State and the Agency for International Development on the global and country-by-country impact of contemporary contraceptive technology and on the strategy by which fertility-limitation programs as a part of U.S. foreign policy are offered and sustained. Could the NRC provide such advice?

4. The extragovernmental arms control and disarmament effort appears to be flagging, partly because arms control and disarmament work has reached a very difficult technical plateau and partly because the private disarmament community is aging. Can or should the NRC seek to stimulate a fresh examination of nuclear and conventional arms control by a young and energetic community of scholars?

5. The next few years contain the prospect of continual crises in food and energy supplies, particularly in developing countries. While the NRC is currently engaged in a major effort to examine the uses of R&D for increasing food production, it is not studying the technical problems inherent in the strategies devised for coping with chronic shortages. Can the NRC create a study group that has the wisdom and balance to issue temperate early warnings of special interest to the technical community and the national and international foreign policy apparatus? Or can the NRC design international impact assessments for some of the studies and projects carried out for domestic purposes? Many NRC reports would bene-

fit from a chapter of speculation "on the international impact of . . ." that are clearly written and are specifically designed to alert the scientific and political communities to problems that have international dimensions.

6. In carrying out foreign programs of the NRC, the Commission is continually reminded that the success or failure of technological programs depends as much on the relationships between people and institutions as on the characteristics of the technology. We need to devise ways for the NRC constituency to collaborate with these institutions, aid their organizational effectiveness, and encourage the growth and advancement of their collaborative associations.

7. The failure of intergovernmental institutions—particularly the United Nations General Assembly and the United Nations Educational, Scientific, and Cultural Organization—to effectively orchestrate the diverse interests of developed and developing nations has led to a modest increase in the number and diversity of nongovernmental institutions engaged in politicotechnical activities. It appears that there is substantial value in participating in these organizations when the NRC can contribute something other than money and when the goals of the organization are coincident with or complementary to ours. The need to strengthen the nongovernmental hand is well perceived, but the ability to do so is limited by resources. It is important to develop an effective means of providing both institutional and financial support to nongovernmental organizations. And the NRC must continue to emphasize the importance of international scientific cooperation as a vigorous and independent part of both national and global culture.

Study Projects

COMMISSION ON INTERNATIONAL RELATIONS

ADVISORY PROGRAM ON THE SAHEL

The term *Sahel* denotes a state of mind as well as geographical territory. Geographically, the Sahel forms a border between the Sahara and the more fertile, tropical savannah to the south. The major part of the Sahel is former French territory, now divided into six countries—Chad, Niger, Mali, Senegal, Mauritania, and Upper Volta. Two other small countries, Gambia, a former British enclave in Senegal, and the Cape Verde Islands, which recently gained independence from Portugal, are now included in the development planning for the Sahel. It is a region of highly variable rainfall, short growing seasons, and drought cycles. Literacy rates hover at about 5 to 10 percent. Most of the region's 24 million people—88 percent in 1970—work in agriculture, largely subsistence or nomadic. Four of the countries are among the poorest on earth; industry contributes significantly to the gross national product (GNP) of only one, Senegal.

The state of mind that the Sahel conveys is despair and hopelessness, a view formed by the 5-year drought (1968–1973) that devastated many parts of the region, wiped out some 30 percent of its livestock, killed some

100,000 people (mostly children), and halved the GNP of several countries. The drought disrupted the transhumant patterns of the nomads, forced many of them (and also settled farmers) into refugee camps, exacerbated the already widening disparity in the quality of lives between city and countryside, and brought massive emergency aid from the developed nations.

The drought ended with rains in June and September of 1974. But there will be more droughts: A drought of the same intensity as the last one will occur, on the average, two times every 100 years and lesser droughts more frequently. But if droughts are usual to the Sahel and if, to quote a report of the U.S. Agency for International Development (AID), "historically, the people of the Sahel have managed [their] environment quite well," * why was the most recent drought so calamitous?

SOME REASONS

Several of the Sahel countries have had and continue to have among the highest population growth rates in the world, and the Sahelian population is now projected to double by 2000. The numbers of livestock increased substantially during the 1960's, a period of relatively good rainfall. Developmental efforts—improved animal health measures, provision of more and deeper bore holes to water the animals, and so on—had considerable positive effects on livestock husbandry, and these were reinforced by the fact that traditionally the Tuareg and Fulani nomads of the region "banked" their cattle, equating numbers with wealth and using the cattle to barter for cloth, food, and wives.

Thus, a variety of pressures were put on land and water resources, with the result that land that hitherto would have lain fallow was planted; the encroachment of the desert quickened and extended into marginal areas; and timber cutting was intensified to meet the need of the larger population for more firewood, the only native source of fuel in the Sahel.

All these were ominous perturbations in a land with scarce resources to which its people had hitherto accommodated in various adaptive ways —e.g., by the cyclical movements of the Tuareg and Fulani pastoralists

* Agency for International Development. 1976. Proposal for a Long-Term Comprehensive Development Program for the Sahel: Major Findings and Programs. Report to the U.S. Congress. Washington, D.C., p. 12.

to follow the seasonal advance and recession of vegetation; by letting a portion of the land lie fallow; and by other measures, many ancient but perfectly adapted to the limits of the land.

CILSS AND THE CLUB

The drought made it clear that the increased demands of both people and livestock had made the region vulnerable, unable to absorb a strong stress. But what is at issue now is not recrimination, although analysis continues to be sought and needed, but rather an effort at least to blunt the impact of droughts and at best to enable the Sahel to sustain itself. The initial effort has come from the Sahelian governments, through their formation of CILSS—the Permanent Interstate Committee for Control of Drought in the Sahel. CILSS, at its inaugural meeting in September 1973 at Ouagadougou in Upper Volta, compiled a list of some 300 projects and identified those that should be given priority, with the cost of the latter estimated at $850 million.

Events evolved thereon, with purposes, strategies, and the various programs discussed in detail at a series of conferences between representatives from the Sahel and potential donor nations. From these meetings emerged the Club des Amis du Sahel, with the United States a member. The Club held its inaugural meeting in Dakar, Senegal, in March 1976. Concurrently, the Congress took steps to frame the U.S. participation in a program for the development of the Sahel, and, in the Foreign Assistance Act, approved on December 17, 1973, it declared that:

The Congress supports the initiative of the United States Government in undertaking consultations and planning with the countries concerned, with other nations providing assistance, with the United Nations, and with other concerned international and regional organizations, toward the development and support of a comprehensive long-term African Sahel development program.

The ultimate purpose of this activity is to develop the Sahel into a region that can sustain its people, that can endure without collapse the anticipated recurrence of severe droughts, and that can deal with a population that is both growing and changing in character. A program for Sahelian development must take account of a culture and economy that are evolving—from an agriculture significantly dependent on nomadic grazing to a settled one, from a heavily rural population to one being urbanized, from an economy dependent on a very few crops to one with a broader economic base.

Moreover, the development effort must deal with the economic and administrative weaknesses that afflict all or several of the Sahelian countries—underadministration and insufficient infrastructure in the rural areas, pricing and taxing policies that impose disproportionate burdens on the producers, negative growth rates with respect to GNP, no sources of fossil energy and insufficiently developed hydropower, inadequate educational systems, and so on.

Quite obviously, the intended program will be a test of our understanding of the development processes and of the abilities of disparate nations to work together to achieve immense regional objectives. The program requires a holistic view, but still must take account of regional geographical differences, of cultural differences, of historical rivalries, and of the relative economic well-being and needs of different countries.

The program has both its near-term and medium- to long-term elements. Near-term efforts may include attempts to increase crop yields, development of new technologies for dryland farming, planning for the development of the river basins and other water resources, and the initiation of new irrigation projects and experiments. Concurrently, educational and training programs will be mounted to provide the personnel needed to direct, manage, and operate these efforts.

The medium-term and long-term programs will obviously build on these beginnings—extending them, turning planning into pilot development programs, and turning the development programs into widespread and conventional practice. Programs of health-care nutrition, maternal care, literacy, and education will be planned and deployed.

In addition to the money and the long-term commitment required by many countries, the program will call for patience. The lesson of the Sahelian drought is that simple, first-order remedies—such as more bore holes to water the livestock—can ultimately extract terrible costs. Thus, obvious and major parts of the development programs—such as the exploitation of Sahelian water resources (principally meaning the Senegal and Niger river basins and Lake Chad, supplemented by the Gambia and Volta river systems)—will be approached carefully and with the most thorough planning. However, the speed of progress must also be adjusted to the need. As an AID report notes, "for the full development of West African river systems, these studies should not be delayed unnecessarily over time while the region continues to struggle to feed its people." •

The role of the NRC—through the Board on Science and Technology for International Development of the Commission on International Relations—will be to advise AID with respect to scientific and technical aspects of the development program, to arrange for U.S. participation in the Technology and Ecology Working Groups of the Club des Amis du Sahel, to identify research that is needed but not being done sufficiently or at all, and to help foster the institutional and personnel relationships needed to enlarge the cadre of people—in the Sahel and in the United States—that can be part of and help shape the development program.

Advisory Program on the Sahel, Board on Science and Technology for International Development, Commission on International Relations. Staff Officer, Michael G. C. McDonald Dow.

• *Ibid.*, p. 16.

GLOBAL ENERGY

Energy studies, with some exceptions, such as those of the Organization for Economic Cooperation and Development (OECD), tend to approach issues from a national stance, with their intent typically to outline policies assuring that there will be enough fuel to satisfy a nation's expected demand. International considerations, such as where oil is to come from, are included in these studies if they are likely to affect national policies. The energy systems study of the International Institute for Applied Systems Analysis (IIASA) * is an effort to weigh global and regional considerations first and then assess their possible effects on national policies, with an emphasis on the long-term (15 to 50 years) implications of various assumptions on energy supply and demand.

The IIASA program is complex, ambitious, and international; it uses, for example, computer programs supplied by the National Center for Atmospheric Research in Boulder, Colorado; the British Meteorological Office in London; and the Power Research Institute of the Siberian branch of the Soviet Academy of Sciences in Irkutsk.

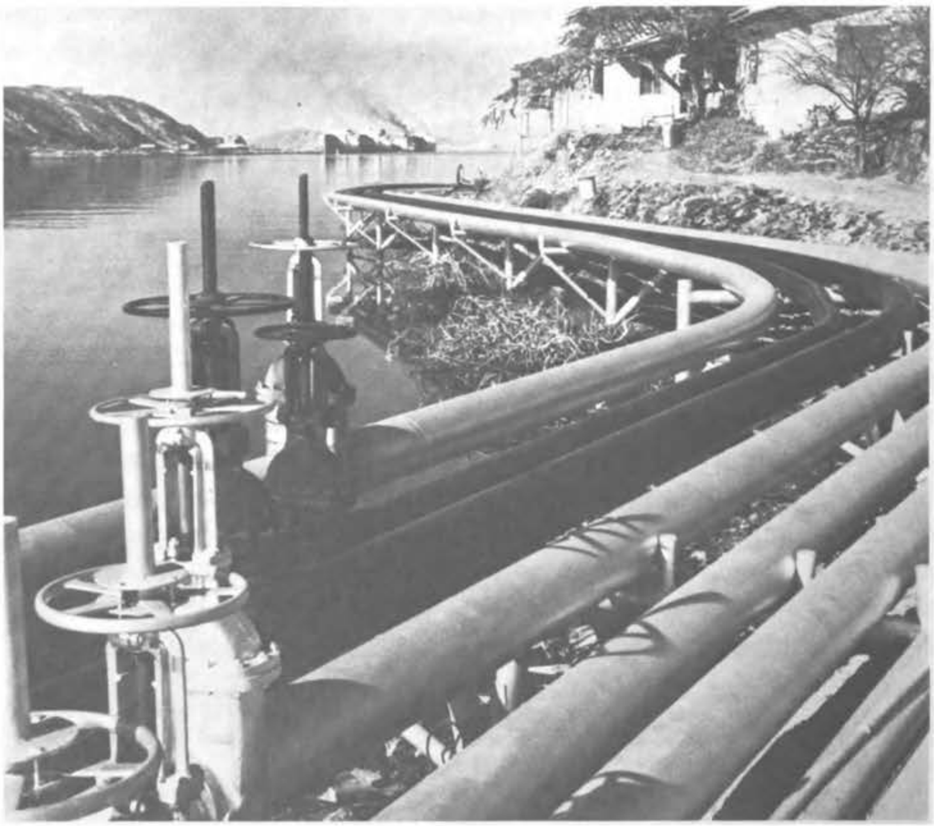
SOME FINDINGS

The IIASA project has analyzed energy resource supplies both as to *primary* resources such as coal or petroleum and *secondary* resources, or the form in which energy is actually distributed and used, e.g., refined oil from petroleum or electricity from coal. The analysis emphasized the importance of secondary resources; any program that attempts to change them is likely to be disruptive, expensive, and unsuccessful. This importance of form rather than source to energy policies is attested by the fact that coal consumption globally has been going down and oil use up, even though the latter is more expensive and demonstrably more vulnerable to stoppage. Moreover, the principal markets for coal have been effectively reduced to those that can use its special qualities—as coke by the steel industry and as furnace fuel by the electrical utilities. The

*For background on IIASA, see The International Institute for Applied Systems Analysis. 1976. *In:* The National Research Council in 1976: Current Issues and Studies. National Academy of Sciences, Washington, D.C., pp. 183–188.

IIASA distinction of primary from secondary energy emphasizes the likely risks of altering local and regional transmission and distribution systems, i.e., those that deal with secondary energy forms. Plans that interfere with the already established infrastructure for the distribution of energy (distances of 5 to 50 kilometers), or its transmittal (distances of 100 to 1,000 kilometers), may not be workable, whatever their attractiveness on paper.

New sources of energy, no matter how exotic or unique, must be provided in a form that can readily couple to the existing infrastructure: Solar electricity must provide power in a way that can be fed into available electrical grids; gas, whatever the primary source, must be transmittable through existing pipeline networks; coal, if it is to gain major markets from which it is now excluded, must be converted into gas and liquids. And nuclear power will be limited to making electricity unless it can be used to provide energy in other conventional secondary forms.



COAL AND URANIUM

Coal is a primary energy resource not easily transformed into secondary forms, and, therefore, its actual markets, in spite of its ample supply, remain limited. And, if lesser-grade, lignitic coal resources are discounted, the geographical distribution of coal is highly uneven, largely concentrated in the United States, the People's Republic of China, and the Soviet Union. That, as the IIASA analysis points out, has geopolitical implications, not least being the necessity for the development of large-scale and quite lengthy transportation systems to get the coal from mine to market. The IIASA analysis has also made clear the importance to the use of coal of what it calls the WELMM constraints—water, energy, land, material, and manpower. Depending on the situation, a coal mine may really be a facility for handling water, overburden, and then the coal.

IIASA's regional and global perspective has also drawn some useful lessons from an analysis of nuclear power, including the instructive point, certainly for the United States, that the daunting elements in nuclear development are not in technology, but in "softer" problems—those of licensing, regulation, standardization, decision making, and other complexities that are institutional rather than technological. The current difficulties over the disposal of waste fuels are immersed in these soft issues, with technology largely a backdrop to the frontal issue of finding mechanisms to assure adequate safeguards over the storage of these wastes.

Having examined the major energy options—coal, fission, fusion, solar electricity, and dry geothermal—IIASA's conclusion is that the future energy problems will *not* be dominated by a limit on resources, but rather by the constraints; there is enough, and it is the "side effects" in expanding and developing various resources that will provide the major problems.

That finding, aside from disagreeing with several conclusions of reports by the Club of Rome, implies some psychological readjustments. For example, technologists are trained to look for optimal solutions, with "optimal" typically translated into solutions that are cheap and somewhat flexible. But this may be a false view, given IIASA's opinion that it is the constraints—and the efforts to deal with them—rather than optimizations that will characterize future technological strategies.

The major constraints identified in IIASA's study include:

- *Time.* It takes some 60 years for a new energy technology to gain half of the market in the United States, as illustrated by the transition from wood to coal, coal to oil. Globally, these transition times are longer, and a bit shorter in Europe.

- *Waste Heat.* With the sizeable increases in energy to be generated the next several decades, the conventional ways of removing waste heat, such as wet cooling towers, may not be enough.
- *Risk.* There is a need to find methods, defensible and understandable to the public, of assessing risk, and, as a corollary, of creating standards incorporating those risks. IIASA has a program on risk analysis, admittedly a byzantine issue, under way with the major goal being the identification of the objective and subjective determinants of risk.
- *Capital.* Future energy sources are likely to be quite costly, particularly in start-up costs; for example, solar electricity will be extremely capital intensive but (apparently) not particularly demanding in operating or fuel costs.

Possible methodology for making choices in a terrain dominated by these and other constraints is being developed by IIASA with the support of the United Nations Environmental Programme and in concert with the International Atomic Energy Agency and the World Health Organization.

HOW TO GET THERE

One not only has to know what the available resources are (and their associated constraints), but also how to get to an intended goal. What is the least unsettling way for a national economy to switch from fossil fuels to uranium for making electricity? In order to assess possible transition strategies, the energy systems project at the International Institute for Applied Systems Analysis has created a linear programming model that attempts to optimize within specified time frames the best allocation of resources for satisfying a given set of demand assumptions.

Because so much is assumed and so many aggregating simplifications are needed, such an exercise is often more useful for the questions it forces than the answers it provides. For example, how much structural change can an economy endure before it collapses? To attempt an answer, the IIASA energy project has borrowed the resiliency theory applied by the IIASA ecology group to its studies of the ecology of spruce budworms

to analyze control strategies for this forest pest. Resiliency here means the capacity of a system to absorb shocks and changes without ceasing to exist. The technique is complex, relying on differential topology and the concept of slow and fast variables used by the French mathematician René Thom in his catastrophe theories.

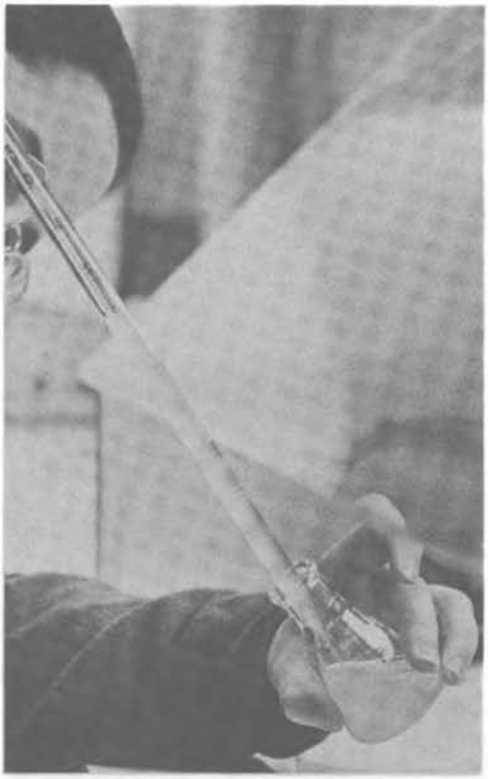
RESULTS

These are highlights of a program still under way. There are several goals, with one being the provision of a model, or set of assumptions, that can be applied to assessing the implications of national and regional energy policies given the global restraints that have been identified. There are now momentous decisions to be made or put off: exploration and exploitation of North Sea oil; expansion of the infrastructure—ships, shore facilities, and so on—for importing liquified natural gas; large-scale deployment of nuclear power, including breeder reactors; sharply increased use of coal, with the associated development of coal-conversion industries; politically sensitive actions on energy conservation.

These decisions are inevitably made locally, but are subject to and indeed affect global situations. IIASA's aim is to help delineate the latter in the hope of aiding the former.

IIASA Energy Systems Program, International Institute for Applied Systems Analysis Program; Leader, Wolf Haefele.

Commission on Human Resources



Issues in Human Resources

MICHAEL J. PELCZAR, JR., AND
ALFRED O. C. NIER

The passage of the postwar "baby boom" through college coupled to other factors such as a leveling off of support in constant dollars for academic research is leading to profound and, to many, quite troubling changes in the nature of the academic research community, including a scarcity of new faculty positions for postdoctoral scientists and engineers. In this article, changes in the academic research communities and their portent are examined by Michael Pelczar. Alfred Nier examines the methods and problems in selecting our most promising graduate students and doctoral researchers for award support.

THE HEALTH OF ACADEMIC RESEARCH

In a recent article entitled "Public and Private Science," Caryl P. Haskins portrayed the environment in which scientific training and research are

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pursued in America as a triangular association composed of the resources of (1) universities and colleges, (2) industry, and (3) government. The spectacular achievements accomplished by this association were admirably expressed by Dr. Haskins:

That tripartite partnership is almost uniquely developed in America—and can be of unique strength and effectiveness. It has been the envy of the world, and clearly one of our great challenges in the years ahead will be to make it work better: to achieve greater permeability, more effective feedback, and better coordination among its components, and to preserve the integrity and effectiveness of the whole. Understanding the tasks of each, recognizing their peculiar strengths and weaknesses, comprehending how best to utilize their capacities, and, above all, preserving an appropriate balance among them and promoting their optimal synergism in the interest of the nation—these are the basic tasks for today and tomorrow.*

The unparalleled successes of the American research enterprise during the past several decades have become legendary. This was made graphic in 1976 when U.S. scholars made a "clean sweep" of the three Nobel prizes given in science. The award of all three science prizes to scholars of one country has only occurred three times previously. All were awarded to Germans in 1905 and to Americans in 1946 and 1968. In 1961, awards went to Americans in all three categories, with the physics prize shared with a German scientist. From 1951 to 1976, Americans have been awarded more than one-half of the total prizes given in science. In the period 1901 to 1950, Americans were awarded only 29 of 164 science prizes given.

A somewhat different, but complementary, assessment of research accomplishments in academic institutions is expressed by Philip Handler in his article "The American University Today." Writing on the central theme of the role of the university as society around it undergoes changes, he refers to the vastly expanded academic scientific activity and achievement that developed from the federal government's support program:

The results were astounding. Knowledge of the physical universe and of the nature of life burgeoned in unprecedented fashion. The increase in the sweep, detail, and sophistication of scientific understanding gained in the last three decades can probably be appreciated only by those privileged to have lived

* Caryl Haskins. 1976. Public and private science. Am. Sci. 64:493–499.

through this era. In that brief historic moment, man learned, for the first time, the nature of life, the structure of the cosmos, and the forces that shape the planet, although the interior of the atomic nucleus became, if anything, even more puzzling. With that newly acquired understanding, whole new industries were born whose products touch almost every aspect of our daily lives; the capabilities of medicine were vastly improved; and the digital computer, originally invented as a tool for the doing of science, appeared on the American scene.*

However, the scene has changed in the aftermath of a steady (and sometimes not so slow) downturn of the dynamic growth experiences of the past two decades. The consequences of this change in the pattern of growth include a leveling off in research funding, further compounded by inflation; the stabilization of enrollments; and the deceleration of new faculty appointments at the very time graduate schools reached new peaks of Ph.D. production in some fields.

Thus, basic research in the physical sciences, which received over $763 million in federal support (in 1972 dollars) in FY 1969, received less than $493 million in FY 1975 ($616 million in FY 1975 dollars). Basic research in psychology, which received $76 million in FY 1967 and $61 million in FY 1969 in federal obligations, received less than $39 million in FY 1975 ($48 million in FY 1975 dollars). Federal obligations for research in engineering, which totalled $197 million in FY 1967, were below $181 million in FY 1975 ($228 million in FY 1975 dollars).

These changes in research funding coincided with a leveling off in student enrollment. The rise and fall of the baby boom of the late forties and early fifties is reflected today in a slowing of the rate of increase of college enrollments. Total student enrollment, which grew by over 3 million in full-time equivalents between 1962 and 1972, is projected to increase by less than 1.4 million between 1972 and 1982 and then to decline. Meanwhile, the physical sciences and mathematics have been attracting a smaller percentage of undergraduates than they did 10 years ago; engineering seems to be recovering somewhat from its earlier decline. The number of doctorate recipients in the physical sciences and engineering has decreased from 5,730 and 3,495 respectively in 1971 to 4,445 and 2,791 in 1975.

Unemployment among doctorate holders has remained low, however.

* Philip Handler. 1976. The American university today. Am. Sci. 64:254–257.

For 1975 the Commission on Human Resources found that 1 percent of doctoral scientists and engineers in the United States were unemployed and seeking work. The unemployment rate among women was 3 percent, while that for men was 0.8 percent.

A third characteristic of the present academic environment is a decline in the appointment of new faculty in a number of fields. According to the American Institute of Physics, the total of physics faculty in all colleges and universities peaked at 11,469 in 1969–1970 and was down to 10,727 in 1975–1976. In doctorate-level departments surveyed by the National Science Foundation in 1968 and again in 1974, the number of electrical engineering faculty showed no increase, the number of faculty in chemical engineering increased by only 1 percent, and the faculty in chemistry and mathematics increased 7 percent. By comparison, faculty in biology increased 16 percent, and faculty in biochemistry increased 18 percent.

Reduced hiring of new faculty has led to an increasing proportion of faculty with tenure. The Carnegie Commission's survey of faculty at 2-year and 4-year institutions in 1969 found 46.7 percent on tenure; in 1973, the American Council in Education reported a figure of 64.7 percent. Data compiled by R. D. Anderson for the American Mathematical Society supports the conclusion that there has been a rapid rise in the proportion of faculty on tenure in mathematics. The proportion of doctorate-holding faculty on tenure in that field increased in both 1974 and 1975. The increase from 1973 to 1974 was 3.5 percent and an additional 2 percent from 1974 to 1975.

Other data confirmed this assessment. In 1974, the National Science Foundation found the proportion of faculty on tenure in doctorate-level science and engineering departments to be 67 percent in mathematics, 77.1 percent in chemistry, 77.4 percent in electrical engineering, 77.7 percent in physics, and 80.7 percent in chemical engineering. By contrast, the proportion on tenure in biochemistry was 65.8 percent, in microbiology 64.8 percent, and in physiology 59.1 percent. In all fields, however, there was a decrease between 1968 and 1974 in the proportion of faculty who had obtained the doctorate within the past 7 years. In most fields—including biochemistry, microbiology, and physiology—departments reporting figures for both years showed a decrease in the absolute number of young faculty. American Council on Education data indicate that the median age of faculty in science and engineering fields employed in doctorate-granting institutions rose from 41 to 44 between 1969 and 1973.

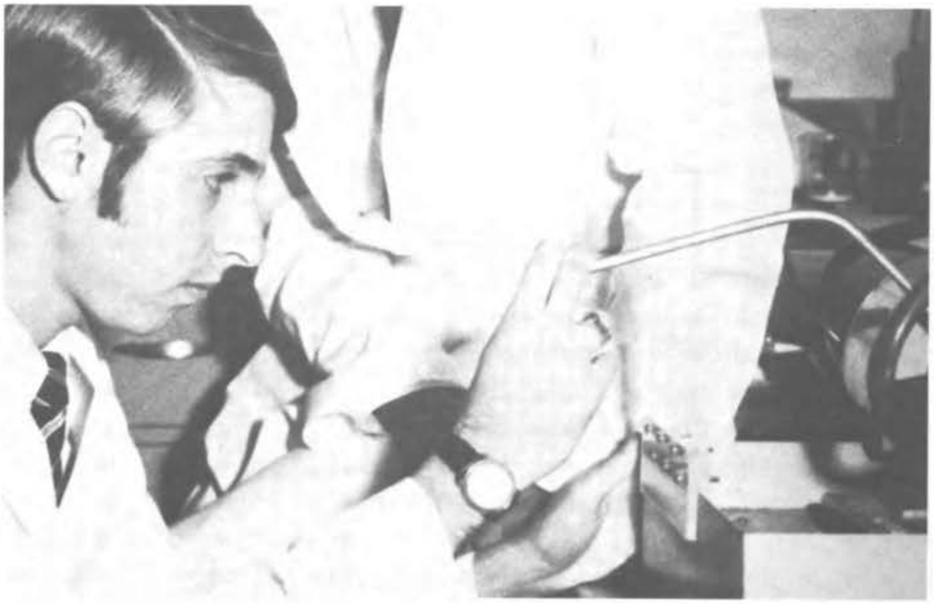
These new circumstances—the leveling off in funding, the decline in student enrollments, and the static condition developing in academic faculties—may pose a serious threat to the productivity and quality of research in American universities and colleges. University departments are experiencing constraints that seriously hamper their flexibility as centers of research. There is a lack of opportunity to use appointments to the faculty to encourage or accommodate new directions in research.

For individuals these same constraints mean seriously reduced career opportunities. This is especially true of young university scientists and engineers without tenure. According to R. D. Anderson, the proportion of new Ph.D.'s appointed to faculty positions in mathematics in 1975, whose prospects of being retained permanently were fair-to-better, ranged from a high of 74 percent in college departments to only 17 percent in the top-ranking doctorate-granting departments. The prospects of new faculty hired from other academic positions were not much better. The proportion whose prospects of permanency were fair-to-better ranged from 72 percent in college departments to 55 percent in the top doctorate-level department in mathematics. Lee Grodzins, who has compiled similar data for physics, found that while new hires at the assistant professor level are only half the number in the late sixties, hires from other institutions at the associate and full professor level have decreased to a quarter of the number in the late sixties. In other words, an assistant professor who does not get tenure in his original appointment is distinctly less likely than before to get tenure at another institution. It has also become more difficult to get the first appointment as an assistant professor. Over 35 percent of postdoctorals in 1973 reported that they were using their postdoctoral appointments as a "holding pattern" until they could find more desirable positions.

The Carnegie Commission on Higher Education evidenced its concern about these problems in two reports, one by Allan M. Cartter * and the other by Roy Radner.†

* Allan M. Cartter. 1976. Ph.D.'s and the Academic Labor Market. Carnegie Commission on Higher Education.

† Roy Radner, Leonard S. Miller, Douglas L. Adkins, and Frederick E. Balderston. 1975. Demand and Supply in U.S. Higher Education. Carnegie Commission on Higher Education.



The Cartter report—after extensive analysis involving enrollment projections for higher education and estimation of the demand for faculty, including recognition of the changing composition of the college and university faculty—concludes that ". . . considerable reduction in the flow of Ph.D's will be required if there is not to be a serious unemployment problem facing new doctorate recipients entering the job market." Cartter points out that ". . . when the demand for doctorates in all closely related fields is contracting simultaneously, then the only appropriate market response is a reduction in the total number of graduate students seeking advanced degrees."

In a section entitled "Implications of the analysis for doctoral-granting institutions and for agencies supporting doctoral education," Radner concludes that

> . . . future academic demand for doctorates, without reference to fields of specialization, could vary over a wide range as a function of future policies of higher education finance and future staffing standards and hiring practices of the various types of institutions. If stringent financing conditions prevail in the 1970s, academic demand will be below the level projected in Cartter's study. . . .

Two other important demand factors evident from Radner's analysis are:

1. The 1980s, by reason of an expected downturn in higher education enrollments, will be far worse than the 1970s.
2. The enrollment expansion of the 1970s implies a considerable expansion of total faculty positions in higher education, but the composition of this expansion—weighted toward public four-year colleges—compels reexamination of present patterns of doctoral training for academic careers.

He further emphasizes that ". . . making more academic jobs available to doctorates and fitting new doctorates properly for them, in terms of both motivation and training, is of high priority for the doctorate-producing institutions."

Two issues of paramount importance, not only to the graduate education community but to the nation and the world, emerge. What will be the impact of the present environment (if allowed to continue) on the future of graduate education and research? How will the productivity and quality of research in the academic community be affected? The answers are likely to identify serious consequences.

New insights and projections for increased opportunities in graduate education and research were eloquently expressed by a panel of the Council of Graduate Schools–Graduate Record Examinations Board panel. Its report, *Scholarship for Society,** made numerous recommendations for new roles in graduate education. The graduate programs in the peer group of universities, however, have not been greatly influenced by these recommendations. David W. Breneman, in his article "Predicting the Response of Graduate Education to No Growth," † states that there is little evidence of creative changes by departments.

There is an urgent need to identify, develop, and assess the potential impact of alternative policies to maintain the strength of science and to provide rewarding research careers for scientists and engineers. Possible examples of such alternatives are: the creation of a structure of university research staff positions with reduced coupling to student enrollments that will provide opportunities for career development, for status, and for

* Panel on Alternate Approaches to Graduate Education. 1973. Scholarship for society. Educational Testing Service, Princeton, N.J.

† David Breneman. 1976. Predicting the response of graduate education to no growth. General Series Reprint #310. The Brookings Institution.

continuity of employment; development of early retirement plans for faculty to provide feasible alternatives to older faculty members and to increase the opportunities for appointment of junior faculty members; encouragement of greater interactions between the research communities in industry, universities, and government; and development of increased opportunities in graduate education that involve industry and government, thereby providing students a wider range of career options and more contact with a variety of research work.

There is a concomitant need for the establishment of national priorities, with the provision of resources, for addressing the major problems confronting society. These problems (urban development, energy, environment, and others, all of which translate into needed improvements in the quality of life) will place a tremendous demand on the need for more human resources at all levels of education and training. Consider the impact of the space program on the community of scientists and engineers.

In the projections of what lies ahead for graduate education, we too frequently use our data base to portray a future much like the past. In a sense, the graduate community has succumbed to a defensive posture rather than asserting a leadership role by pointing the way for a new era of performance by the tripartite partnership of universities, industry, and government. Now is the time for the development of creative programs in full confidence of our ability to succeed, given the commitment by all three parties of the triangle. To throw some additional light on these issues and consider the national policy alternatives involved, the Board on Human-Resource Data and Analyses proposes to conduct a study of postdoctoral scientists and engineers over the next 2 years. The study will place particular emphasis on young researchers and those in a transitional period of their careers. It will examine and evaluate possible new patterns of training and employment to ensure the vitality of the research system in the United States.

IDENTIFICATION OF TALENTED SCIENTISTS AND ENGINEERS

Whatever the changes in the system for training our new scientists and engineers, there must be continuing efforts to assure that sufficient support is provided our ablest graduate students and researchers. Within the

National Research Council, the interest in selection procedures by which those to be supported are identified goes back to 1919, when the National Research Fellowships administered by NRC were initiated. From 1919 to 1955, 1,289 fellowships, with support from the Rockefeller Foundation, were awarded in mathematics and in the biological, medical, and physical sciences. The subsequent achievements of the awardees is dramatic testimony to the merit of the award and the validity of the selection procedures that were used.

Beginning in the mid-1950's, the NRC has been involved in a number of programs of awards to graduate students, as well as to postdoctoral scientists and engineers. These activities were centered first in the NRC's Office of Scientific Personnel and now in its successor, the Commission on Human Resources. The number and kinds of programs have varied with time, depending on the availability of funds and the interests of sponsors. The Commission has also been a source of advice for other organizations establishing award programs.

The Commission, through the Board on Fellowships and Associateships, now provides evaluative service to the National Science Foundation (NSF) for its Graduate Fellowship and National Needs Postdoctoral Fellowship programs. It also administers Postdoctoral Research Associateship programs for selected federal research organizations. In the Associateship programs, which provide research opportunities for able doctoral graduates, NRC is responsible for a number of aspects of the programs, including evaluation of applicants.

In its present fellowship and associateship awards, the Commission must consider varying criteria and objectives. Thus, the Graduate Fellowship Program of the National Science Foundation concerns the identification of talented undergraduates contemplating doctoral study in science and engineering; while, in postdoctoral award programs, the selection involves the differentiation from among doctoral graduates of those persons most likely to contribute significantly in research. Another task in some programs is to differentiate among senior postdoctoral persons who have already attained significant status in science.

The NRC's awards program involves large numbers of applicants and awards (see Table 1). Selection schemes and procedures that serve nicely if only a few applicants are involved are entirely unsuitable if the applicants number hundreds or thousands and if the number of awardees is

TABLE 1 Scale of NRC Selection Activity in 1976

Program	Applicants	Awardees
NSF Graduate Fellowship	5,366	550
NSF National Needs Postdoctoral Fellowships	455	118
NRC Postdoctoral Associateships	1,014	234

comparably large. For example, in a small-scale program personal interviews may be useful, whereas interview techniques are not feasible in large programs.

The essential NRC selection procedure is to bring together panels of leading practitioners in science and technical fields to consider documentary information about each of the applicants. The applications are grouped according to quality, based on a composite judgment by individual panelists. Each applicant's file is reviewed independently several times.

Information now used at NRC in selecting awardees differs in detail from program to program according to the level of awardee activity (graduate student or postdoctoral researcher), but it is similar in kind. The principal information considered by evaluation panelists includes:

- General information—education, employment, honors, education or career objectives, and the like
- Undergraduate and graduate academic record
- Information about previous and current research
- Proposed plan of study and/or research
- Confidential reference reports (usually four in number) on the applicant from persons chosen by the applicant
- List of publications, if any

In addition, in the Graduate Fellowship Program, results of the Graduate Record Examination are usually available (Verbal and Quantitative Aptitude Tests and, in most fields, the Advanced Test). In the NRC Associateship programs, the research plan of an applicant must be endorsed by the federal agency proposed as host. Agency endorsement often includes comment about the proposed research that is helpful in the selection process.

In the Postdoctoral Fellowship and Associateship programs, the selection process gives more attention to research achievement than in the Graduate Fellowship Program, in which applicants are at an earlier stage of their careers. Also research plans of postdoctoral applicants often have an interdisciplinary emphasis. It is NRC's experience that, as one might expect, considerably more time is expended in evaluation of a postdoctoral applicant than of an undergraduate seeking support for graduate study.

A number of issues and problems have developed over time for which there are, as yet, no satisfactory answers. There has been, for example, a growing recognition that prediction of academic performance in graduate school may involve different factors than does prediction of career achievement in scientific and technical research. The latter is seemingly a more complicated matter. There are also problems resulting from grade inflation and from legislation emphasizing freedom of information and at the same time individual privacy.

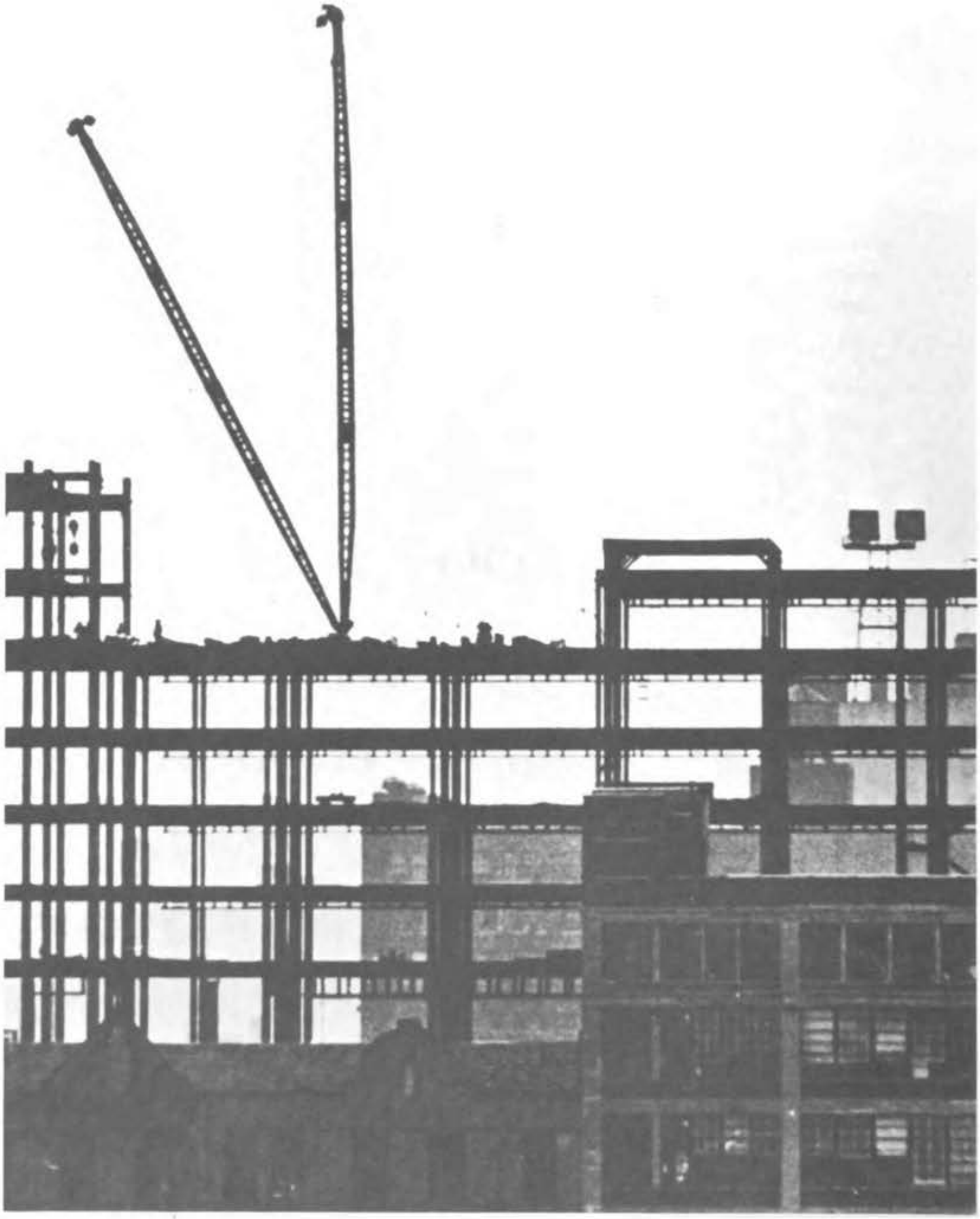
Grade inflation tends to make records of academic achievement more uniform and, therefore, less useful as a discriminator. But self-correcting trends may already be underway in educational institutions.

It is conceivable that the Privacy Act of 1974, the Freedom of Information Act, and the like may cause letters of recommendation to be more bland, less candid, and therefore less useful. This has not yet occurred in the NRC award programs. So far as we can tell, there has been no reduction in the usefulness of the confidential reference reports in the selection process. But the new legislation and the climate of the times may not have their full impact for some years.

In view of the real problems of grade inflation and of the potential decrease of usefulness of reference reports, the Commission on Human Resources is interested in research on the selection process and in the development of new or additional bases for identification of able scientists and engineers. The Commission has delegated responsibility for this area of its activities to the Board on Fellowships and Associateships. Among other matters, the Board plans to consider in the next year the question of research on selection procedures. Topics that may receive attention include the shifting significance of academic grades, the changing significance of national standardized tests, the possible loss of candor of reference reports, and the differing educational opportunities and backgrounds of applicants—including women and minorities.

Several possible outcomes from the Board's exploration of these and similar subjects are sought: new selection criteria, improved selection instruments and procedures, and improved prediction of research achievement.

Commission on Sociotechnical Systems



Giving Advice: Beyond Hardware

HARVEY BROOKS

Traditionally, the National Research Council has dealt primarily with scientific and technical questions; when considering a particular social delivery system, such as transportation or building, NRC advisory committees concerned themselves with how new technology might improve the effectiveness of the system and what research would be necessary to bring about improvements in the "hard" technology associated with the system.

This situation has changed rapidly in recent years as it became increasingly apparent that the barriers to the adoption of more efficient or effective technology lay more in organizational and social questions than in lack of the necessary technical knowledge. The creation of the Commission on Sociotechnical Systems, as implied by the name, was in part a response to this new and broadened definition of the mission of NRC.

The new orientation of NRC is reflected in many of the projects undertaken under the auspices of the Commission; examples include studies entitled "Toward an Improved U.S. Merchant Marine," "Earthquake

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Prediction and Public Policy," and "The Socioeconomic Effects of Earthquake Prediction."

One of the accompanying essays (pp. 184–190), on the activities of the Transportation Research Board (TRB) in railroad research, illustrates the mixed nature of the systems studies that are required if one is to truly address the full range of problems of a particular delivery system. It does no good to lay out a menu of potentially useful new hardware if the organizational and economic barriers to its development and adoption are endemic to the system. One must still deal with science and technology in the traditional sense, but they have to be studied in the context of the whole process of innovation and the resources needed to ensure the adoption of that innovation. However, this makes the ideal of "objectivity" and "impartiality" in NRC reports much more difficult to attain and leads to reports that some will see as more "political" than is appropriate for NRC. This applies especially when overcoming the barriers to technological innovation may involve some form of governmental intervention in the finances or the decision making of an industry such as railroads, shipping, or construction.

The line between responsible professional opinion and seeming political advocacy is often difficult to draw. Often, organizational recommendations or suggestions for governmental interventions cannot be backed up with the same kind of solid evidence and data that are possible for strictly technical recommendations. Unfortunately it simply is not possible to carry out an experiment or to pin down causal relations through careful observation or data collection in the organizational and managerial sphere, especially when one is dealing with prospective changes. Retrospective case studies are valuable, but their relevance to a new situation is always somewhat in doubt.

BUILDING, HOUSING, AND URBAN DESIGN

170 Energy conservation in building design and the risks and liabilities of the providers of buildings are newly important issues in the construction industry. The two problems are in fact related. Innovation in building design to meet new standards of thermal performance is required by new energy circumstances in the United States. Indeed, the Energy Conservation and Production Act of 1976 (ECPA) requires that no later than 3 years

after the date of enactment the Secretary of Housing and Urban Development ". . . shall develop and publish . . . proposed performance standards for new commercial buildings . . ." and ". . . for new residential buildings." This performance approach, as contrasted with the traditional "specification" approach to building regulation, is advantageous because it encourages variety, flexibility, and innovation in building design, with focus on the functions the buildings are to perform. But this very flexibility increases the risks incurred by the builder, especially in a time of the rising incidence of "malpractice"-type legal actions in almost all the technical professions. Performance is much harder to predict and to establish than conformity to a design specification, and, in a system characterized by performance standards, criteria for the responsibility, and hence legal liability, of the builder are much harder to develop.

The Building Research Advisory Board (BRAB) has established a new committee on thermal performance of buildings whose task is to design a research and test program necessary to put the prediction of thermal performance on a sufficiently scientific basis so that the actual performance of a given design can be assessed with confidence. Indications are, from existing efforts at full-scale testing, that actual performance may deviate 20 to 80 percent from that predicted using existing handbooks and thermal performance calculation practices. The first problem to be attacked is that of the building envelope; the issue is the prediction, from a knowledge of the basic thermal properties of the individual components, of the performance of the composite envelope components as assembled. Such matters as moisture condensation and air circulation within exterior building envelope components and dynamic response of these components to changing outside temperatures and other conditions all require study. The practice in the past has been to compensate for poor predictions by oversizing the heating system; with current prices and the prospect of mandatory standards, this is no longer acceptable. It is impractical to tear down a building when its actual performance in terms of heat loss does not agree with predictions. The stakes involved in accurate predictions have thus enormously increased in the last few years.

The Building Research Advisory Board also has two contracts with the Energy Research and Development Administration (ERDA) in the field of energy conservation, one for bringing to bear the knowledge and experience of the international building community and the other to advise ERDA in evaluating the efficacy of its energy conservation goals in building. Other activities of BRAB include a study of the organization and management of construction and a study of accessible environments for the disabled.

The organization and management task is being carried out by the Technology Assessment and Utilization group of BRAB. Building has become more complex as higher physical and functional performance goals are sought and as efforts are made to raise productivity in order to hold down construction costs, presently rising at twice the rate of the consumer price index. The need and requirements for energy conservation and the increased emphasis on performance standards add new dimensions to the management problem. The aim of the study is to better define the construction process as a total system within the general political and economic climate in which it will have to operate in the future, to evaluate organizational and management technologies, and to explore new possibilities for improved technologies.

A significant proportion of the U.S. population is permanently or temporarily disabled at any given time. Today there is a growing demand that all public facilities from transportation to commercial buildings be designed so that they are accessible to the disabled to the maximum extent possible, frequently without much regard to cost. One BRAB activity provides advice and assistance to the Architectural and Transportation Barriers Compliance Board of the Department of Health, Education, and Welfare (HEW) in developing criteria on which it can judge the adequacy of standards and practices of federal agencies. The other activity is assistance to HEW in developing strategies for educating the building community to be more responsive to the needs of the disabled. In both of these activities the wide contacts of BRAB in the building community make it an indispensable instrument in the dissemination and discussion of new requirements and in achieving general acceptance and compliance with these requirements.

MARITIME TRANSPORTATION

Three reports were completed under the auspices of the Maritime Transportation Research Board (MTRB) during the past year. One, *Toward an*

Improved U.S. Merchant Marine, has already been referred to as an example of the breadth of the considerations involved in Commission studies. The rapid introduction of containerization, stimulation of U.S. trade by the 1971 currency devaluation, and strong promotional activities of government have temporarily arrested the decline of the U.S. merchant marine. But more fundamental changes are probably needed. Technology alone is not enough; there is a need for an institutional foundation that will enable the industry to take full advantage of new technology. Major changes must be explored in the areas of government support programs, industry marketing and management practices, and labor relations. The report focused primarily on the delineation of needed research in these policy areas as a necessary foundation for considering future policy changes. In the meanwhile, partly in response to this report, the MTRB is undertaking a study on the absorption of new technology by the maritime industry.

The MTRB report *Port Development in the United States* complemented the report on the merchant marine. While considerable progress in port modernization has been made to match the containerization revolution, new problems have arisen partly as a result of the competitive relations among ports and of the need for port facilities to be compatible with new environmental sensitivities and to balance environmental and economic considerations in their planning. Recommendations of the report cover port planning, operations, rate regulation, environmental impacts, labor relations, and potential sources of finance. The report recommended a federal aid-to-ports program as necessary if ports were to meet new environmental standards while keeping rates competitive; otherwise projected revenues would be inadequate to satisfy projected capital needs.

The intent of the MTRB report *Maritime Metrication,* published in February 1976, was to develop a plan for orderly conversion to the international system of metric units by the U.S. maritime industry. In response to this report the Maritime Administration has issued a Request-for-Proposal for a consultant to prepare a detailed master plan "for the Maritime Administration to execute the responsibilities established by the MTRB report."

A new activity, which is a logical follow-up to the report on port development, is a study now under way on the impact of changing maritime services on local populations. The last decade has been a period of rapid change in land-side maritime facilities, brought about by the technological revolution in cargo handling and by the migration toward the urban periphery of industrial and commercial activities served by ports. The result is that service changes that benefit large populations may adversely impact local communities or groups who are affected by the installation of new facilities or by removal of employment opportunities to less-accessible locations.

The primary objective of the new committee is to emphasize the process aspects of planning waterfront facilities. In particular, the committee is examining the effectiveness of broad community participation in the planning and decision-making phases in order to suggest better ways of communicating with those likely to be adversely affected by change. Concern is with the nature of involvement, the structure of the process, the composition of the groups involved, and the stage of planning at which community involvement should begin. A possible end result would be elimination of some of the present complexity of regulations,

overlapping jurisdictions, and multiplicity and confusion of actors, which is largely the inheritance of history.

The committee recognizes that in any such planning process there will be substantial and legitimate differences of interest; not all groups can be satisfied with the final decision, and some people will be hurt. It is essential to develop a procedure, regarded as fair by all, for minimizing the adverse effects or adequately compensating those who are required to sacrifice their interests to the general welfare.

It is obvious that what applies to port facilities is equally applicable to other public facilities, and, to a considerable extent, the present study may be regarded as a pilot program for examination of a generic problem common to many different areas of interest under the jurisdiction of the Commission on Sociotechnical Systems.

TRANSPORTATION RESEARCH BOARD

The high level of interest in problems related to participation by groups in decisions that affect them is reflected in several programs carried out through the National Highway Cooperative Research Program (NCHRP) of the Transportation Research Board (TRB). The selection of NCHRP projects is made on the basis of consultation and voting by a large representative group from state highway departments and others; hence the selection of projects reflects the problems that currently concern the broad transportation community. An example of this kind of program is a current project on residential dislocation resulting from highway decisions. The need for study of this problem has come sharply into focus following the passage of the Uniform Relocation Act of 1970. The purpose of this act was to secure "fair and equitable treatment of persons displaced as a result of federal and federally assisted programs in order that such persons shall not suffer disproportionate injuries as a result of programs designed for the benefit of the public as a whole."

Regulations of the Federal Highway Administration require inventories of impacts, specifications of suitable replacement housing, and action plans for relocation for each of any alternate highway proposals considered in a given project.

The plan of the NCHRP research project called for a series of case studies to develop relationships between dislocation consequences and geographic and socioeconomic variables characterizing the groups affected. A detailed study will be made on six sites throughout the United States where new highways are being planned. These sites are in Fresno, California; Birmingham, Alabama; Little Rock, Arkansas; Auburn, New York; Gardena, California; and St. Petersburg, Florida. The research strategy involved interviewing 549 households in the "first wave" (390 scheduled to be relocated and 159 to remain near the highway right-of-way), followed by a sample of 190 households in the "second wave," chosen from among the 390 dislocated households.

An important preliminary conclusion of the work so far is that the consequences of dislocation are not predictable from the social characteristics of displaced households, and no evidence was found that current compensation practices discriminate for or against any particular population subgroup. But it was also clear that the greatest concerns of the dislocated households were economic and that there was a general perception that current compensation was inadequate to cover the real costs of dislocation, as well as unnecessarily slow. As might be expected, it was the elderly who suffered most from dislocation.

TRB also held two conferences for the Urban Mass Transportation Administration (UMTA) to "try out" on the affected interests proposed regulations and criteria for distribution of federal grant money for public transport facilities. These conferences provided feedback to UMTA prior to publication of final guidelines in the *Federal Register*.

TRB has now taken over the information systems for highway, rail, marine, and air transportation, and it also provides a Communications and Coordination Center for the National Network of Transportation Research Information Services (TRISNET). The TRISNET committee also develops advisory reports on specific issues related to the dissemination of information and the evaluation of information services.

EMERGENCY SERVICES AND CONTINGENCY PLANNING

In the past decade a rapid evolution has occurred in the need for and the organization of international disaster assistance. During the last 12 years, the United States government has responded to disasters in other countries in which over 3.6 million people lost their lives and 474 million people were seriously affected. It has contributed $1.6 billion out of a total of $3.6 billion donated for foreign disaster assistance. Seventy-five percent of all U.S. government disaster assistance has been expended in the last 5 years, and since 1957 the public sector share of U.S. disaster assistance has expanded from 15 percent to more than 80 percent. Responsibility for U.S. public disaster assistance has resided in the Office of the Foreign Disaster Relief Coordinator, recently renamed the Office of Foreign Disaster Assistance (OFDA), of the Agency for International Development (AID). The two areas of disasters generating the greatest number of victims where the U.S. government has provided assistance are civil strife or other hostilities and drought or famine situations. Many observers believe that the number and severity of disasters will increase substantially in the coming decade, primarily as a consequence of population growth.

NRC has a long tradition of involvement in disaster issues, such as the extensive series of studies on the engineering, physical, biological, and social aspects of the 1964 Alaska earthquake and the current series of on-the-spot studies of the structural aspects of earthquake damage. It was thus natural that as AID acquired increased responsibilities for the coordination of U.S. disaster assistance it turned to NRC for advice. An AID contract signed in May 1976 has resulted in the creation of a new Committee on International Disaster Assistance to provide guidance to AID/OFDA on the U.S. role in foreign disaster assistance, on the identification of problems in the disaster field to which better scientific and technical knowledge can contribute, on assessment of the state of the art in disaster assistance, and on the formulation of a long-range research program to improve U.S. capabilities. The committee will use a broad systems approach that will attempt to integrate disaster mitigation through preparedness, emergency operations, organization of relief activities, and rehabilitation. In the past these various aspects of disaster assistance have tended to be treated in a fragmented way with little coordination between them.

Last year's report of the Advisory Committee on Emergency Planning panel on the public policy implications of earthquake prediction has attracted a great deal of attention and has led to a new contract with the National Science Foundation (NSF) to set up the Committee on Socioeconomic Effects of Earthquake Predictions (CSEEP). The earlier report, *Earthquake Prediction and Public Policy*, stressed the need to develop a systematic, empirically based body of knowledge on socioeconomic responses to earthquake predictions as a foundation for planning. Of course, much research into the effects of earthquake prediction cannot be conducted in the absence of actual predictions; for such kinds of research the committee will suggest research designs that can be put into effect when a prediction occurs. However, other kinds of research can be carried out in the absence of predictions; e.g., how predictions and warnings are or might be disseminated in the seismological community and the probable effects of present laws, regulations, and government jurisdictions if predictions are made. Some information is available from the Chinese experience, and further interpretation and analysis is possible on how this experience might or might not translate to a U.S. setting. One of the major functions of the committee will be to develop criteria for NSF to use in evaluating and assigning priorities to research proposals related to the socioeconomic effects of earthquake prediction.

MATERIALS

The principal Commission effort in the field of materials is concentrated under the jurisdiction of the National Materials Advisory Board (NMAB), although much materials work also goes on under the auspices of BRAB and TRB. The application of new energy conservation standards in building, for example, will require more precise knowledge on the thermal properties of building materials, especially under dynamic conditions, although as indicated earlier the largest uncertainties are not in the properties of the components but in the behavior of complex assemblies of components. The work of the TRB, especially its Group 2, "Design and Construction of Transportation Facilities," involves important issues in structures and in the properties of concrete, pavement composites, bituminous materials, and general design criteria.

Of the many projects undertaken specifically by the NMAB, one of the most interesting is the series of studies on the fire safety aspects of polymeric materials; this is reported in an accompanying essay (pp. 191–196). Another activity is that of the Committee on Electroslag Remelting and Plasma Arc Melting, which was charged by the Department of Defense with assessing the state of the art and the U.S. position in both fields and with identifying needed research and development. Interest in the subject had been aroused by reports that the Soviets were ahead of the United States in certain aspects of these technologies. However, the comparative economics of electroslag remelting, plasma arc melting, and more traditional processes cannot be summarized in any simple statement. The new processes are superior in certain applications but inferior in others.

MILITARY PERSONNEL SUPPLIES

The Advisory Board on Military Personnel Supplies advises the U.S. Army Natick Research and Development Command on its programs. Here we will select only two examples of recent accomplishments.

The Board has advised Natick with respect to the development of a rapid radiometric screening technique for estimating the level of food-borne bacteria. The new method promises to accelerate greatly the process of assessing the microbiological quality of foods for distribution.

Another promising development is the thermoprocessing of foods in half-size steam-table containers. Foods packaged in these containers can be made commercially sterile and can be stored for long periods without refrigeration. Thus they can be used as replacement for frozen or canned items. Substantial interest in this process has developed in the civilian sector, and a major food company is currently test-marketing the concept in the Milwaukee area for use in commercial food systems.

Study Projects

COMMISSION ON SOCIOTECHNICAL SYSTEMS

NATIONAL INSTITUTE OF BUILDING SCIENCES

In the United States, the power to regulate building has been perceived principally as a "police power" reserved to the states. Historically, many states enacted home-rule provisions that delegated these powers to local communities, resulting in literally thousands of local regulatory jurisdictions. However, some states reserved these powers and others, in recent years, have reclaimed it. The federal government regulates its own construction and at various times and in various ways has assumed the right to regulate building in which federal funds are involved, directly and indirectly.

Initially, building codes and other regulatory instruments were intended to protect public health and safety; one could not build in such a way that would put his family, tenants or neighbors at risk. This concept has also been vastly expanded in recent years to include property protection and, increasingly, protection of the individual against the builder and even himself. A plethora of federal, state, and local agencies has arisen to regulate such aspects of building as the occupational health and safety of workmen and tenants, consumer products, or exposure to natural disasters. And ever-present has been the power of the federal government to regulate products flowing in interstate commerce, a power that can affect materials, products, and manufactured housing. Also, in 1976, the Energy Conservation and Development Act extended federal powers to effect building regulation in the interest of energy conservation.

Finally, there still are many aspects of building that are not regulated by government but are controlled by the private sector in the interest of assuring quality and performance of the end product and equity in the marketplace. In short, the regulatory picture in housing, building, and community design and development—the latter involving yet another vast area of regulation to control the nature and rate of development, environmental quality, and so on—is and is becoming increasingly more comprehensive and complex.

Contemporary federal concern for building regulation can be traced to the Hoover Commission; and in 1972, the Congress addressed itself anew to the issue. The result was the recommended creation of the National Institute of Building Sciences (NIBS) as part of the authorizing legislation of the 1974 Housing and Community Development Act. Among various reasons for creating the Institute, the Congress noted that

> the lack of an authoritative national source to make findings and to advise both the public and the private sectors of the economy with respect to the use of building science and technology, in achieving nationally accepted standards, and other technical provisions for use in federal, state, and local housing and building regulations, is an obstacle to efforts by and imposes severe burdens upon all those who procure, design, construct, use, operate, maintain, and retire physical facilities, and frequently results in the failure to take full advantage of new and useful developments in technology that could improve our living environment. . . .

The Act further noted that

> model building codes or even a single national code will not completely resolve the problem; that the lack of uniform housing and building regulatory provisions increases the costs of construction and thereby reduces the amount of housing and other facilities that can be provided; and that . . . the existence of a single authoritative nationally recognized institution to provide for the evaluation of new technology could facilitate introduction of such innovations and their acceptance at the federal, state, and local levels.

The Act went on to authorize the establishment of an "appropriate, nonprofit, nongovernmental institute to be known as the National Institute of Building Sciences," and mandated that it be created with, among others, the "advice and assistance of the National Academy of Sciences–National Academy of Engineering–National Research Council."

The legislation authorized a Board of Directors appointed by the President of the United States, with the advice and consent of the Senate. The legislation also stipulated that the members of the initial Board serve as incorporators and take actions necessary to establish the Institute. On April 19, 1976, the President of the United States nominated 18 persons to serve on the initial Board and designated Otis M. Mader of the Aluminum Company of America as Chairman. These nominations were confirmed by the Senate on June 24, 1976; and, on July 9, 1976, acting for the President, the Secretary of the Department of Housing and Urban Development, Carla Hills, swore in the chairman and 17 other members of the initial Board in the auditorium of the National Academy of Sciences. On September 8, 1976, Articles of Incorporation were filed with the District of Columbia Recorder of Deeds, and NIBS became a corporate entity. The National Academy of Sciences has received $140, 000 from the U.S. Department of Housing and Urban Development to provide the Institute with initial funding and to enable NRC to provide advice and assistance in establishing the Institute.

The purpose of the new Institute is to spur the infusion of building science and technology into the building industry. Part of that effort, as required by the authorizing legislation, is the development of "performance criteria, standards, and other technical provisions . . . for adoption by building regulating jurisdictions and agencies, including test methods and other evaluative techniques relating to building systems, subsystems, components, products, and materials with due regard for consumer problems."

In all its functions, the Institute is required by the legislation to involve other interested parties, public and private; to decentralize its activities as much as efficiently possible; and to coordinate with various agencies of the federal government, including the Department of Justice, "to ensure that the national interest is promoted and protected. . . ."

The NIBS Board of Directors has divided the proposed program into three parts:

- *Building Regulatory Support*—development, promulgation, and maintenance of performance criteria and standards; evaluation and prequalification of existing and new building technology; preparation of a research agenda and supporting investigations and special studies; and assembly, storage, and dissemination of technical data and other information associated with performance criteria and standards
- *Other Missions*—organization of a Consultative Council and liaison with the building industry; development of information conferences, literature, and publications; adjudication of building technology and standards disputes
- *Administration and Organization*

Advice to the fledgling Institute is being provided by the Building Research Advisory Board (BRAB) of the Commission on Sociotechnical Systems. BRAB will probably continue its advisory role beyond the Institute's formative stage, as well as continuing to deal with other regulatory issues not directly related to the NIBS charge, such as community and environmental standards and criteria.

Committee on Advisory Services to the National Institute of Building Sciences, Building Research Advisory Board, Commission on Sociotechnical Systems. Committee Chairman, Charles E. Schaffner of Syska and Hennessy, Inc.; Staff Officer, Robert M. Dillon.

RAIL TRANSPORT

This decade began with the collapse into bankruptcy of the nation's largest railroad, the Penn Central. The recession in the early seventies and hurricane Agnes in 1972 aggravated a desperate financial situation for railroads, particularly those operating in the Northeast.

The federal government responded in several ways: by the creation in 1971 of Amtrak, the National Railroad Passenger Corporation; by the creation in 1973 of the United States Railway Association, the prelude to the emergence in 1976 of ConRail, the Consolidated Rail Corporation; and, also in 1976, by the enactment of the Railroad Revitalization and Regulatory Reform Act—the 4R Act.

The critical problems for U.S. railroads include finance, marketing, and industry structure. Railroads generally face severe problems in raising the capital needed to upgrade their plant to remain competitive and to meet transport requirements; for example, how does a company refinance maturing 4.5 percent mortgage bonds in a 10 percent money market while earning 3 percent or less on invested capital?

Railroads must improve their services to customers to compete effectively in today's multimodal transport market. They must accurately determine costs to establish attractive but profitable rates. They must upgrade, often rehabilitate, an aged physical plant. They must somehow modernize labor agreements and route structures that date from the steam locomotive era. And they must do this in a climate of inflation, recessions, and growing resource shortages.

TRB AND THE RAILS

The Transportation Research Board (TRB) since 1972 has operated the Railroad Research Information Service, to provide ready access to abstracts of technical papers and important research reports.

In 1975, a special TRB committee recommended more direct involvement by the TRB in rail research. This had several results, including the convocation in 1975 of a 4-week Railroad Research Conference and the subsequent formation of five new committees to deal with specific rail issues: surface freight transport regulation, electrification systems, the states' role in rail transport, track structure system design, and intermodal freight transport.

REGULATION

In recent years, a broad range of criticism has been directed at government regulation of business, particularly the regulation of transport. While much of this criticism can be attributed to special-interest groups, including the rail carriers, a significant portion has come from the research community.

There is concern over the costs to the public of inefficiencies due to regulation, and indeed several researchers have recently attempted to quantify those costs. Another concern is that the benefits of regulation and the economic costs it imposes may not in all cases accrue to the same parties. In the specific case of transport, researchers have argued that regulation has raised the cost of goods to consumers and that it has impeded technological change.

Elements in these evaluations include the two classes of regulation. The more traditional one is "vertical" regulation, with the regulating agency having authority over and responsibility for an entire industry, e.g., the regulation of the railroad industry by the Interstate Commerce Commission (ICC). In contrast, there is also "horizontal" regulation, where the regulating agency has broad authority over specific aspects of many industries, but total responsibility for none. Typical is the control of the Environmental Protection Agency (EPA) over sources of pollution from *all* industry. Although EPA can control emissions from the railroads, among other industries, it has no overall responsibility for the well-being of the railroad industry.

The complexity of regulation, the problems of assessing its impact, and the difficulties of weighing costs and benefits have led not only to criticism of the research work on transport regulation, but also to inability of the research community to unite on the issues.

Against that background, TRB established its Committee on Surface Freight Transport Regulation and empowered it to

> . . . consider all aspects of research pertaining to surface freight transport regulation of all kinds. Consideration shall be given to research into the impact of regulation on social, public, and private costs and benefits; among the various modes; on regulated vis-à-vis unregulated carriers; and on technological change.

ELECTRIFICATION

Railroads around the world, except those in North America, are turning to electric propulsion to help improve service, lower costs, reduce adverse environmental impacts, and, in some cases, reduce dependence on imported fuels. The Japanese Tokaido Line, between Tokyo and Osaka, is, of course, electrified, as are the improved services on British and French railways. And, notably, electrification is not limited to the wealthy industrialized countries. Indeed, a reasonable question is why the wealthy and capital-intensive United States does not electrify its railroads as have less wealthy, relatively more labor-intensive countries such as Taiwan, Yugoslavia, and the Soviet Union. The answer is not simple and involves factors that range from the private ownership and freight orientation of U.S. railroads to the national policies of other nations and the passenger orientation of their railroads.

The TRB Committee on Electrification Systems will be involved with economic, social, institutional, and technical research pertaining to railroad electrification. The committee is not, however, limited to main-line railroad electrification. Its scope covers electrification systems for urban transit systems, and its membership reflects this broader role.

STATES AND RAIL TRANSPORT

Historically, the states have had a major role in highway transport, but their involvement with rail has been limited to tax collection, rate regulation, and, more recently and for only a few states, the operation of commuter rail services. But the rail crisis in the Northeast forced states in that region to take a more direct role to avoid the potentially severe impact of a crippling loss of rail service.

Federal legislation in rail transport has in several cases followed the model of the long-standing federal–state relationships in highway matters. But the past marginal involvement of states with their railroads means that many states that are well able to handle highway issues suddenly are confronted by problems and policy needs in rail transport that they are poorly, if at all, prepared to handle. Likewise, the railroads face new problems in dealing with the states.

Some of the immediate issues to be resolved include subsidization of service and rehabilitation of branch lines, and, for some states, an increasingly serious problem with commuter rail service. The states must also decide what role rail transport should have in the state economy. Should they continue to support branch-line freight service? Should they subsidize the shift of freight to trucks, and what will that do to the highways? Or should they simply abandon the service and accept the economic impact? Also, some states are deeply involved with redevelopment programs in large metropolitan areas that involve substantial relocation of railroad facilities; other states are involved, directly or through transit authorities, with the conversion of railroad right-of-ways to rapid transit use.

To help states deal with these issues and also to apply its experience


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Amtrak

with the federal–state relationships in highway transport, TRB established the Committee on the State Role in Rail Transport to

> . . . consider all aspects of research in the emerging role of the states in the field of rail transport. The committee's work shall be to encourage research and communication in, but not be limited to, state rail planning; financing, organization, and administration of state rail programs; and integration of rail transport into the overall state transport planning process.

TRACK

Nothing is more characteristic of or fundamental to a railroad than track. But years of deferred maintenance (neglect) have permitted once-good tracks to deteriorate to the point where train speeds over such track must be drastically reduced to avoid derailments. Although the principal need is for money to rehabilitate this track, research can help by improving maintenance management and methods, by developing improved materials, and by transfer of technology from other fields. Although railway track is very different from highway pavement, the permanent right-of-way of a railway is not so different from that of a highway: Both consist of a structure (track or pavement) laid on an earth embankment. The highway community has completed valuable research on soils, materials, embankment stabilization, drainage, bridges, and wayside environment applicable to problems of railroad track.

The state of the art for track has been advanced in other parts of the world, particularly in Europe and Japan. Although such developments cannot always be adopted for U.S. railroads, because of our heavier axle loadings and the great distance (costs) involved, much can be learned from them. Here, again, there is a role for research. The current scarcity of timber and the resulting higher prices for timber crossties have aroused the interest of U.S. railroads in the development of an adequate concrete crosstie. Planning for high-speed passenger trains in the Northeast Corridor has stimulated interest in new approaches to track structure. Again, much research will be required, and, again, transfer to railroads of certain aspects of highway technology seems promising.

The transfer of highway technology to the railroads has already begun. The American Railway Engineering Association (AREA) has adopted most of the steel construction specifications of the American

Association of State Highway and Transportation Officials (AASHTO); and is in the process of rewriting the concrete construction specifications using information generated by highway research.

The new TRB Committee on Track Structure System Design will approach track research from a total systems viewpoint that considers the track structure, the individual components, the supporting roadbed, the loading applied to the track, and the resulting interactions among loading, track components, and roadbed.

INTERMODAL FREIGHT TRANSPORT

Intermodal freight traffic that moves through without transloading has grown impressively in recent years. The most familiar manifestation of this intermodal growth is the "piggyback" shipment of highway trailers on railroad flatcars; but the most dramatic success has been the use of containers by the maritime operators. The development of specialized containerships and containerports has been a part of the almost total commitment of maritime operators to containers for all except bulk cargo, a commitment that has extended inland to the origin and destination points for freight moving in containers. For the inland part of the movement, the container is generally handled by highway truck or by railroad. But inland transport has not adopted containerization for its *own* purposes. The railroads seem to prefer to handle highway trailers rather than containers. Containerization for inland movements always seems to be "just around the corner"; yet that corner is never turned. The obstacles to wider use of containerization in inland transport appear to be institutional and historical rather than technological and apparently are related to the structure of inland transport in the United States.

The new TRB Committee on Intermodal Freight Transport will consider research into all aspects of intermodal freight transport.

Involvement with the problems of the railroads is a relatively new activity for the Transportation Research Board. With the support provided by the Federal Railroad Administration of the U.S. Department of Transportation and by the Association of American Railroads, a private group, TRB will continue to expand its rail research activities as one of its contributions to a truly comprehensive and active national program for dealing with current and future problems in transportation.

FIRE SAFETY ASPECTS OF POLYMERIC MATERIALS

On March 22, 1975, at about 12:20 CDT, a candle flame ignited polyurethane air sealants between the Unit 1 reactor building and a cable spreading room of the Browns Ferry nuclear plant in Alabama.* The fire spread into the walls of the reactor building, eventually burning some 4,000 pounds of polyvinyl chloride with the attendant evolution of 1,400 pounds of chlorine.

The fire department at nearby Athens was called about 40 minutes after the fire began and arrived shortly thereafter. The fire chief's recommendation that water be used on the fire was turned down, out of a general belief that "water should not be used on electrical fires" and a specific one that short-circuiting caused by water flooding would make it more difficult to control the reactor. At about 7:00 p.m., water was used; no burning was evident by 7:15 p.m., and the fire was officially declared out by 7:45 p.m.

In an assessment of this fire, the U.S. Nuclear Regulatory Commission essentially agreed with the fire chief that water should have been used immediately.†

The incident contains many lessons, including the fact that, in a structure where safety is an intense concern, a major fire hazard did exist and that, when there was a fire, technically trained personnel could not immediately cope with it. Moreover, there is a lesson in the fact that the major damage came from fires within the building walls, where the burning materials were difficult to get at and emitted fumes opaque and toxic enough to severely discourage fire-fighting attempts.

Polymeric materials—including those that burned at Browns Ferry—are ubiquitous in commercial and residential structures, in virtually all forms of transportation, in furniture, in clothing, and in many other uses. Polymeric materials are not new, if one includes cellulosic materials such as paper and wood. What has changed is the diversity of polymeric materials, as the historical ones have been joined by synthetic polymers

* U.S. Nuclear Regulatory Commission. 1976. Recommendations Related to Browns Ferry Fire. National Technical Information Service. Springfield, Va. (NUREG–0050), *passim*.
† *Ibid.*, pp. 23–24.

that are adaptable to specific uses, often inexpensive because they are adaptable or easy to make, versatile in their applications, or lightweight in comparison to natural materials.

But, as Browns Ferry perhaps demonstrated, materials however novel can be dangerous if misused. All synthetic polymers—and the natural ones, for that matter—will burn if supplied with sufficient heat and oxygen. But beyond that simple axiom there are complexities because of the immense uncertainties of the likelihood that a given polymeric material will burn under varying conditions, its rate of burning, the nature of the toxic fumes emitted, and above all the damage and risk to human life that may ensue. Different polymeric materials burn differently, depending, for instance, on whether they are homogeneous or combined with other polymers, as in blended fibers. Their burning characteristics depend on their setting; on whether, for instance, they are sited in the corner of a room, in wall panels, in an air duct, or in an airplane cabin. One upshot is that a material that is combustible may not be hazardous—if its fire cannot spread; or, put another way, flammability is the property of a room or building, not of any one material. And, aside from the geometry and the settings in which synthetic polymers are used, the behavior of the polymers in a fire can depend not only on their chemical structures, but also on their formulation into a product. As a reviewer remarked:

> Generalizations on the behavior of polymers during combustion should be made with great care. Pyrolysis reactions and decomposition products, and therefore the succeeding oxidation reactions and combustion products, vary with temperature, heating rate, endotherms and exotherms, diffusion rates and amounts and characteristics of any solid char.*

STATISTICS AND SITUATIONS

The point is that most statistics are not very helpful in analyzing fire risks associated with various polymeric materials, and the analysis must be determined by the particular use and situation. Conventional statistics can be deceptive in aggregating the multiple factors affecting the ignition, burning rate, smoke emissions, and so on of a fire into a single

* Carlos J. Hilado. 1973. An overview of the fire behavior of polymers. Fire Technol. 9(3):199.

TABLE 1

Disciplinary studies

1. Materials—state of the art
2. Test methods, specifications, and standards glossary—state of the art
3. Special problems of smoke and toxicity
4. Fire dynamics and fire scenarios
5. Executive summary

Specific uses

6. Aircraft (civil and military)
7. Residential and nonresidential buildings, custodial buildings, and mobile homes
8. Land vehicles
9. Ships
10. Mines and bunkers

number. However, the very detailed statistical studies of Britain's Home Office and Johns Hopkins University are proving immensely helpful to the technical community in understanding more exactly the initiation and behavior of fires, as well as their damage to life and property.

The importance of being specific in discussing the fire safety aspects of polymers underlies an NRC study now under way. The study, to be completed in October 1977 under the aegis of the National Materials Advisory Board of the Commission on Sociotechnical Systems, will eventually produce 10 volumes on the fire safety aspects of polymeric materials: 5 disciplinary reports and the remainder on fire safety aspects of polymers in specific uses (Table 1). The sponsors of the study and their particular interests are given in Table 2.

TESTS

The committee's work has already reinforced the general feeling among fire experts that small-scale tests do not adequately predict the nature of a fire and the associated hazards under actual conditions and that, as expressed by a presidential commission, "[m]ost tests do not simulate complexities of real fires." * The problem seems to be rooted not simply in

* National Commission on Fire Prevention and Control. 1973. America Burning. Washington, D.C. p. 65.

the inadequacy of test designs but also in a lack of fundamental information: Combustion processes in fires are poorly understood, and there appears to be no reliable way, for example, to relate the chemical and physical properties of polymeric materials to the emission of smoke and the formation of toxic gases during a fire. The results are tests and

TABLE 2

Sponsor	Interest
Department of Agriculture	Flammability problems of wood (a natural polymer) and fibers (natural and synthetic polymers)
National Bureau of Standards	Test methods, specifications, standards, material properties relevant to fire
Department of Defense	Aircraft, vehicle, ship, and fabric fire hazards
National Institute of Occupational Safety and Health	Fire hazards in the work place and during processing of polymers
Department of Housing and Urban Development	Fire hazards in buildings, mobile homes; standards for insurance
Bureau of Mines	Fire hazards arising from polymeric usage in mines—chiefly belts, electrical insulation, and barriers
U.S. Coast Guard	Fire hazards in construction, furnishing, and carry-on goods in merchant ships
Federal Aviation Administration	Fire hazards in the extensive use of polymers aboard commercial aircraft
Energy Research and Development Administration	Fire hazards associated with electrical and thermal insulation, computers, offices
Environmental Protection Agency	Hazards associated with manufacture, fabrication, scrap disposal, and combustion products of fire-retarded polymeric materials, particularly after these enter the environment
Consumer Product Safety Commission	Fire hazards associated with consumer products, particularly flammable textiles, and associated toxicity problems
U.S. Postal Service	Fire hazards associated with paper dust, polymeric containers and equipment, and the major hazard—the mail

measurements that do not reliably predict the combustibility and behavior of a particular material in a fire under different conditions.

Data that are available are often of poor quality—imprecise and incomplete. Specifications and standards may not be reliable or consistent, with the same words having different meanings to different people. Accordingly, the Committee has prepared a new glossary.

FIRE DYNAMICS AND SCENARIOS

A major task of the Committee has been to collect the data, evaluate it, sort out the reliable, and identify those areas where further measurements and research are needed. The Committee has turned to fire dynamics and scenarios in part to provide a framework for evaluating and using available data and to provide some priorities for efforts to fill in the gaps. Fire dynamics means a careful and, where possible, quantitative description of what actually happens in a fire—ignition temperatures and conditions, the rate of flame spreading, burning intensities, combustion products, smoke opacity. For many situations, precise data for any of these elements are not available, with analysts often having to fall back on qualitative and largely empirical information, as is the case, for example, with high-rise buildings, wide-body aircraft, new products, and similar situations in which sufficient experience and tests covering various conditions are not available.

In spite of the shortcomings of small-scale tests, and inadequate data, the Committee has collated and evaluated information available on fire dynamics and used that to generate fire scenarios, which it defines as generalized descriptions of real and hypothetical fire situations. The advantage of the scenario approach is that it can be fitted to quite different potential fire situations, perhaps revealing shortcomings in data or illustrating which materials in what form and geometry are best for a particular use in terms of fire safety. Thus, in the case of aircraft cabins, the Committee has applied its scenario approach to identify problems for different uses of polymeric materials in aircraft cabins: seat cushions, wall paneling, air ducts, galley equipment, emergency oxygen supply, lavatory furnishings, electrical and thermal insulation, and windows.

The United States is surely the world's most technologically advanced country. It also has the world's worst fire safety record, as measured by per capita losses.* Whether the two facts are related is problematical. But, given the evidence provided by the Committee and other groups, such as the National Commission on Fire Prevention and Control, we can now assume that our technological ingenuity in devising and using materials has not been matched by a comparable effort to ensure their safety. The Committee's goal is to point out how the gap can be narrowed.

Committee on Fire Safety Aspects of Polymeric Materials, National Materials Advisory Board, Commission on Sociotechnical Systems. Committee Chairman, Herman S. Mark of the Polytechnic Institute of New York; Committee Consultant, Robert S. Shane.

* Howard W. Emmons. 1974. Fire and fire protection. Sci. Am. 231(1): p. 21.

Commission on Natural Resources


HEMLOCK
CATHEDRAL

Comprehensive Environmental Management

GORDON J. F. MacDONALD

Federal environmental policy has been shaped the past several years by the passage of laws dealing with air, noise, water pollution, and, in 1976, toxic substances. These laws are quite dissimilar, but they do have two common characteristics: They mandate strict reliance on complex regulations intended to limit the emission of pollutants and they all require heavy public and private financing.

These two characteristics form an environmental policy prohibitive in theory and expensive. This policy, consisting of environmental regulations and laws now in effect, is fragmented, sometimes ineffective, difficult to administer, and costly to the public. Reform will be both difficult and expensive. But even though several attempts to improve environmental policies have fallen short of expectations, I still believe that we can do better. I believe we can create alternative strategies for maintaining a healthy environment that are less costly and more efficient.

Gordon J. F. MacDonald is Chairman, Commission on Natural Resources, and Henry Luce Professor of Environmental Studies and Policy and Professor of Earth Sciences at Dartmouth College.

FLAWS

First, what precisely *is* wrong with current policies? Certainly the fault is not wholly in poor administration or execution; it is in part generic, due to several basic flaws in environmental legislation:

- The natural unity of the environment and the land-use implications of environmental laws were ignored. We failed to recognize that air, water, and land are interwoven and inseparable parts of a whole, whatever the legislation says; and we compounded this failing by concentrating our policies on the wrong parts—air and water. Efforts to control air and water pollution, if not accompanied by strong measures for controlling land use, will be ineffective, since what happens on land usually determines the extent of air and water pollution.
- In addition to treating air and water as separate entities, the applicable pieces of legislation handle them very differently. Air pollution is regulated for the most part by the federal government. Water pollution control relies to a large extent on regional, state, and local administration. Land and its use, except for the one-third of the country's land owned by the federal government, is dealt with in good part by purely local regulations, including zoning and property taxes. No effort has been made at consolidation or coordination by different levels of government to meet different and sometimes conflicting goals.
- Current environmental laws treat air and water resources as free public goods, with the cost of abuse still borne by the public rather than by the user.
- Our environmental policies ignore resource problems—from energy and minerals to renewable resources. A comprehensive management system would insure that the goals of pollution abatement are consistent with the resolution of resources concerns.

Against this background, the weaknesses in our environmental laws now seem inevitable—the consequence of applying the wrong tools to poorly understood problems. Existing environmental laws rest in good part on inappropriate and misleading assumptions, for example, the legalistic assumption that simply to prohibit a harmful activity is to stop it. Thus, when the direct enforcement of a prohibition does not produce the expected results, the immediate inclination is to cite faults in the law's penalties, provisions, or administration; rarely is it suggested that the fault is in the premises on which the law is based.

ENVIRONMENTAL LITIGATION

But instead of reevaluating the assumptions in these laws—for example, that air and water are free goods and therefore cannot be treated as property, or that adversary proceedings are applicable in all situations—we simply advocate stronger laws. This call for strength fails to recognize that our reliance on the traditional legal structure as a framework for environmental policy actually weakens environmental efforts.

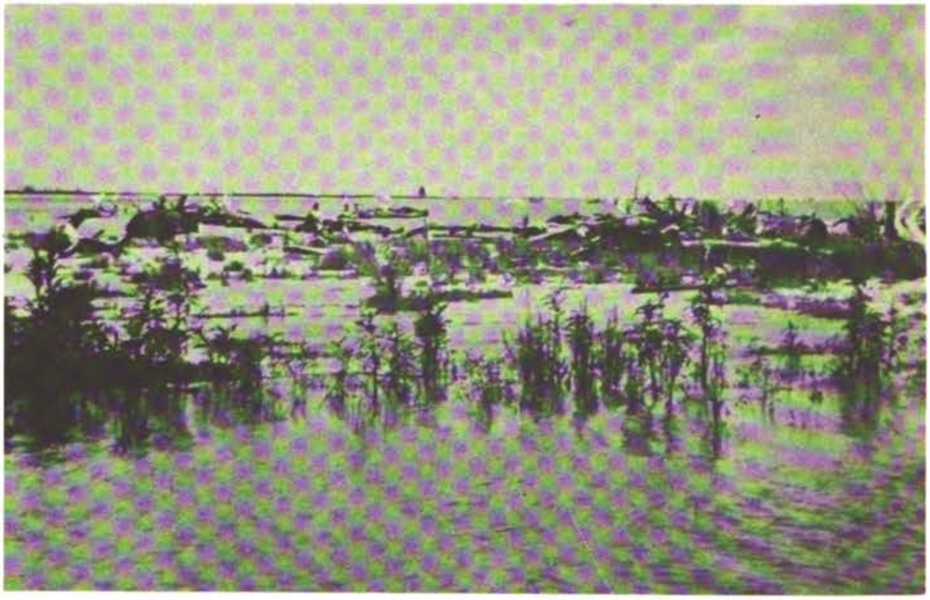
The Constitution wisely provides that legislation cannot impose "undue burdens" on interstate commerce and that all laws are subject to due process. The result is courts clogged with environmental cases and the irony of legislation probably having produced more litigation than pollution abatement. Nor is there any incentive under the present regulatory system for polluters to develop cheaper methods of pollution abatement; rather, the tendency is to retain high-cost technology, since it strengthens "undue burden" arguments before the courts.

ENVIRONMENTAL MANAGEMENT AND COSTS

The regulatory approach to environmental management also distorts market mechanisms. By failing to provide the proper disincentives against pollution and the appropriate incentives for pollution abatement, the regulatory approach at best treats pollution after it occurs—not before; and it does this largely at the expense of the public rather than polluting industries. These public costs include the unquantifiable ones of damage to health or aesthetics and the misuse of material resources; and they include the dollar costs, indirect as payment through taxes for sewage-treatment plants and other abatements or directly in the form, for example, of higher car prices for automobile emission controls.

EXTERNALITIES

There has been—and perhaps still is—considerable confusion as to whether the primary goal of environmental policy is to treat pollution before or after it occurs. To date, the latter purely remedial approach



has dominated environmental efforts. But the result has not been to reduce the residual mass, but only to mitigate its harm to certain parts of the environment.

Most economic activities return waste residuals to the environment, with a large portion of these, as stipulated by the Second Law of Thermodynamics, rendered both unusable and unreturnable. But waste residuals can be harmlessly dispersed into the environment to a certain extent, given some low level of use. However, a point is reached when residual wastes affect several users of a common resource, such as air or water; and therefore the residual wastes produced by one user of the resource now affect others. Such spillover effects, or externalities, are not effectively discouraged by our current environmental regulations. Single-point sources of pollution are often difficult to locate, and they require continual monitoring, making their regulation very difficult.

INTERMEDIA SPILLOVERS

Moreover, environmental regulations don't recognize that spillover effects do not respect the artificial divisions we have imposed on the environment. Waste residuals never disappear, but only change their form; they must go someplace, and that place is usually another environmental medium. Air pollution in one area may precipitate as acid rain elsewhere. Water pollutants can transpire from the water into the air. Burning sewage sludge, which is still done, may "solve" a solid waste problem, but it also pollutes the air. Intermedia spillovers are (or should be) instructive to makers of environmental policy. For just as air pollution can become a water pollution problem or land misuses result in air pollution, so attempts to regulate one environmental medium such as air will eventually affect other environmental media and attempts to regulate them. For example, it is now recognized that underlying the control of air pollution is the need to control many activities on land. The Supreme Court's interpretation of EPA's mandate "to preserve and enhance the Nation's air quality" implies that EPA must prohibit the degradation of air quality exceeding the minimum standards set by the Agency. Such a requirement for nondegradation of air quality can be a powerful determinant in decisions on industrial siting, urban development, and other uses of the land.

The Clean Air Act Amendments of 1970 contain two other examples of air pollution controls relating to land use: the control of urban transportation and the control of indirect sources, the latter being nonpolluting facilities such as shopping centers or stadia that attract substantial traffic. The legal situation in regards to both mandates is, not untypically, quite muddled, with various and sometimes contradictory court decisions leaving EPA uncertain of its power and duties *vis-à-vis* the states. The Congress has also restricted the funding needed to enforce indirect source pollution controls, and EPA has indefinitely delayed their implementation.

But in considering both transportation and indirect source pollution controls, their strong influence—or rather EPA's potentially strong influence—on the use of land and its economic development has become apparent. Because of this, both houses of Congress are considering amendments to the Clean Air Act. The Senate Public Works Committee's Subcommittee on Environmental Pollution stresses a regional approach for both air quality planning and the setting of compliance schedules for transportation control measures. However, regional agencies would be required to apply to circuit courts for authority to promulgate transportation controls if a state's plan is rejected. In contrast, the House Interstate and Commerce Committee's Subcommittee on Health and Environment has proposed an approach relying on federal and local cooperation. Under the House bill, implementation plans for controlling indirect sources, transportation pollution, and significant deterioration would require federal consultations with the affected local governments, regional agencies, or councils of government. These latter groups can also impose EPA's pollution control plans if they decide they have adequate authority.

WATER POLLUTION CONTROL AND LAND USE

There are similar linkages between efforts to control water pollution and effects on land use. These linkages, implicit in the Federal Water Pollution Control Act of 1972, have been recognized in several ways. For example, in March 1975 EPA and the U.S. Department of Housing and Urban Development signed an agreement designed to streamline land-use planning at local, regional, and state levels. This agreement attempts to define the relationship between EPA's Area Waste Treatment Management Planning Program under Section 208 of the 1972 Federal Water Pollution Control Act and Housing and Urban Development's Comprehensive Planning Assistance Program under Section 701 of the Housing Act of 1954.

Section 208 of the 1972 Act is important for land-use planning, since it provides a basis for regulating nonpoint sources of pollution. The plan required by Section 208 must establish a regulatory program to control the location, modification, and construction of all facilities that may discharge pollution; and the program must also contain long-term specifications for the construction and use of municipal sewage-treatment plants.

The requirements of Section 208 apply to the state, but may be carried out either by local agencies or by the state. The Act provides that the governor of each state may designate for area-wide planning those areas with severe water-quality control problems. In all areas of the state not so designated, the state itself is responsible for the 208 planning. The federal government provides the planning funds.

The muscle behind 208 is that once the 208 plan is approved by EPA and the agency responsible for its implementation has been designated by the state, all grants for the construction of municipal sewage-treatment plants, must be made to the designated agency (or, as often happens in practice, to the state itself) and must be in conformity with the approved plan. Also, no permit may be issued under the National Pollutant Discharge Elimination System if the permit conflicts with the approved 208 plan. Thus, the 208 plan must be implemented; once approved, it cannot be ignored.

The planning process involved in the Water Pollution Control Act is not limited to Section 208. Section 303 of the Act requires that the state participate in a continuing planning process. Plans prepared under Section 303 do not require new regulatory source control programs such as those required by Section 208, but are essentially management documents spelling out what needs to be done with regard to water pollution problems of river basins.

As with air quality, a nondegradation principle in water-quality planning is introduced in the Federal Water Pollution Control Act of 1972. That Act holds that all water bodies whose actual water quality is better than that required by the water-quality standards should be protected from degradation. How this nondegradation is to be implemented and consequent implications for water quality and land use are still uncertain as EPA delays issuing guidelines.

Another section of the Water Pollution Control Act, which has far-reaching land-use implications, is Section 201. This section authorizes the Administrator of EPA to make grants for planning and construction of publicly owned sewage-treatment plants. The intent of Section 201 is clear: to improve water quality. However, construction grants awarded under this section can have enormous implications for land development, since in large measure the size and location of sewage-treatment facilities along with interceptor sewer lines determine the extent and shape of community growth.

The long-range implications of such sewer construction were first clearly outlined in a study on construction and residential land use sponsored by the Council on Environmental Quality. In examining events since the passage of the Federal Water Pollution Control Act, it appears that many localities are seeking sewer lines and sewage-treatment plants not only to improve water quality but also to increase their tax base by using a federal subsidy to foster suburban growth on vacant land. This certainly runs counter to the stated intent of the Act, which requires the EPA Administrator to encourage sewer planning that combines considerations of open space and recreation with those of waste management.

These examples are intended to illustrate the overlapping and at times contradictory effects of air and water pollution laws, the effects on land use of these laws and, conversely, the fact that land use can be a prime determinant of the nature and degree of air and water pollution. And the examples illustrate that in place of a fragmented approach to

environmental problems, what is badly needed is truly comprehensive environmental management.

ENVIRONMENT AND THE ECONOMY

The key to mounting such a comprehensive policy is the recognition that pollution is an economic activity and that our failure to consider our resources as economic goods causes continued pollution as well as economic misallocations. My contention is that pollution occurs and will continue to occur in unacceptably large amounts until we rectify the failure to incorporate our environmental resources into our economic system. Because shared and abused resources are common property, resources cannot be or can only be imperfectly assigned an economic value. They are incorrectly considered free and used accordingly. Similarly, because air and water resources cannot fairly or easily be reduced to individual ownership, they are mistakenly excluded from an economic system founded on the principle of private property.

In contrast, land is the one environmental medium that can be weighed in economic terms: as property or as real estate. The fact that land is already a part of the economic system, that its value is commonly recognized, and that most pollution originates on land emphasize the centrality of land use in efforts to abate pollution and better allocate costs. To repeat a familiar statement that is nevertheless close to the mark: We as a society make much better tax collectors than regulators, particularly at the federal level.

EFFLUENT AND LAND-USE CHARGES

To couple the need to protect the environment with the realities of our economic system, I recommend a comprehensive management policy relying on effluent charges, the classification of land according to priority uses, and land-use charges based on that classification.

Effluent charges or taxes should be set at a level that encourages the reduction of pollution to ambient levels and spurs innovative research and development efforts by industry to improve internal pollution controls and to devise nonpolluting processes. Ambient levels would be set and the monies collected regionally.

Also, states would classify their land according to priority and secondary uses by applying regional environmental standards still to be developed. A system of charges would be devised by each state based on a valuation of the cost differences between the assigned priority use of the land and its actual use.

USER VERSUS EFFLUENT CHARGES

The use of effluent charges has long been advocated by resource economists as the most effective and equitable means of abating pollution in our economic system. This suggestion inevitably sparks controversy. Part of this is due to the confusion between user charges and effluent charges. Although commonly considered synonymous, these charges are distinct concepts and result in different ends. User charges are tied to the cost of sewage-treatment facilities provided by municipalities; they reflect the cost to the community of cleaning up pollution after it has occurred. The revenues collected through user charges pay the government to build and operate treatment plants, but do not necessarily incite the polluter to stop pollution.

In contrast, effluent charges are not related to the external cost of treating pollution, but rather to the internal cost of preventing it. Market mechanisms now operate because each firm must decide internally by how much its effluent tax must be reduced—and therefore the amount by which its pollution emissions must be reduced—if it is to remain profitable and in business. Such decisions are now imposed externally, to the detriment both of economic efficiency and administrative enforcement. Because effluent taxes are not biased toward any particular form of pollution abatement, unlike most existing regulations that specify equipment and processes, the charged industry or firm can itself determine the cheapest method. This is especially attractive since it encourages not just "end-of-the-pipe" measures, but also more basic changes in production processes and the use of raw materials. In sum, effluent charges prod polluters to apply the least wasteful production methods and most efficient abatement procedures and to internalize decisions on the level of pollutants allowed and the avenues of research and development to be pursued. Charges are probably more effective in reducing pollution, since they do not call for an omniscient regulatory agency to make decisions that the industry is far better equipped to do.

Because firms will opt toward the least expensive pollution control, effluent charges should maximize pollution abatement and minimize cost. Because the costs of pollution control tend to increase exponentially with linear increases in percentage of treated effluent, charges can be set high enough to achieve the desired abatement level. Put another way, since effluent charges are based on unit of pollution emitted, there is continued economic pressure to reduce pollution even below ambient standards—to further reduce costs and to increase profits. Under the present regulatory system, a firm needs only to reduce pollution to ambient standards and has no incentive to do more.

CONS

Two arguments used against an effluent charge system are that it needs the same information base as the present system and that it is neither easier nor cheaper to administer.

But *any* system for environmental management will require a sophisticated information base. And the intensive search by industry for ways to reduce effluent charges by reducing its pollution would assure a constant expansion of the information base, a pressure lacking in the existing regulatory approach.

The second argument—that the charge system is not any cheaper to administer—is valid. But the system still has two cost advantages: First, it generates its own revenue and obtains it directly from the polluter instead of through the taxpaying public; and, second, there is evidence that even with similar administrative costs the effluent tax system still yields more benefits than a regulatory system.

Arguments against effluent charges also challenge the statement that the charges would exert continuous pressure on the discharger to improve pollution abatement technology. Rather than polluters innovating, it is argued that in reality the innovation occurs outside the polluting industry, i.e., in the pollution-control industry. But the distinction between the polluting industry and the pollution-control industry assumes a too strict isolation in this era of corporate interests and multifaceted firms; and it ignores the fundamental interconnections between polluting industries and pollution-control industries, with the latter existing only to serve the former. Not only will the demand for pollution-control technology be intensified, but also the spurring of competition among both polluters and pollution-control firms to find ways to reduce effluent charges makes both for greater innovation and its more rapid adoption.

REAL COSTS

The use of pollution charges will result in higher consumer prices. But the ultimate effects should still be beneficial, for the charge system should reduce the market distortions and economic dislocations that occur when only the public bears the costs of environmental damage and its treatment. Rather than all the taxpayers paying for the damage done to the public resources, the consumer will pay higher prices for goods whose production and use incurs environmental harm. This will increase consumer awareness of the *real* costs of purchases. Because products whose manufacture and use entail little pollution would in time be cheaper than those that cause more damage, the consumer would be inclined to buy more of the former. In this way, effluent charges are quite compatible with the market mechanisms and the goals of overall reduction of residual discharges into our environment.

Standards to protect health and the environment have been set for air and water pollution, but not for land use; nor has it been recognized that these standards have vast implications for land use. Conversely, the existing air and water standard can be used—through a system of land-use charges—to establish land-use controls.

The regulation of land use is now largely done locally, mainly by the use of zoning and property taxes. Yet, generally speaking, zoning as a regulatory tool has not been very effective, with variances the rule rather than the exception. Local units of government are often unable to consider larger regional questions; and affected citizens may not be involved in the decision-making process, because of the lack of notice and information, or, on occasion, because of venality on the part of those responsible.

Associated with the failures of zoning have been the contradictory instructions given to the local authorities by state and federal agencies, resulting from contradictions in federal legislation. Some steps have been taken to improve the situation, such as the agreement between EPA and the Department of Housing and Urban Development to streamline land-use planning at the local, regional, and state levels. However, for the most part, these agreements between federal agencies seem to be cosmetic and do not deal with actual local problems.

Regulatory measures, particularly zoning, can and do distort the market system. Arbitrary zoning decisions have over the years enhanced or decreased the market value of land in artificial and often capricious ways. These difficulties are further exacerbated by the fact that zoning and property taxation are not considered by the same units in local governments; and, therefore, conflicts can and do arise when zoning regulations run counter in their intention to property taxation.

Property taxation is now the main source of revenue for local governments, providing something like $50 billion in 1976. There are wide variations in tax rates, with those in cities often higher than those in adjoining suburbs where the income per individual may be several times higher. The effects of property taxes on land use are many and varied. For example, under the tax system applicable in many areas, large tracts of vacant and close-in suburban land, as well as central sites that could be renovated and rebuilt, are instead withheld from the market in expectation of price increases. This land is taxed at effectively low rates in relation to realistic market values, but improvements on the land are subject to relatively greater tax burdens. Consequently, prices are high in urbanizing areas, and developers leapfrog out to cheaper land for residential development. The Rockefeller Task Force on Land Use and Urban Growth in its report, *The Use of Land,** which appeared 4 years ago, documents this phenomenon in impressive detail.

The results are that community sizes are not optimal; the costs of providing basic services such as water, sewage, and education are increased; and commuter problems are intensified.

LAND-USE CHARGES

In a land-use charge system, the charges will be based on the value assigned to the difference between the priority and actual use. Priority uses, secondary uses, and on up the ladder will be determined by a classification system based on criteria that are already documented and recognized. These criteria incorporate descriptions of the soil and subsoil char-

* Rockefeller Brothers Foundation. 1973. The Use of Land. Thomas Y. Crowell, New York.

acteristics of the land area, vegetation, natural animal life, and surface and groundwater characteristics. I would also include the historical setting of the land—how it has been used in the past and what the traditional perceptions of its use and value have been by the community. On the basis of this information—much of it available from the U.S. Geological Survey, the U.S. Census Bureau, and the U.S. Department of Agriculture's Soil and Water Conservation Service, as well as various state and local agencies—at least a preliminary judgment can be made of the land's carrying capacity. Carrying capacity measures the resiliency of land: the uses to which it can be put without irredeemably changing it. Once a marsh is dredged and filled, it will never return to its highly productive biological state. Once a steep slope is developed for residential use (a practice too often followed in Southern California), it will erode, shift, and slide, never to be the same again. Rich, deep alluvial soil turned into a suburban development will not soon, if ever, be returned to productive agriculture.

Land description is a relatively straightforward and largely scientific concept. True, assigning use priorities or classifying land does require value judgments and indeed should involve intangibles, such as the land's history, aesthetics, or people's notion of the values of nature. But, again, the scientific basis is on relatively good ground. For example, we know that swamps and marshes play an extraordinary role in maintaining the biota that characterizes ecosystems, as, in very different ways, do desert scrublands. These values can be assessed in terms of how they contribute to the health of the world about them.

Who should undertake the task of land classification, given that a combination of scientific, social, and even political judgments are involved? I believe that the responsibility should be the state's, but delegated as far as possible to local authorities. The federal role should be to provide basic scientific data and to try to insure the adequacy of historical records.

The classification of land leads directly to assigning priorities for its use. For example, developed land that is of limited ecological value can be given the highest priority for heavy industrial development. Other lands, because of their soil and precipitation characteristics, should have agricultural or rangeland uses as their highest priority. Still others, for historical and social reasons, should be maintained and enhanced for residential and commercial purposes.

Land classifications and priority assignments are neither simple nor easy and must be a calculus of environmental, economic, and regional elements. Moreover, the cooperation of federal, state, and local agencies is necessary. For instance, the Secretary of the Interior would provide the criteria for defining environmentally critical areas, in consultation with state and local agencies.

Similarly, the Secretary of the Interior, the Secretary of Transportation, and the Secretary of Housing and Urban Development should be required to develop guidelines defining areas critical to economic development. Consultation with the Secretary of Commerce and with state agencies responsible for the economic development would be essential. Finally, the Secretary of the Interior and the Secretary of Housing and Urban Development should develop criteria, again in cooperation with the states, to define important regional developments. These three areas—environment, economic development, and regional considerations—should have priority with respect to classification and promulgation of land-use charges.

In my view, the states should be required, following action at the federal level, to define and develop priority uses of land within a given period of time of the issuance of the relevant criteria. Such a program should be supported through grants by the federal agencies.

By use I do not mean a very strict and confining definition. Rather I would leave it up to the state to establish the classification and definitions for priority uses of the land. For example, heavy industry, light industry, dense residential, light residential, agricultural, recreational, and wilderness might be the initial categories of such a priority use classification system.

MARKET VS. REGULATION

The basic concept of employing economic incentives or land-use charges implies a tax based on the difference between the assigned priority use for the particular land and its actual use. If an industry wishes to locate on a wetland, it may do so provided that it is charged to an extent commensurate with the total cost to society for that use. That cost should be borne by industry on an annual basis and should reflect the losses of fisheries, wildlife, recreation, and so on. Or, the state may value its wetlands so highly that development should be prohibited altogether. Such prohibitive zoning should be allowed in a very limited way similar to the existing limitations on the discharge of highly toxic materials into the environment.

Unlike the property tax, the primary intent of the land-use charge is not to raise revenue, but rather to apply market mechanisms to influencing land-use decisions. Revenues raised by users' charges can be used to continually improve and revise land classifications and also to administer the use-charge system. Revenues, over and above that required for the implementation of the process, could be used to increase land holdings benefiting the general public. But, ideally, the land users' charge system would generate little or no surplus revenue and should not be too heavily relied upon to generate monies for governmental administration.

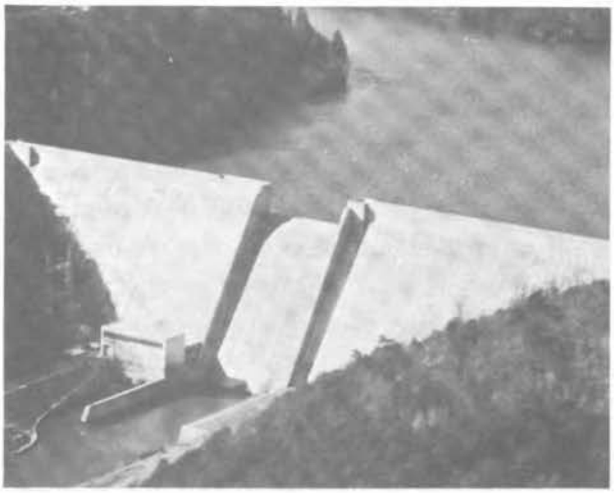
The imposition of land-use charges mandates another major reform: the abandonment of property taxes as a significant source of local revenue. Any system of land-use planning and of user charges superimposed on the existing system of land or property taxes can only intensify the chaos. Furthermore, the municipal desires for revenue might understandably conflict with the maintenance of priority land-use standards. Therefore, instead of property taxes, I suggest a switch to some form of federal revenue sharing, both general and special, but recognize that this may mean higher federal taxes.

Clearly, such major changes cannot be accomplished overnight, but neither can any of the other suggestions I have made. However, it is imperative that we make a start towards substituting economic measures for regulatory ones, especially since implementing these suggestions will neither be easy nor rapid.

Some of the questions sure to be raised in response to my suggestions constitute a valid criticism and reflect valid fears. Will the institutions responsible for land classification be less susceptible to developmental pressures and political pressures? I think the required scientific data base, plus a system of public hearings, will in part aid objectivity and fairness. How will the land users' charge be determined? How can we be sure that they will be high enough to discourage damaging developments? These are tough and serious questions since they focus on the long-term real value of land as opposed to the immediate market value. They are concerns that challenge our short-term, dollar-and-cents conception of land. They need public attention and discussion.

Or will use charges based on land classifications simply create another bureaucracy? Again, I repeat the statement that we have been better tax collectors than regulators. While there will indeed be additional people involved in this system, it seems realistic to expect the benefits to far exceed the costs of additional bureaucracy.

Our present pollution-control laws for water and air have deep and lasting implications with respect to how we use land, air, and water. We should recognize these, study them, and consider alternatives. At the same time we badly need to reexamine the fundamental institutions for wisely managing all our resources, especially our lands. I have suggested a system that moves away from arbitrary regulation towards the use of market forces to influence decision making. Effluent taxes appear to be a highly efficient means of treating pollution problems. A land classification system with a series of charges for use of land at levels other than the priority use would allow the market system to influence the actual use of land. Effluent charges coupled with land-use charges could lead to an environmental management system that is truly comprehensive.



Study Projects

COMMISSION ON NATURAL RESOURCES

DEVELOPMENT OF OFFSHORE OIL AND GAS RESOURCES

Exploration and exploitation of oil and gas reserves on federal offshore lands is guided principally by two agencies of the U.S. Department of the Interior: the Bureau of Land Management, which controls the leasing procedures, and the U.S. Geological Survey, which by its orders and notices regulates offshore operations after a lease is granted.

Some 18,000 offshore wells have now been drilled, principally in the Gulf of Mexico, which is the world's most intensively exploited offshore oil and gas region.* Some 16 percent of the U.S. domestic oil and gas production came from offshore wells in 1975. By 2000, depending upon whether pessimism or optimism underlies the projection, 10 to 20 percent of the domestic consumption of oil and gas may come from off shore.

A considerable part of that future outer continental shelf (OCS) pro-

* Offshore is generally land 3 miles beyond a state's coastline, excepting Texas and Florida, whose domain extends further for historical reasons.

duction will come from the Gulf of Alaska and the mid-Atlantic. However, experience in operating in these waters is limited, and much of the experience gained in Gulf of Mexico OCS operations and the Santa Barbara Channel may not be comparable. The Council on Environmental Quality (CEQ) pointed out that

> operations in both frontier OCS regions would confront harsher conditions than have previously been faced in other U.S. offshore areas. Storm conditions in part of the Atlantic may be more severe than in the Gulf of Mexico or in the North Sea. Weather conditions generally will be even worse in the Gulf of Alaska. Earthquakes and tidal waves also present serious problems in the Gulf of Alaska with large (Richter magnitude 7) earthquakes expected every 3 to 5 years and giant (Richter magnitude 8) earthquakes expected every 25 years in the area where oil and gas development has been proposed.*

Aside from the newness of the territory, the development of tracts in the Gulf of Alaska and Atlantic is likely to be more rapid than the pace of operations in the Gulf of Mexico during the past several decades.

Infusing these elements are the still sizable uncertainties of the impact that spilled oil has on the marine environment, particularly the various ecosystems it penetrates. Spillages tend to be small—1 or 2 gallons—and the total volume is accounted by a very few spills; thus, from 1971 to 1975, there were some 5,000 spills in the Gulf of Mexico, but most of the total volume of the spills—some 51,000 barrels, or less than a hundredth of a percent of the total volume of oil produced in the Gulf—was accounted for by 5 spills.

But while the overall spill volume is comparatively small, and the record of the OCS industry in controlling spills is steadily improving, local impacts of even medium spills can be severe and long-lasting.

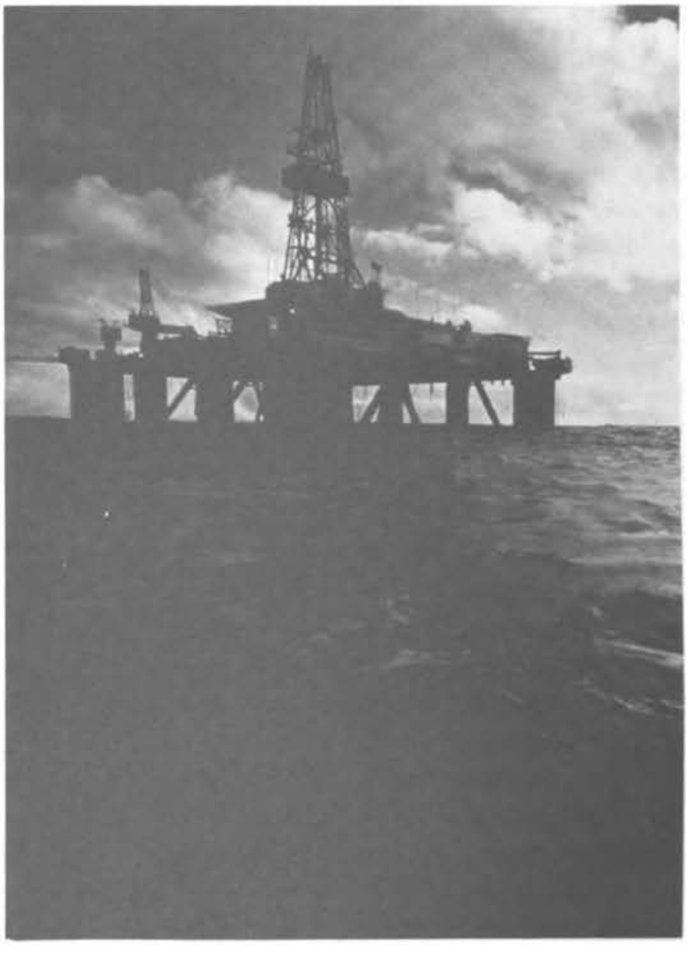
In a 1974 critique † of a CEQ report, *OCS Oil and Gas—An Environmental Assessment*, an NRC committee commented that

> present knowledge is inadequate for assessing thoroughly the likely physical and biological consequences of OCS development activities. . . . Information is available in varying degrees of completeness. For example, the topography of

* Council on Environmental Quality. 1974. Fifth Annual Report. Washington, D.C., p. 470.
† Issues in the Assessment of Environmental Imacts of Oil and Gas Production on the Outer Continental Shelf. 1974. National Academy of Sciences–National Academy of Engineering, Washington, D.C.

coastal areas is well known. However, weather conditions, sea states and ocean currents are only partially known and do not provide an adequate base for assessment, design or operation in every area.

The report emphasized the value of ecological science, given comprehensive and evaluated data, in assessing the major issues relating to the development of a particular area and in recommending adequate monitoring systems and safeguards. It noted that "[a]ny stress that seriously alters the dynamics of an ecosystem should be avoided, since critical changes in its productivity may result." And it suggested that the prime element in an ecological assessment prior to development should be the resiliency of the affected ecosystems:



a system operating normally can overcome and repair temporary losses of its renewable resources in variable but reasonable periods of time. Therefore, the danger of environmental intrusion by man is not necessarily the temporary loss of populations but rather the loss of or permanent change in the dynamics of the system that supports its productivity. For this reason studies of the recovery of ecosystems from catastrophic damage resulting from natural stress are particularly critical.

The report further emphasized ecological interrelationships:

For example, the Louisiana delta and marshlands are considered the controlling factors for fisheries production in the northern Gulf of Mexico. The Chesapeake Bay area has a similar relationship with the mid-Atlantic region and, without doubt, there are other such areas along every coastline that can be similarly identified as critically important to production of renewable resources.

While the resiliency of a particular ecological niche is the essential element in an evaluation prior to development, actually gauging it can be difficult, given the dynamic nature of ecosystems, the common paucity of data, and the inadequacy of most models used to synthesize the data.

ONSHORE

Onshore impacts—particularly at pipeline landing points—are often considerable, but to date the issues are poorly analyzed and debated, with only refinery siting receiving significant attention. Yet the landfall of pipelines—easily the dominant mode for carrying oil from OCS well to shore—can have considerable environmental impact. The NRC report pointed out that "[d]redging, filling, and damming in unstable estuarine and deltaic regions can alter drainage patterns, leading to loss of land and to changes in the physical and chemical environment with resultant ecosystem changes. Much less damage may occur, however, if pipelines come ashore at stable shores." *

ENVIRONMENTAL STUDIES

In sum, federal policy in regard to OCS development is being set among intense pressure to find more domestic sources of oil and gas, intended

* *Ibid.*, p. 31.

operations in new seas with new conditions, and significant uncertainties on environmental effects, including oil spills and onshore impacts. The pivotal role belongs to the Bureau of Land Management, since it controls the lease sales and also must make the first determination of the probable environmental impact of developing a particular OCS tract.

To fine-tune its ability to project impacts, the Bureau in 1973 organized its environmental studies program. The program includes a summation or collation of what is known about conditions in a particular OCS area that may be leased and "benchmark" studies, including evaluation of existing information and generation of new data, to provide a baseline for analyzing changes in the tract as it is developed. Such changes are followed in the monitoring phase of the program, which relies on the mix of biological and chemical measurements. Another phase of the program is special studies, intended to find the causes and assess the consequences of changes from baseline levels detected by the monitoring studies. Approximately $50 million is projected to be spent yearly on the environmental studies program, and the program is now scheduled to continue for several years. It is obviously a difficult program with a demanding task. Tracts were leased in the northeastern portion of the Gulf of Alaska in the spring of 1976 and mid-Atlantic tracts in the fall of 1976. The faster pace—in leasing, in exploratory drilling, in the construction of production platforms, and in building facilities for moving oil to shore and processing it *—increases the demands on the program. To help ensure its optimum effectiveness, the Bureau of Land Management has asked NRC to examine the environmental studies program. That study is now being conducted by the Environmental Studies Board of the Commission on Natural Resources, with the cooperation of the Marine Board of the Assembly of Engineering. In the words of the proposal, the NRC study will "seek to determine strengths, weaknesses, and possible changes so that the OCS study program might better meet its objectives."

Committee to Evaluate Outer Continental Shelf Studies, Environmental Studies Board, Commission on Natural Resources. Committee Chairman, Philip Johnson of Oak Ridge Associated Universities; Staff Officer, Richard H. Burroughs.

* For details on leasing, exploration, and production see Don E. Kash *et al.* 1973. Energy Under the Oceans. University of Oklahoma Press, Norman. Another useful, shorter review is Leasing and Management of Energy Resources on the Outer Continental Shelf, prepared by the Bureau of Land Management and the U.S. Geological Survey (USGS: INF–74–33).

AQUACULTURAL PRODUCTION IN THE UNITED STATES

Aquaculture, the cultivation of water-dwelling organisms, is an old and successful endeavor. In many parts of the world, particularly Southeast Asia and the Orient, aquacultural food production is a significant enterprise, and its importance to human nutrition is generally acknowledged.

During the past 5 years, production from aquaculture worldwide has doubled, and present world aquaculture production is about 6 million metric tons, 8.6 percent of seafood supplies. In the United States, the 1973 production of fish was 2.1 million metric tons, of which 73,000 metric tons were produced by aquaculture. Total U.S. consumption of fisheries' products is about 3.4 million metric tons. Thus, aquaculture provides about 3.4 percent of U.S. production and a little over 2 percent of the fish consumption. Because of the existence of very extensive areas of suitable aquatic habitat and the availability of technologies for several species, the potential exists in the United States for significant increases in fish production by culture, especially in estuarine and marine environments.

Although aquaculture has existed for a long time, its development has been slow. The desirability of expanding its scope and production has been recognized, by those engaged in the culture of such species as oysters, catfish, and trout and by those attempting to develop industries for shrimp, mussels, and related products. Interest in aquaculture has intensified in recent years, and government, academic, and industrial groups have increased their involvement in aquaculture research and development. Results were encouraging in many cases, but in others they fell short of expectations. Moreover, many of the problems, some of which had seemed near solution, proved intractable, often for economic reasons.

In countries where aquaculture has been given national priority and steps taken to tackle administrative and legal conflicts, aquacultural production has expanded. Between 1966 and 1976 world aquacultural production increased by about 20 percent, from 5 to 6 million metric tons. This latter figure, by recent estimates,* may double by 1985 and

* T. V. R. Pillay. 1976. The state of aquaculture, 1975. FAO Technical Conference on Aquaculture, Kyoto, Japan, 26 May–2 June 1976. FIR/AQ/Conf/76/R.36.

possibly climb to 30 million metric tons by the year 2000. Unfortunately, this favorable growth in aquaculture does not extend to the United States, where aquacultural development has stagnated.

An expansion of aquacultural production in the United States requires research on production, disease, genetics, nutrition, and environmental stress. Production systems and research and development on processing, distribution, harvesting, energy, and fertilizer requirements are additional areas needing attention. But biology and engineering are not the only constraints to progress in aquaculture in the United States, nor are they necessarily the most important ones. Economic, legal, and institutional areas also need thorough examination, including the effects of demand and supply on present and projected prices, the availability of financing, zoning laws, permit systems, local controls, access to water areas, and competition for water areas. While legal, social, and economic factors have great influence on the development of aquaculture, these aspects have usually not received the attention they deserve. For instance, brackish or saline water is needed to cultivate marine organisms. This means that major aquaculture producers must have access to estuarine and shore areas to a greater extent than is now possible.

Thus, realizing the potential of aquaculture will require overcoming certain legal and institutional constraints and advancing scientific knowledge and developing technologies to enable production at competitive prices. The future development of aquaculture in the United States is likely to be a function of the federal, state, and industrial roles in aquaculture. "What should be done, who should be responsible, and how should it be done," are the key questions to be addressed by the Committee on Aquaculture of the NRC Board on Agriculture and Renewable Resources.

The Committee will examine:

- The biological and technical constraints to the development of aquaculture, including research needs in such areas as reproduction, genetics, nutrition, disease, and environmental requirements (including pollution of cultured organisms)
- The constraints resulting from inadequate information on production systems and research and development requirements in such areas as processing, marketing distribution, harvesting, energy, and fertilizer needs
- The economic, legal, and institutional constraints to aquaculture
- The federal role with respect to aquaculture

The Committee will set forward reasons why aquaculture is lagging in the United States, express an opinion as to its future, and offer guidance to the federal government as to its function in the development of aquaculture.

Committee on Aquaculture, Commission on Natural Resources. Committee Chairman, Don Walsh of the University of Southern California; Staff Officer, Bille Hougart.

SOLIDIFYING RADIOACTIVE WASTES

The lifetime of commercial nuclear power, while short, has been a stormy one, marked by evolving concerns: possible biological dangers from radiation leakages; reactor hazards, with the "loss-of-coolant accident" a focus; skepticism on economics; and more recently the problem of "closing the fuel cycle." The latter phrase includes the problem of what happens to fuel elements after their tour of duty within a reactor core. Usually, about a third of the fuel elements of a reactor are taken out after some 2 years of "burn-up." The fuel elements are sheared apart and the fuel dissolved, typically with nitric acid. After a series of chemical and physical separations varying according to process, two products are obtained: (1) still usuable fuels such as uranium and plutonium potentially available for recycling back into reactor cores, and (2) low- and high-level wastes.

Low-level wastes contain less than 1/1000 the radioactivity of high-level wastes and do not constitute as serious a disposal problem as high-level wastes.* These are a mix of radioactive elements: fission products such as cesium-137 and strontium-90 and transuranium elements such as plutonium-239—all of which are both highly toxic and long-lived, some requiring storage for thousands of years before they reach innocuous levels. High-level wastes are a problem that apparently cannot be solved, other than by waiting. The problem is how and where to store them. Most of the high-level wastes that now exist—mostly from government programs, such as the production of plutonium for military uses—are stored as liquids. However, with the continued expansion of commercial nuclear power, the volume of high-level liquid wastes will increase enormously. And liquids can have difficulties: They are potentially reactive, clumsy to handle, possibly corrosive, and leakable. Therefore, a priority in closing the fuel cycle is to devise and evaluate efficient, reliable, and safe methods of converting high-level liquid wastes into solids. Once solidified, the wastes can be encapsulated and transported to a government repository, the nature of which is still uncertain and disputed,

* For a discussion of low-level waste disposal, see The Shallow Land Burial of Low-Level Radioactively Contaminated Solid Waste. 1976. National Academy of Sciences, Washington, D.C.

although the NRC Committee on Radioactive Waste Management has consistently opted for bedded salt.

Turning a liquid into a solid should be a straightforward matter, but it is not when complex chemical mixtures that are both hot and intensely radioactive are involved. Accordingly, the U.S. Nuclear Regulatory Commission has asked the National Research Council to examine the issue. A Panel on Waste Solidification has been formed by the Committee on Radioactive Waste Management. The intent of the panel, to excerpt the National Research Council's proposal to the Nuclear Regulatory Commission, is to

> review and evaluate the various methods of solidification of liquid radioactive wastes with particular emphasis on the expected chemical, physical, and mechanical properties of the final product of each method, as they relate to the proposed criteria to be published by the Nuclear Regulatory Commission for solidified radioactive waste. Emphasis will be placed on the waste produced in light water reactors.

There are several ways to solidify wastes: * For example, they can be calcined, turned into various glasses or ceramics, or mixed with cement or asphalt. Whatever method is used, it will be evaluated against several criteria:

- Is it a good conductor of heat? This criterion is more important for power plant wastes than military, or defense, wastes, since the former has a higher power density—more heat per unit volume.
- How leachable is it; that is, how readily are the wastes dissolved by water? Obviously that criterion is particularly critical to long-term storage to assuring that the solidified wastes once interred remain in place.
- Is it stable? Or can the mix of chemicals, intense radiation, and heat in the stored waste in time break down the solid matrix?
- Is the solid mechanically rugged, not liable to break apart during

* Much of the following discussion relies on a report (DP-1335), "Solid Forms for Savannah River Wastes," by R. M. Wallace, H. L. Hull, and R. F. Bradley. The report was issued in December 1973 by the Savannah River Laboratory of E. I. du Pont de Nemours & Co. and is available from the National Technical Information Service, Springfield, Va. 22151.

transport or during a disaster at the storage site, such as an earthquake or an airplane crash?

Furthermore, volumes and costs associated with these solidified wastes should be low, although both considerations will be modulated by the primary need to assure safety; for example, minimal volume requires less storage space and saves costs, but may also generate more heat, making cooling more difficult.

DIFFICULTIES

All of the various solidification techniques have some problems in satisfying these criteria. Calcines, while simple to produce, are usually quite leachable, as well as porous and friable, raising the likelihood that their contained radioactive wastes can leak and scatter. Glasses—whether

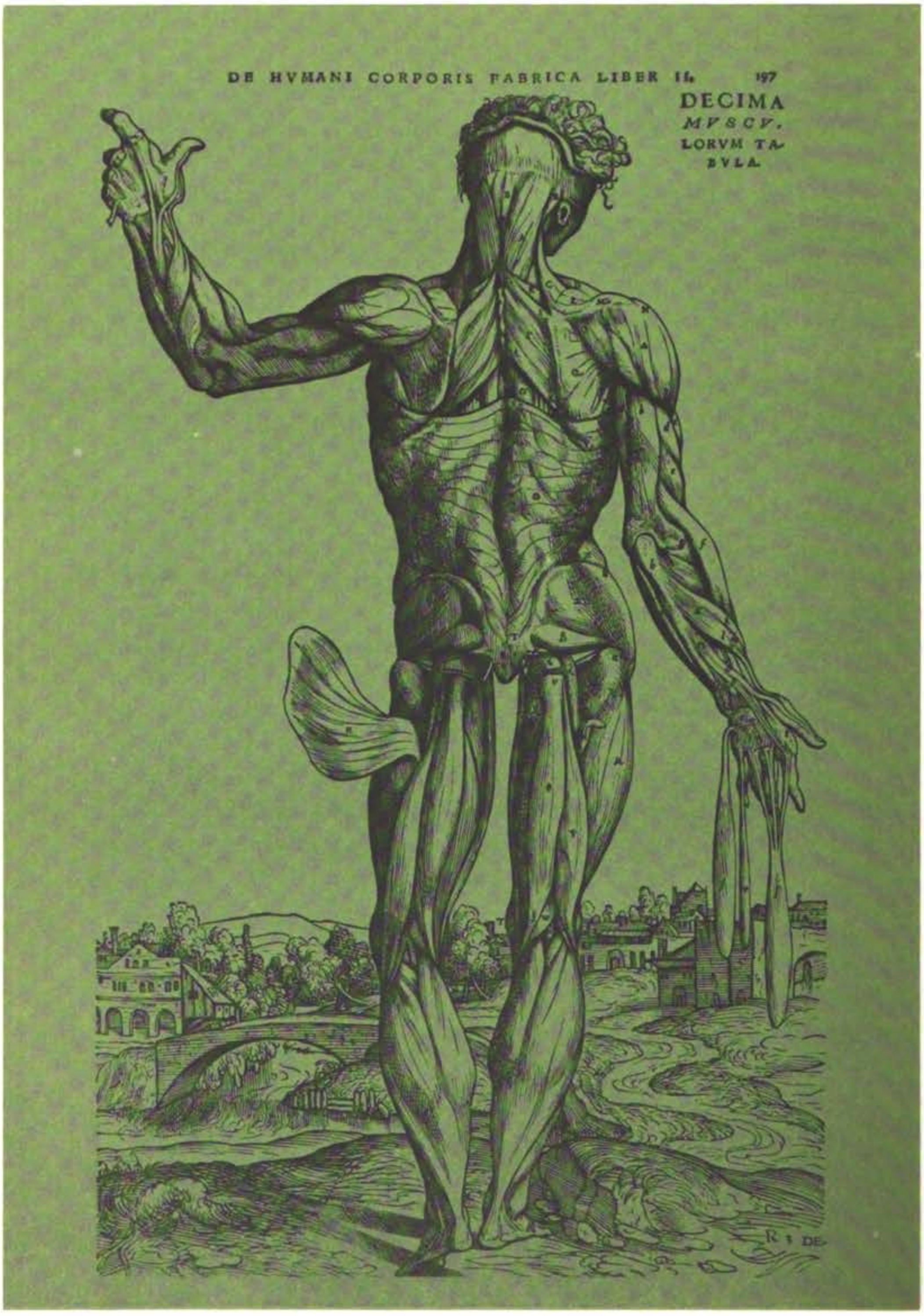
phosphate, borosilicate, aluminosilicate, or some other types—are all leachable to various degrees, with phosphate glasses most leachable and aluminosilicate glasses the least. And glasses can devitrify into a structure laced by microscopic cracks, increasing their leachability. Asphalts are simple to make, but are flammable at high temperatures and are poorly resistant to intense radiation. Cement can also be quite leachable.

Whatever the solidification method applied—whether the ones recounted or others such as metal composites and ceramics—its successful use depends directly on the nature of the wastes, which can vary enormously in chemical and physical properties according to the reprocessing method used. Thus, mercury, sulfates, and fluorides complicate the production of glasses; soluble salts weaken the structure of cement, increasing its leachability.

There are over 23 million gallons of high-level radioactive wastes at ERDA's Hanford Reservation alone, in addition to another 29 million gallons temporarily stored as a solid form called salt-cake. The growth of commercial nuclear power will enormously increase the quantities of these wastes; for example, a 1,000 megawatt (electric) nuclear power plant operating for a year yields some 10,000 gallons of high-level liquid wastes.

It is obvious that if both existing and future high-level wastes are to be stored safely, decisions must soon be made on the reliability, provision of safety, and applicability of different methods for solidifying wastes. The intent of the Panel on Waste Solidification is to help assure that the ablest technical knowledge is involved in reaching those decisions.

Panel on Waste Solidification, Committee on Radioactive Waste Management, Commission on Natural Resources. Panel Chairman, Rustum Roy of the Pennsylvania State University; Staff Officer, Richard I. Milstein.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II

INSTITUTE OF MEDICINE


Der Arzt

Stock-Taking after Five Years

DAVID A. HAMBURG

After a formative 5 years of organizational life spent in studying the nation's health policy issues, the Institute of Medicine has recently directed some of its analytic energies toward studying itself. The Institute is now sufficiently mature that it is possible to sort out its basic characteristics from the superficial, to evaluate realistically its strengths and limitations, and to raise questions crucial to its future.

In the many discussions during the late 1960's that led to the founding of the Institute, a variety of quite different concepts were advanced for what it should be and do. Given the sweep occupied by problems of "protection and advancement of the health of the public," as the 1970 charter was to put the Institute's task, the various ideas of what the Institute is and should do sometimes shared only their ambiguities. But if the founders had differing visions of the future of the Institute, they were in complete agreement on their high expectations. These expectations were infectious, so that soon not only the founders were enthusiastic but also the first member groups, the nucleus of staff, and even some of the agencies, legislators, foundations, and industries who would be its clients.

David A. Hamburg is President, Institute of Medicine.

It is doubtful that any real-life institution could have fulfilled those expectations. And the Institute in its first few years has not, giving rise to differing perceptions—sometimes unsatisfied ones—of what we have been and should be about. The present reassessment reflects in great measure the concerns on those perceptions as expressed by the members at the 1975 annual meeting. The expectations for the Institute are still high, as they realistically should be; it is a young and vigorous organization that can learn from the experience of its formative years.

There are fundamental assets of the Institute that must be listed at the outset of this inventory. These include the broad mandate of its charter, which encompasses every interest pertinent to the health of the public and thereby precludes the establishment of an organization that simply recognizes the accomplishments of individuals or becomes preoccupied with any particular profession or science. The vision of the charter and the pattern set by charter members have created a membership of great distinction and diversity, with a strong commitment to work in Institute activities. Supporting that effort are the talents of a dedicated and competent staff of individuals experienced in health policy matters and governmental processes. Another undoubted asset is the Institute's existence as a semiautonomous branch of the National Academy of Sciences, whose traditions provide a distinguished family history for its newest offspring.

In its first 5 years, the Institute has had few precedents to guide it in tackling the very formidable tasks of building a membership and staff, of devising workable operating procedures, of establishing its place in the Academy complex, of meriting rapid credibility in the health community and the government, and of beginning to tackle substantive problems rife with complexity and controversy. It has been a very large order, and it has left a predictable trail of unresolved questions.

These include an apparent ambiguity of mission, a lack of balance and cohesiveness in program substance, a limited knowledge by members about the programs and therefore insufficient participation by them, and uncertainty as to the optimum composition of membership and staff and the optimum complementarity of their roles. It is toward the resolution of those problems and the enhancement of the Institute's effectiveness in advancing considerations of health policy that its governing Council, members, and staff have been working in their deliberations of recent months.

The primary mission of the Institute is to help find ways to improve the health of the public. The Institute's activities flow naturally from that conceptual mission, which is both fundamental and very extensive. We must be concerned with policies bearing on the major aspects of health—patient care, prevention of disease, education, and the science underlying the entire enterprise. Each of these aspects has an ethical component and must be considered in a social context; each deals not only with overt disease, gross morbidity and mortality, but also involves the quality of life in more subtle ways.

The Institute cannot deal exhaustively with all of those aspects of health. But if it is to be a useful institution in the long run, it cannot be narrow in outlook. Its program activities enable the monitoring of important developments in patient care, prevention, education, and research; and its projects must be responsive to these developments.

However the various activities of the Institute may differ, they revolve around two basic functions—the convening of relevant talent and the analysis of policy options. In the convening function, its effectiveness has been proved repeatedly; people of high competence have answered its calls and contributed their efforts. I have no doubt that it will continue to learn the conditions under which different kinds of gatherings are most useful and thereby sharpen the application of its best demonstrated function.

In the matter of policy analysis, there seems to be a general agreement that the Institute should engage in, and publish on, a wider range of health issues than essayed thus far. Such analyses may be long term or short, concise or extended, but they will suspend from the same essential framework. The girders of that framework include a careful assessment of evidence toward judgments of what is highly probable, moderately probable, or least so, and what evidence is crucially lacking; a formulation of alternative actions on the basis of present evidence and professional judgment, carefully distinguished from each other; an explanation of advantages and limitations of the alternatives and clearly stated reasons for preferences if those exist; and proposals for assessing the effectiveness of a recommended policy to facilitate corrections, if necessary.

A blending of the Institute's program interests, its proved success in convening good minds for the task at hand, and an institutional outreach toward more extensive policy analysis is first being directed toward an enterprise to enhance the conceptual basis of our program activities. It will enlist the membership and staff in the preparation of several working papers to be available during 1977. Each will provide an overview of a major health endeavor, and each will be designed to help clarify critical issues and opportunities that deserve priority attention in Institute activities.

The topics for the working papers already launched are (1) health services, with particular attention to plans for national health insurance; (2) health science policies for research; and (3) prevention of disease. Two others are under serious consideration: (1) education for the health professions and (2) mental health. Several themes are envisioned for each working paper: an assessment of current problems, directions that might best be taken in the future, the principal hindrances to progress in those directions, the most current information and best judgments available for overcoming those hindrances, and evaluations of the prospects that could reasonably be expected to arise on any particular path that might be traveled.

If these working papers prove to be useful extramurally, they might be recast from time to time—perhaps on a 4-year cycle to coincide roughly with national elections or perhaps on an annual basis. For the present, they are needed as part of the reassessment of the Institute's functioning.

No discussion of program activities would be complete without mention of the importance of following through on those activities—doing all we can to assure that our effort will be taken seriously, will stimulate, and will lead a step or two toward progress. The climate is relatively favorable for attention to our statements: The Academy enjoys wide respect, and regard for the young Institute is spreading; health issues have a high salience for the public and government. But we cannot take it for granted that our work will necessarily come to the attention of those who do or should have serious interest in the problems we study.

Following through on our study reports and conferences will take various forms as required by the groups for whom the project is most meaningful. In any event, the Institute's role is largely an educational one; its main value in public policy will come through increased understanding of the essential facts, issues, and alternatives it presents. This requires that it apply ingenuity to the tasks of education, as well as to the tasks of research.

Much of the strength that the Institute can apply to its work comes from the extraordinary pool of talent, knowledge, dedication, foresight, and judgment that is its membership. The members' commitments to serve are made with their acceptances of election. We have benefited greatly from their participation, but we do not believe the limits of their involvement have been reached. Part of our introspection entails finding more ways to stimulate the members' interest, to gain more of their time, to help them learn from each other, and generally to create the best possible conditions for their sustained engagement in our tasks.

This point in the Institute's life also is a good time to examine its relationships with its audiences. The federal government will remain a primary audience for its activities, as well as a source of program proposals and contract funds. But it also must be diligent in communicating with other constituencies, including the many associations of professionals and organizations in the health field, scientific societies, state and local governments, academic institutions, and other entities in the private sector with a growing interest in health policy, such as business and labor.

The Institute's interplay with the federal government has not always resulted in its being able to undertake studies leading to recommendations on basic policy issues. For the maintenance of its complete integrity, the Institute must be able to initiate activities of its own choosing, as well as respond to requests of government and other constituencies. This cannot be done unless a substantial portion of the Institute's support comes in a reasonably dependable way from private sources; the crucial source has been—and will be for years to come—the large, professionally managed philanthropic foundations most interested in health matters. Without their help, the Institute never would have come as far as it has. But it is not realistic to view the support of these foundations only as seed money. We must earn their continuing support by our accomplishments. We must inspire their belief that the Institute merits a role in long-term, independent scrutiny of the larger issues of medicine and health.

I believe that we are well embarked on that course, and we will proceed even more steadily as a result of our effort to reconnoiter the complex topography of health policy in the late seventies.

Study Projects

INSTITUTE OF MEDICINE

MEDICAL MALPRACTICE: OTHER WAYS TO SETTLE?

Much of the public associates medical malpractice with huge judgments. And indeed a patient has on occasion successfully sued his doctor for substantial sums. Medical malpractice litigation, from those few accounts, has taken on some of the dash of a very lucrative lottery.

But for the average litigant, as for the average lottery player, the situation is quite different. The National Association of Insurance Commissioners keeps track of medical malpractice claims and the indemnity—if any—that insurance companies pay on them. The records for the 12 months ending in mid-1976 show nearly 12,000 cases closed. In 60 percent of those cases, no indemnity was paid. In only 1 percent of those cases was the award a half-million dollars or more. In only 7 cases out of the 12,000 was the award $1 million or more, and in each of those 7 it was just about a flat million.

During the same 12 months, the average total indemnity paid per incident of alleged malpractice was $11,722, most usually on behalf of two defendants, a doctor and a hospital. The awards in nearly 90 percent of all incidents ran less than $20,000.

Indemnity awards are only a small part of the total financial picture of the tort law/liability insurance system by which most medical malpractice claims are settled in the United States. Indemnity payments have been estimated to amount to as little as 17 cents of every premium dollar that the physician pays to his malpractice insurance company. The rest goes for the company's administration of its insurance program, fees for lawyers, court costs, and other items that don't give monetary succor to a victim of medical malpractice, but do lubricate the system that enables him to sue.

Lawyers' fees can be a big part of the money—one-third or more—in huge settlements, but not much in the average malpractice case. Most of the lawyers for that 60 percent of last year's litigants who got no indemnity payment presumably took the failure with a shrug, having worked for a contingency fee based on a percentage of the potential award. Some lawyers perhaps managed to collect fees from the patients. The lawyers for the doctors and hospitals who were sued had a more dependable income. The average expense of defending each of those 12,000 cases was $1,579; and that includes the average expense—$893—of defending each of those 7,000 cases closed with no indemnity paid.

If medical malpractice suits are not customarily settled in large money figures, neither are they settled with much celerity. Only 50 percent are disposed of within 1½ years of their filing, and 10 percent are still pending after 6½ years. The turtle-paced nature of malpractice litigation not only adds to the costs of the suits, but also poses great difficulties in realistic premium-setting by insurance companies, who can pretty well tell what it will cost to defend a claim this year, but are hard-pressed even to guess what it'll cost 5 years from now.

The import of some of these figures to the average doctor, who isn't suing, was recently added up by the American Medical Association's (AMA) statistical researchers. Each time a patient visited a doctor in 1975, according to the AMA, his bill for that office visit included an average of about $1.24 for the doctor's malpractice insurance premium. The premium

accounted for a little more than 8 percent of the average physician's total expense of conducting a medical practice.

And why are these figures becoming of such interest? Because that $1.24 per patient visit that went to pay insurance premiums was more than four times what it was only 2 years earlier, in 1973. And that 8-plus percent that insurance premiums constitute of the doctor's business expenses was only 2.4 percent in 1973. To put it another way, the average physician paid $610 for malpractice coverage in 1968; by 1973 the premium was three times higher—$1,905; and, according to federal surveys of the insurance industry, the average premium per physician in 1975 was $4,533.

The costs of the present system of malpractice adjudication and indemnification extend far beyond insurance premiums and damage awards. They also include the expenses of practicing "defensive medicine" in order to minimize the likelihood of lawsuits. A 1976 survey of some members by the Texas Medical Association indicated that 66 percent were ordering more laboratory tests than before, 51 percent were delegating less responsibility to others for patient care, and 48 percent were admitting more patients to the hospital.

An increasing national interest in physicians' professional liability was apparent even before the appointment in 1971 of a Department of Health, Education, and Welfare Secretary's Commission on Medical Malpractice. The report of that Commission in 1973 was reviewed by a special panel of the Institute of Medicine, which then urged that the Institute develop a proposal for a study of alternatives to the present system for dealing with medical injuries.

Late in 1975, grants were made by the W. R. Hewlett and Henry J. Kaiser Family foundations to support such a study. Another Institute advisory committee reconsidered the study objectives and reaffirmed that the Institute could best contribute to easing the malpractice situation by exploring other mechanisms for settling claims.

The steering committee and staff of the study, now called Medical Injury Compensation, will try to answer three broad questions:

- What should a medical injury compensation system try to achieve? Although compensation may be the main goal, there may also exist ancillary goals, such as improving medical-care quality or protecting practitioners from financial hardship.
- What approaches to compensation most effectively accomplish the goals? Many alternatives to tort law have been suggested, ranging from arbitration to no-fault insurance.
- What are the implications of using the alternatives—for medicine, law, insurers, and patients?

A final report of the study is scheduled for publication in the late fall of 1977.

Study of Medical Injury Compensation, Institute of Medicine. Study Chairman, John R. Hogness of the University of Washington; Staff Officer, Barbara W. Cohen.

VALUE DIMENSIONS OF HEALTH POLICY

Policymaking is a political activity—an effort to accommodate competing interests according to predetermined procedures and subject to public scrutiny at several points in the process. Thus, the selection of public policies that affect biomedical research, the delivery of medical care, or the use of techniques to prevent disease is a political activity in which decisions emerge from a setting of often complex technical data and competing social, political, and economic interests.

Policymaking in health affairs, if not more difficult than that in other enterprises, is singularly riddled with values and assumptions about such matters as the proper role of government, the responsibilities of medical-care providers, and the individual rights that affect the selection of alternative courses of action. These values and assumptions, however, are seldom clearly articulated; they simply pervade the positions taken by policymakers on particular issues.

The values implicit in health policy have become of more widespread concern in recent years, as advancements in medical technology have produced unanticipated and sometimes untoward results, as the likelihood has increased of guaranteeing medical service to everyone in the nation, and as medical scientists have begun to turn toward prevention of disease as a serious alternative to attempting its cure. These and other developments raise a distinct possibility of changes in long-standing health policies, changes that will necessitate reexamination not only of scientific information but also of the relative values placed long ago on certain choices. Where, for instance, lies the choice between striving for increases in human longevity or reducing disabilities of the elderly so as to improve their quality of life? Or, does the preservation of individual liberties outweigh the desirability of altering individual behavior—not smoking or dieting, for example—so as to lessen the possibility of premature death?

The Institute of Medicine began a sustained move into consideration of these matters with the sponsorship in 1973 of a Conference on Health Care and Changing Values, the first event in what was to become a series of conferences, membership meetings, commissioned papers, and other activities designed to focus attention on the social values and ethical features of medical research and health care. That 1973 conference—supported by the U.S. Department of Health, Education, and Welfare—represented a leap of interest, over and beyond a preoccupation with the ethics of human experimentation, into relatively unexplored territory. Now there were problems of the implications for social justice in the way health resources are allocated, the possibly adverse social consequences of using new medical technologies, or the push of government and institutions into the making of decisions traditionally left to individual physicians and patients.

Exploration of these and many other issues in this new territory has increased in urgency with the rise in our total national expenditures for medical care, which has posed a near certainty that there eventually will be limits on the resources that can be spent in pursuit of health. These limits, when reached, will affect not only the patients but also the health workers whose ethic is to do whatever may be necessary to sustain life.

Efforts of the Institute to plumb these matters were greatly aided in December 1974 with the award by the Andrew W. Mellon Foundation of a 3-year grant for a program to examine the competing political, economic, and social values inherent in health policy decisions. The grant has facilitated not only the establishment of specific projects for the study of such values, but also the integration of value considerations into existing projects whose ethical components are apparent but whose principal directions are toward other ends.

The Mellon grant also has aided newly undertaken efforts of the Institute to assess value choices and conflicts in potential policy changes that could affect the conduct and mission of biomedical research, to forecast the implications of health programs likely to be developed pursuant to the National Health Promotion and Disease Prevention Act of 1976 (Public Law 94–317), and to discern the implications of legislation and other proposals that will change the composition and distribution of health manpower.

One result of the Institute's efforts to analyze values implicit in various health efforts was its contribution to the planning of the Institute's 1975 annual meeting, on "The Implications of Guaranteeing Medical Care." Principal speakers addressed the consequences of accepting that there is a "right" to medical care. One example of the assertion of such a right would be the enactment of a comprehensive national health insurance plan, with its implications for the federal government, for providers


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of medical care, and for the public. The papers, commentary, and open discussions provided a timely examination of health issues whose surge toward legislation threatens to outdistance the attendant value considerations.

The value dimensions of social policies that affect dependent old persons were discussed in detail at the 1976 Anglo-American Conference on Health Care of the Elderly, cosponsored by the Institute of Medicine, the Royal Society of Medicine in London, and the Royal Society of Medicine Foundation in New York. Papers and commentary of a wide-ranging program delved into problems associated with the aging process and the consequences of demographic trends that virtually guarantee steady rises in the proportion of elderly citizens in the United States, the United Kingdom, and other developed countries. Sharp increases in the number of dependent older persons in the United States predicted for the year 2020 through 2050—the "baby boom" coming of age—will affect not only the organization and delivery of health and social services to the elderly, but also the national economy and political system. Today's health and social service institutions are not designed to cope with the burden of illness and disability of our current elderly, much less the larger number of old Americans projected after the turn of the century. The development of adequate programs and institutions could require resources of such magnitude as to drain the finances of the working population and precipitate confrontations between the generations. The Institute currently is planning a follow-up project to the Anglo-American conference, which can begin to analyze a broad range of possible recommendations for public policy on care of the dependent elderly and on reducing or postponing their dependency.

In still another approach to the study of values, an advisory committee to the Institute president has, over the past years, commissioned the writing of several scholarly papers on the ethical implications of proposed strategies for promoting health and on the assertions of medical-care providers to professional autonomy in their decisions on how and where they practice. The advisory committee has aided the Institute in distinguishing between the various forms of ethical inquiry now prevalent. The Institute's studies of values are described as being in the realm of "social ethics," where the emphasis is on institutional and societal decisions affecting many people, rather than on the moral dilemmas of individual decision making, as is the case in medical ethics.

With the encouragement of the Andrew W. Mellon Foundation, the Institute intends to continue to work beyond mere reflection on moral concerns in health policy decisions so as to ensure that broad social ramifications of such decisions do not escape attention. In 1977, the Program on Value Dimensions of Health Policy will include the sponsorship of a resident senior scholar at the Institute. The program also will sponsor the preparation of papers that detail the value components inherent in each of five working documents on health policy matters that the Institute intends to issue during 1977.

Program in Value Dimensions of Health Policy, Institute of Medicine.
Staff Officer, Michael R. Pollard.

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Reports of the NRC Published in 1976*

ASSEMBLY OF BEHAVIORAL AND SOCIAL SCIENCES

Assessing Vocational Education Research and Development. (Committee on Vocational Education Research and Development; 138 pp.; available from the NAS Printing and Publishing Office; ISBN 0-309-02526-5; $8.00.)

Committee on Energy Consumption Measurement: Interim Report. (Committee on Energy Consumption Measurement; 30 pp.; limited number of copies available from the committee.)

The Comprehensive Employment and Training Act. Impact on People, Places, Programs: An Interim Report. (Committee on Evaluation of Employment and Training Programs; 175 pp.; available from the NAS Printing and Publishing Office; ISBN 0-309-02443-9; $6.00.)

First Interprofessional Standards for Visual Field Testing. (Working Group 39 on Standards for Testing Visual Fields and Visual Acuity, Committee on Vision; available in the *Journal of the American Optometric Association,* June 1976.)

Review of FAA [Federal Aviation Administration] Concorde Survey Plans. (Committee on Community Reactions to the Concorde; 7 pp.; limited number of copies available from the NAS Office of Information.)

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Social and Behavioral Science Programs in the National Science Foundation: Final Report. (Committee on Social Sciences in the National Science Foundation; 103 pp.; limited number of copies available from the committee.)

Toward a National Policy for Children and Families. (Advisory Committee on Child Development; 133 pp.; available from the NAS Printing and Publishing Office; ISBN 0-309-02533-8; $6.25.)

Transition to Decentralized Manpower Programs. Eight Area Studies: An Interim Report. (Committee on Evaluation of Employment and Training Programs; 184 pp.; limited number of copies available from the committee.)

ASSEMBLY OF ENGINEERING

Criteria for Energy Storage R&D [Research and Development]. (Committee on Advanced Energy Storage Systems, Energy Engineering Board; 110 pp.; available from the NAS Printing and Publishing Office; ISBN 0-309-02530-3; $6.25.)

Directory of Organizations in Engineering Programs for Minorities. (Committee on Minorities in Engineering; 125 pp.; limited number of copies available from the committee.)

Drilling for Energy Resources. (Ad Hoc Committee on Technology of Drilling for Energy Resources, Energy Engineering Board; 67 pp.; limited number of copies available from the board.)

Electronic Message Systems for the U.S. Postal Service. (U.S. Postal Service Support Panel, Committee on Telecommunications; 51 pp.; available from NTIS; PB 262 892; $4.50 paper, $3.00 microfiche.)

Executive Presentation—Recommendations on Better Contracting for Underground Construction. (Subcommittee on Contracting Practices, U.S. National Committee on Tunneling Technology; 21 pp.; limited number of copies available from the committee.)

An Information Systems Resource Center for Local Governments. (Urban Information Systems Inter-Agency Committee Support Panel, Committee on Telecommunications; 15 pp.; limited number of copies available from the committee.)

Interim Report of the National Research Council Committee on Nuclear and Alternative Energy Systems. (Committee on Nuclear and Alternative Energy Systems; 56 pp.; limited number of copies available from the committee.)

Local Government Information Systems—A Study of USAC [Urban Information Systems Inter-Agency Committee] and the Future Application of Computer Technology. (Urban Information Systems Inter-Agency Committee Support Panel, Committee on Telecommunications; 52 pp.; limited number of copies available from the assembly.)

The Manned Undersea Science and Technology Program—An Appraisal. (Panel on Undersea Facilities, Marine Board; 30 pp.; limited number of copies available from the board.)

Seafloor Engineering: National Needs and Research Requirements. (Committee on Seafloor Engineering, Marine Board; 81 pp.; available from NTIS; PB 254 171; $5.00 paper, $2.25 microfiche.)

Waste Management for the Coastal Zone: Concepts for the Assessment of Ocean Outfalls. (Panel on Coastal Waste Management Practices, Marine Board; 24 pp.; limited number of copies available from the board.)

ASSEMBLY OF LIFE SCIENCES

Background of Angina Pectoris: Social and Environmental Factors in Relation to Smoking. [*American Journal of Epidemiology,* January 1976] (Collaborative study by the Follow-up Agency of the U.S. National Research Council and the Karolinska Institute of Stockholm, Sweden; limited number of reprints available from the agency.)

Chlorine and Hydrogen Chloride [Medical and Biologic Effects of Environmental Pollutants]. (Subcommittee on Chlorine and Hydrogen Chloride, Committee on Medical and Biologic Effects of Environmental Pollutants, Division of Medical Sciences; 289 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02519–2; $10.00.)

Clinical Evaluation of Rancho Los Amigos Hospital/Medtronic Inc. Implanted Neuromuscular Assist Device. (Subcommittee on Evaluation, Committee on Prosthetics Research and Development, Division of Medical Sciences; 105 pp.; limited number of copies available from the committee.)

Copper [Medical and Biologic Effects of Environmental Pollutants]. (Subcommittee on Copper, Committee on Medical and Biologic Effects of Environmental Pollutants, Division of Medical Sciences; 124 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02536–2; $7.00.)

Documentation of a Clinical Evaluation of Selected Cybercom Communication Systems. (Committee on Prosthetics Research and Development and the Committee on Prosthetic–Orthotic Education; 70 pp.; limited number of copies available from the assembly.)

Evaluation of Testing for Cystic Fibrosis. [*Journal of Pediatrics,* April 1976, Part 2] (Committee for a Study for Evaluation of Testing for Cystic Fibrosis, Division of Medical Sciences; limited number of reprints available from the committee.)

Evaluation of the Ortho-Walk Type B Pneumatic Orthosis on Thirty-Seven Paraplegic Patients. (Committee on Prosthetics Research and Development and the Committee on Prosthetic–Orthotic Education, Division of Medical Sciences; 71 pp.; limited number of copies available from the Committee on Prosthetics Research and Development.)

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Fuels and Fuel Additives for Highway Vehicles and Their Combustion Products: A Guide to Evaluation of Their Potential Effects on Health. (Committee on Toxicology; 43 pp.; available from NTIS; PB 254 088; $4.50 paper, $2.25 microfiche.)

Guide for the Care and Use of the Nude (Thymus-Deficient) Mouse in Biomedical Research. [*ILAR News,* January 1976] (Committee on Care and Use of the "Nude"

Mouse, Institute of Laboratory Animal Resources, Division of Biological Sciences; limited number of reprints available from the institute.)

Health Effects of Alpha Emitting Particles in the Respiratory Tract (EPA 520/4-76-013). (Ad Hoc Committee on "Hot Particles," Advisory Committee on the Biological Effects of Ionizing Radiations, Division of Medical Sciences; 126 pp.; available from the Office of Radiation Programs, AWS-460, U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. 20460.)

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Implications of Pediatric Hospitalization Rates. (Committee on Implications of Declining Pediatric Hospitalization Rates, Board on Maternal, Child, and Family Health Research, Division of Medical Sciences; 69 pp.; available from NTIS; PB 263 079; $4.50 paper, $3.00 microfiche.)

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Maternal and Child Health Research. (Committee on Maternal and Child Health Research, Division of Medical Sciences; 159 pp.; available from NTIS; PB 256 025; $6.75 paper, $2.25 microfiche.)

Molluscan Pathology. [*Marine Fisheries Review,* October 1976] Report of a workshop held in Wye Mills, Maryland, September 3-5, 1976. (Cosponsored by the Institute of Laboratory Animal Resources, Division of Biological Sciences, National Research Council, and the Registry of Comparative Pathology, Armed Forces Institute of Pathology; limited number of reprints available from the institute.)

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Oral Contraceptives and Nutrition. (Committee on Nutrition of the Mother and Preschool Child, Food and Nutrition Board, Division of Biological Sciences; 5 pp.; limited number of copies available from the board.)

Perspectives on the Control of Viral Hepatitis, Type B. (Joint statement by the Committee on Viral Hepatitis, Division of Medical Sciences, National Research Council, and the Public Health Service Advisory Committee on Immunization Practices, U.S. Department of Health, Education, and Welfare; available in the U.S. Public Health Service Center for Disease Control, *Morbidity and Mortality Weekly Report* 25:3-11, May 7, 1976, supplement.)

Primate Population Surveys in Guyana and Bolivia. (Committee on Conservation of

Nonhuman Primates, Institute of Laboratory Animal Resources, Division of Biological Sciences; 5 pp.; limited number of copies available from the institute.)

Recommendations for the Prevention of Lead Poisoning in Children. (Ad Hoc Committee on Lead in Paint, Committee on Toxicology; 75 pp.; available from NTIS; PB 275 645; $4.50 paper, $3.00 microfiche.)

Science and Epilepsy: Neuroscience Gains in Epilepsy Research. (Committee on Brain Sciences, Division of Medical Sciences; 303 pp.; available from Raven Press, 1140 Avenue of the Americas, New York, New York 10036; ISBN 0-89004-072-9; $18.50.)

Science and Technology in the Service of the Physically Handicapped. (Committee on National Needs for the Rehabilitation of the Physically Handicapped, Division of Medical Sciences; *Volume 1,* 75 pp.; available from NTIS, PB 261 450, $5.00 paper, $3.00 microfiche; *Volume 2: Supporting Papers,* 107 pp., available from NTIS, PB 261 451, $5.50 paper, $3.00 microfiche; *Summary,* 29 pp., available from the division.)

Selenium [Medical and Biologic Effects of Environmental Pollutants]. (Subcommittee on Selenium, Committee on Medical and Biologic Effects of Environmental Pollutants, Division of Medical Sciences; 203 pp.; available from the NAS Printing and Publishing Office; ISBN 0-309-02503-6; $10.25.)

Selenium and Human Health. (Committee on Nutritional Misinformation, Food and Nutrition Board, Division of Biological Sciences; 4 pp.; limited number of copies available from the board.)

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Study of Institutional Differences in Postoperative Mortality. (Coordinating Center for the Institutional Differences Study, Stanford Center for Health Care Research, Stanford University; for the Policy Committee for the Study of Institutional Differences in Postoperative Mortality; 796 pp.; available from NTIS; PB 250 940; $18.75 paper, $2.25 microfiche.)

Vapor-Phase Organic Pollutants: Volatile Hydrocarbons and Oxidation Products [Medical and Biologic Effects of Environmental Pollutants]. (Panel on Vapor-Phase Organic Pollutants, Committee on Medical and Biologic Effects of Environmental Pollutants, Division of Medical Sciences; 411 pp.; available from the NAS Printing and Publishing Office; ISBN 0-309-02441-2; $13.00.)

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Analysis of Risk in the Water Transportation of Hazardous Materials. (Risk Analysis and Hazard Evaluation Panel, Committee on Hazardous Materials; 109 pp.; limited number of copies available from the committee.)

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Earth Science Investigations in the United States Antarctic Research Program (USARP) for the Period July 1, 1975–June 30, 1976. (Working Group on Geology, Scientific Committee on Antarctic Research, International Council of Scientific Unions, Polar Research Board; 40 pp.; limited number of copies available from the board.)

Education in Hydrology and Water Resources in the United States—1965–1974—An Overview with Recommendations: Final Report. (Work Group on Education and Training, U.S. National Committee for the International Hydrological Decade; 82 pp.; available from NTIS; PB 257 915; $5.00 paper, $3.00 microfiche.)

An Evaluative Report on the Experimental Technology Incentives Program: National Bureau of Standards—Fiscal Year 1975. (Evaluation Panels for the National Bureau of Standards; 8 pp.; limited number of copies available from the panels.)

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An Evaluative Report on the Institute for Materials Research: National Bureau of Standards—Fiscal Year 1976. (Evaluation Panels for the National Bureau of Standards; 40 pp.; limited number of copies available from the panels.)

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Geodynamics Project: U.S. Progress Report—1975. (U.S. Geodynamics Committee, Geophysics Research Board; 87 pp.; limited number of copies available from the committee.)

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Halocarbons: Effects on Stratospheric Ozone. (Panel on Atmospheric Chemistry, Committee on Impacts of Stratospheric Change; 367 pp., available from the NAS Printing and Publishing Office; ISBN 0–309–02532–X; $10.25.)

Halocarbons: Environmental Effects of Chlorofluoromethane Release. (Committee on Impacts of Stratospheric Change; 134 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02529–X; $6.26.)

Institutional Arrangements for the Space Telescope. Report of a study at Woods Hole, Massachusetts, July 19–30, 1976. (Space Science Board; 48 pp.; limited number of copies available from the board.)

International Discussion of Space Observatories. Report of a conference held in Williamsburg, Virginia, January 26–29, 1976. (Cosponsored by the Space Science Board of the U.S. National Research Council and the European Science Foundation; 15 pp.; limited number of copies available from the board.)

Multichannel Seismic Reflection System Needs of the U.S. Academic Community. (Ocean Sciences Board; 37 pp.; limited number of copies available from the board.)

Needs and Opportunities for the National Resource for Computation in Chemistry. Report of a workshop held in Woods Hole, Massachusetts, July 13–16, 1976. (Planning Committee for a National Resource for Computation in Chemistry; 166 pp.; limited number of copies available from the Office of Chemistry and Chemical Technology.)

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Hoc Panel on Accelerator-Related Atomic Physics Research, Committee on Atomic and Molecular Science; 64 pp.; limited number of copies available from the committee.)

Report of the Subcommittee on Energy-Related Atomic and Molecular Science. (Subcommittee on Energy-Related Atomic and Molecular Science, Committee on Atomic and Molecular Science; 80 pp.; limited number of copies available from the board.)

Report on Space Science: 1975. (Space Science Board; 237 pp.; limited number of copies available from the board.)

Report on United States Antarctic Research Activities for February 1975 to October 1976; United States Antarctic Research Activities Planned for October 1976–September 1977. [Report Number 18 to Scientific Committee on Antarctic Research of the International Council of Scientific Unions.] (Polar Research Board; 84 pp.; limited number of copies available from the board.)

Scientific Plan for the Proposed Nansen Drift Station. (Committee for the Nansen Drift Station, Polar Research Board; 247 pp.; limited number of copies available from the committee.)

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Status and Future Potential of Crystallography. Report of a conference, February 10–11, 1975. (U.S. National Committee for Crystallography; 80 pp.; limited number of copies available from the Office of Chemistry and Chemical Technology.)

Supplement to 1974 List of Radio and Radar Astronomy Observatories. (Committee on Radio Frequencies; 22 pp.; limited number of copies available from the committee.)

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XXVIII Conference of the International Union of Pure and Applied Chemistry, Madrid, Spain, September 2–11, 1975: Report of the Delegation from the National Academy of Sciences–National Research Council. (U.S. National Committee for the International Union of Pure and Applied Chemistry; 46 pp.; limited number of copies available from the Office of Chemistry and Chemical Technology.)

The Use of Balloons for Physics and Astronomy. (Balloon Study Committee, Geophysics Research Board; 162 pp.; limited number of copies available from the board.)

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Aquatic Weed Management: Some Prospects for the Sudan and Nile Basin. Report of a workshop held in Khartoum, Democratic Republic of the Sudan, November 24–29, 1975. (Cosponsored by the National Academy of Sciences of the United States of America and the National Council of Research, Agricultural Research Council, Democratic Republic of the Sudan; 64 pp.; limited number of copies available from the Board on Science and Technology for International Development.)

"A Conference on Agriculture." Report of a meeting held at the National Academy of Sciences, February 20–21, 1975. (Cosponsored by the Committee on Scholarly Communication with the People's Republic of China of the U.S. National Research Council, the American Council of Learned Societies, and the Social Science Research Council; available from *The China Quarterly*, September 1976, pp. 596–610.)

Energy for Rural Development: Renewable Resources and Alternative Technologies for Developing Countries. (Panel on Renewable Energy Resources, Committee on Technology Innovation, Board on Science and Technology for International Development; 306 pp.; limited number of copies available from the board.)

Ferrocement, A Versatile Construction Material: Its Increasing Use in Asia. Report of the Workshop on Introduction of Technologies in Asia—Ferrocement, A Case Study, held in Bangkok, Thailand, November 5–8, 1974. (Cosponsored by the National Academy of Sciences of the United States of America and the Asian Institute of Technology of Bangkok, Thailand; 112 pp.; limited number of copies available from the Board on Science and Technology for International Development.)

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Report of the Joint Ad Hoc Committee for Scientific and Technical Cooperation. Report of a meeting held in Washington, D.C., July 1–3, 1975. (Cosponsored by the Board on Science and Technology for International Development of the U.S. National Research Council and the Council for Scientific and Industrial Research of Ghana; 120 pp.; available from NTIS; PB 243 367; $5.50 paper, $3.00 microfiche.)

The Role of U.S. Engineering Schools in Development Assistance. (Panel on the Role of U.S. Engineering Schools in Development Assistance, Board on Science and Technology for International Development, and the Office of the Foreign Secretary, National Academy of Engineering; 35 pp.; limited number of copies available from the office.)

Science and Technology Policy, Research Management and Planning in the Arab Republic of Egypt. Report of a Symposium on Science Policy Planning held in Cairo, April 30–May 1, 1975, and a Workshop on the Management and Planning of Research held in Cairo, May 3–8, 1975. (Cosponsored by the Board on Science and Technology for International Development of the U.S. National Research Council, the Academy of Scientific Research and Technology of the Arab Republic of Egypt, and the National Science Foundation of the United States of America; 98 pp.; limited number of copies available from the board.)

Science Information Programs: I: The Argentine Telex Network for Scientific and Technical Information; II: Computer-Based Information Services for Science and Technology—Report of Activities, August 15–December 31, 1972, and Brief Summary of Follow-on Activities, January 1, 1973–Present. (Cosponsored by the Board on Science and Technology for International Development of the U.S.

National Research Council, National Academy of Sciences of the United States of America, and the Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina; in cooperation with the U.S. Agency for International Development; 130 pp.; available from NTIS; PB 259 991; $6.00 paper, $3.00 microfiche.)

Solid State Physics in the People's Republic of China. CSCPRC Report Number 1. (Cosponsored by the Committee on Scholarly Communication with the People's Republic of China of the U.S. National Research Council, the American Council of Learned Societies, and the Social Science Research Council; 203 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02523–0; $10.25.)

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USSR–USA Symposium on Chemistry and Physics of Proteins. Report of a symposium held in Riga, U.S.S.R., August 4–8, 1976. (Cosponsored by the Organizing Committee for the National Academy of Sciences of the United States of America and the Organizing Committee for the Academy of Sciences of the Union of Soviet Socialist Republics; 7 pp.; limited number of copies available from the commission.)

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Climate and Food: Climatic Fluctuation and U.S. Agricultural Production. (Committee on Climate and Weather Fluctuations and Agricultural Production, Board on Agriculture and Renewable Resources; 212 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02522–2; $7.75.)

Disposal in the Marine Environment: An Oceanographic Assessment. An Analytical Study for the U.S. Environmental Protection Agency. (Ocean Disposal Study Steering Committee, Ocean Science Committee, Ocean Affairs Board; available from the NAS Printing and Publishing Office; ISBN 0–309–02446–3; $5.00.)

Early Action on the Global Environmental Monitoring System. (International Environmental Programs Committee, Environmental Studies Board; 26 pp.; limited number of copies available from the committee.)

Gas Reserve Estimation of Offshore Producible Shut-In Leases in the Gulf of Mexico. (Panel on Gas Reserve Estimation, Board on Mineral Resources; 179 pp.; available from the Conservation Division, U.S. Geological Survey, 640 National Center, Reston, Virginia 22092.)

Mineral Resources and the Environment, Supplementary Report: Coal Workers' Pneumoconiosis—Medical Considerations, Some Social Implications. (Panel on Coal Workers' Pneumoconiosis: Medical Considerations, Some Social Implications, Committee on Mineral Resources and the Environment; 149 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02424–2; $6.00.)

National Residuals Discharge Inventory: An Analysis of the Generation, Discharge, Cost of Control, and Regional Distribution of Liquid Wastes to be Expected in Achieving the Requirements of Public Law 92–500. (Study Committee on Water Quality Policy, Environmental Studies Board; 231 pp.; available from NTIS; PB 252 288; $8.00 paper, $3.00 microfiche.)

Natural Gas from Unconventional Geologic Sources. (Board on Mineral Resources; 245 pp.; available from the Technical Information Center, Office of Public Affairs, Energy Research and Development Administration, P.O. Box 62, Oak Ridge, Tennessee 37830.)

Nutrient Requirements of Beef Cattle. Fifth Revised Edition. [Nutrient Requirements of Domestic Animals Number 4.] (Subcommittee on Beef Cattle Nutrition, Committee on Animal Nutrition; Board on Agriculture and Renewable Resources; 56 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02419–6; $3.75.)

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Resource and Environmental Surveys from Space with the Thematic Mapper in the 1980's. (Committee on Remote Sensing Programs for Earth Resource Surveys; 129 pp.; limited number of copies available from the committee.)

Review of the (National Commission on Water Quality) Staff Draft Report, November 1975. (Study Committee on Water Quality Policy, Environmental Studies Board; 75 pp.; available from NTIS; PB 252 040; $4.50 paper, $3.00 microfiche.)

The Shallow Land Burial of Low-Level Radioactively Contaminated Solid Waste. (Panel on Land Burial, Committee on Radioactive Waste Management; 167 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02535–4; $7.00.)

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Application of Fracture Mechanics Analysis Techniques in High Performance Marine Systems. (Committee on Application of Fracture Mechanics Analysis Techniques to Marine Systems, National Materials Advisory Board; 15 pp.; available from NTIS; AD/A–025 148; $4.00 paper, $2.25 microfiche.)

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Maritime Metrication: A Recommended Metric Conversion Plan for the U.S. Maritime Industry. (Panel on Metrication in the U.S. Maritime Industry, Maritime Transportation Research Board; 132 pp.; available from the NAS Printing and Publishing Office; ISBN 0–309–02447–1; $5.25.)

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