The Federal Government and the Scientific Community

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Some years ago Lady Jackson—Barbara Ward—said that "The forces of change unleashed on the world in the last century can be used for good or evil. For good to create a dynamic society of free citizens working together, or for evil to set in motion the destroying juggernaut of the totalitarian state. But one thing cannot be done with the spirit of the age, and that is to ignore it, to repress it, or pretend it isn't there."

What are the consequences of the spirit of our age for science and the uses of science? It is in that light that I would like to share with you my concerns for our system of higher education, and for the future of the scientific endeavor.

Since the invention of the steam engine opened the industrial revolution, scientific understanding has been consciously applied to human affairs. The human population, then about one billion, assumed an exponential growth pattern; increasingly, man's environment became the product of his own creation and societies arose where leadership was no longer held by force of arms but by common consent. Such societies fostered a continuing equalization of privilege, diffusion of privilege to those previously without it by curtailment of the special privileges of others. This was evident in our Bill of Rights, in subsequent amendments to the Constitution, in the Anti-Trust Acts and in the spate of post-World War II civil rights legislation.

Massive new industries arose here and abroad; the lot of the average man improved steadily as science-based technology surrounded every aspect of human endeavor. Joyfully welcomed for two centuries, only in our own time has it become evident that these processes are not limitless, that population growth and exploitation of the resources of the planet can become threats to the very survival of the species.

Economic expansion—like population growth—burgeoned exponentially, trebling in the United States in the last two decades while population itself increased by only one-third. The most dramatic change in our life style was that occasioned by the fact that as our population grew from 100 to 200 million, the agricultural labor force declined from almost 14 million to less than 4 million, depopulating the countryside while providing the labor force for productive and service industries but also generating urban ghettos.

So remarkable were these developments that, in 1968, one party platform could state that (*1*)

> We believe that a nation wealthy beyond the dreams of most of mankind—a nation with a twentieth of the world's population but possessing half the world's manufactured goods—has the capacity and the duty to assure to all its citizens the opportunities to enjoy the full measure of the blessings of American life. For the first time in the history of the world it is within the power of a nation to eradicate from its borders the age-old curse of poverty.

But not only has that promise not yet been realized, a variety of other difficulties confront the nation as well: the specter of nuclear war could not be dispelled; the disparity between the quality of life of those in the more developed nations and those in the developing nations grew ever larger; international tensions remained and a war in a far distant country cast a continuing pall over every aspect of our society; minority groups, ever more forcefully, demanded translation of well-intentioned legislation into the reality of their daily lives; suddenly, we awakened to widespread repugnance to the diverse penalties of insufficiently regulated technologies; universities found themselves subject to pressures they could not satisfy; the family lost its position as the stabilizing unit of society; and unrest became the order of the day.

Although the great bulk of Americans continue to go about their daily tasks, much as before, the pace of change which, like economic and population growth, had long been held as yardsticks of American accomplishments aroused increasing apprehension. Led by its youth, the nation embarked upon a frenetic, sometimes destructive search for new values, for a clear sense of direction, and for some perception of new national purpose.

One senses a deepening national despair, yet what we are witnessing is not failure but the culmination of a great historic success. Our historic national concern for the individual combined with our unwillingness to resort to force or repression underlie many of our difficulties. Hence, the increasing share of national wealth available to most individual Americans; hence, the permissive attitudes of parents and the uncertainties of their children; hence, the growing marital discord and rising divorce rate as we retreat from an authoritarian relationship between man and wife; hence, the accelerated growth of university student bodies; hence, our tolerance for diverse militant, even revolutionary, groups; and hence, the vacillation of our international posture. The sense of a headlong rush into an uncertain future has generated a national desire for leadership, stability, and assurance that the problems of the day are understood by someone and are manageable.

A biochemist would be a poseur indeed to address himself to the diverse aspects of these paramount problems, but it is within that turbulent landscape that one must view the current academic and scientific scene, ever cognizant of the vast distance we have come in the few thousand years since man invented language, the few hundred years of the printed word, the two centuries of the industrial revolution, the one century of electric power, only two decades of the computer-based scientific revolution, and 18 months since man first set foot on the moon.

The author is president of the National Academy of Sciences. This article is the text of an address delivered on 26 December 1970 at the AAAS meeting, Chicago, Illinois.

Political Commitment to Education and Research

Since the founding of the nation, our public commitment to education has been extended from a few years of grade school to graduate school. Let me quote a recent political party plank (*2*):

Education is the chief instrument for making good the American promise. . . . Every citizen has a basic right to as much education and training as he desires and can master—from pre-school through graduate studies—even if his family cannot pay for this education. Our rapidly expanding educational frontiers require a redoubling of efforts to insure the vitality of a diverse higher education system. . . .

At the same time the other party said (*3*):

The rapidly mounting enrollments and costs of colleges and universities deprive many qualified young people of the opportunity to obtain a quality college education. . . . No young American should be denied a quality education because he cannot afford it.

Only a few years before, a president had said that (*4*):

At the apex of the educational pyramid . . . is the vital top segment where education and research become inseparable. The federal government has supported academic research in agriculture for over a half-century and in the physical sciences, life sciences, and engineering since World War II; the returns on this national investment have been immense.

The same presidential document ordered all federal agencies to act so as to:

a. Encourage the maintenance of outstanding quality in science and science education at those universities where it exists; b. Provide research funds to academic institutions under conditions affording them the opportunity to improve and extend their programs for research and science education, and; c. Contribute to the improvement of potentially strong universities through a variety of measures.

Both parties have been equally explicit with respect to science. According to one (*5*):

In science and technology the nation must maintain leadership against increasingly challenging competition from abroad. Crucial to this leadership is growth in the supply of gifted, skilled scientists and engineers. Government encouragement in this critical area should be stable. . . . Vigorous effort should be directed toward increasing the application of science and technology including the social sciences to the solution of such pressing human problems as housing, transportation, education, environmental pollution, law enforcement, and job training. We support a strong program of research in the sciences with protection for the independence and integrity of participating individuals and institutions. An increase in the number of centers of scientific creativity and excellence, geographically dispersed . . . will also have our support.

That year, the other party said (*6*):

We lead the world in science and technology. This has produced a dramatic effect on the daily lives of all of us. To maintain our undisputed national leadership in science, and further its manifold applications for the betterment of mankind, the federal government has a clear obligation to foster and support creative men and women in the research community, public and private. In addition to the physical sciences, the social sciences will be encouraged and assisted to identify and deal with the problem areas of society.

The national commitment to research related specifically to health has been reiterated each time a new institute has been created at the National Institutes of Health. One president stated his view of the underlying philosophy in the following terms (*7*):

We are determined that the vital link between pure research and practical achievement will never be broken. We are determined that research and discovery yield results which not only increase man's knowledge but the strength of his body and the length of his life. We do this because we have no choice. And we do it because we believe in Thomas Jefferson's words, that the care of human life and happiness is the first and only legitimate object of good government.

In the 1968 campaign one party said (*8*):

Expansion of the number of doctors, nurses, and supporting staff to relieve shortages and spread the availability of health-care services will have our support.

The other said that (*9*):

The best of modern medical care should be made available to every American. . . . We will raise the level of research in all fields of health. . . . We must build new medical, dental and medical service schools and increase the capacity of existing ones to train more doctors, dentists, nurses and technicians. . . .

These, then, have been the commitments made by both parties, implicit in the actions, explicit in the statements of five consecutive presidents. In sum: education for all citizens to the extent that they are educable, independent of their financial means; an excellent if not great university to serve each region of the nation; maintenance of our international scientific leadership; a vigorous national biomedical research program; and increasing utilization of the national technical capability to secure the common defense and promote the general welfare. Thus measured, where do we stand?

Decline of the Scientific Enterprise

Both political parties must be held accountable for a retreat from these great goals which began about 4 years ago but which becomes more painful as the gulf widens between resources made available, on the one hand, and scientific opportunity and national needs on the other.

For the individual student, stipend support through fellowships and traineeships from federal funds is now disappearing, to be replaced by loans, a reflection of the philosophy of this Administration. This loss is regrettable in view of the remarkable upward social mobility provided by such programs, which have supported only about a third of all students who receive the Ph.D. To the extent to which such actions are justified by current indications of technical unemployment, they seem shortsighted indeed or an expression of lack of confidence in the national future.

Over the last five fiscal years, the purchasing power of funds available for the support of science has diminished by perhaps 20 to 25 percent. To what extent the scientific enterprise may be imperiled is unclear. Certain it is that young investigators fail to find support and that established investigators lose it; important new, but costly, starts on major scientific enterprises are deferred and our leadership in some disciplines, for example, radio astronomy, is being lost to other, more determined, nations.

To be sure, total federal and other public funds available in support of academic institutions, per se, have recently grown considerably and are at an all-time high. Yet, as the Carnegie Commission Report (*10*) indicated, many are on the brink of insolvency. A small start was made by the National Science Foundation to generate centers of academic scientific excellence across the country, but that program has been under wraps for several years, and it is doubtful that such a commitment is any longer in being.

Medical schools, which had been transformed from trade schools into substantial educational and research centers by skillful utilization of funds designated for biomedical research,

find themselves in desperate financial straits; funds so designated have continued to flow, indeed in augmented amount, but are diverted in part either to highly targeted research or to studies concerned with the delivery of health care rather than improvement in the potential quality of that care.

Reduction in the scale of research and development by the National Aeronautics and Space Administration and by the Department of Defense has, for the first time since World War II, created relatively large-scale unemployment of engineers and physical scientists; when coupled with the pause in the economy and the financial problems of higher education, the employment prospects of the Ph.D. class of 1971 seem rather forbidding.

On each of these fronts, then, our steps falter. And the morale of the scientific and academic communities, already seriously shaken by the problems of life on campus, may soon be broken. No, the scientific enterprise has not been dismantled. Indeed, the quality of much of our scientific endeavor was never greater, the quality of science education never better. However, the events summarized above have generated a level of apprehension which goes far beyond the reality of current fiscal problems, much like a rumor suggesting scarcity of some commodity during the war, or a run on a bank in the great depression. And I can only assume that investigators so distracted are less creative than they otherwise might have been.

The most important action the government could take in these regards would be to provide assurance of some minimum level of stable funding, corrected annually for inflation, thereby assuring some acceptable level of effort in each principal area of scientific endeavor.

Public Attitudes and Public Support

But why this failure of our nation to behave in accordance with its expressed commitments?

There never was a federal commitment to underwrite higher education, for all of the statements I read to you earlier. But there can be no doubt that there would be greater willingness on the part of government and public bodies generally to assist the universities in their current financial distress and to support academic science were it not for the chaotic condition of the campus itself with both faculties and student bodies in disarray.

What is the public to make of professors who demand prohibition of DDT while arguing for the legalization of hashish; who deny concern with the mores of their students while proclaiming their own expertise with respect to our foreign policy, urban problems, or economy; who are appalled by violence in the ghetto but not by that of some students on campus; who take public positions on environmental pollution, yet are strangely quiet with respect to drug abuse on campus? How shall the public react to "trashing" the provost's office or the willful politicization of the campus by students and faculty who demand that the university —once a community of individual scholars—collectively adopt positions on public issues when they do nothing else collectively?

I am among those who deny that there is any place for classified research on campus—but how should free citizens react to the rejection of all unclassified defense-sponsored research on campus in a nation which believes that civilian control of the military is essential to our liberties?

The entrenchment of an adversary culture and the increasing number of neo-Luddite know-nothings are disharmonious with the culture shared by most of the tax-paying public. Some years ago, when these processes were barely evident, Irving Kristol predicted the rising political activities of the campus community, saying (*11*):

> The first objective—already accomplished in large measure—is to weaken control of the administration and to dispossess it of its authoritative powers over campus activities. From this point the movement into politics proper—including elections—is about as predictable as anything can be.

That prediction has indeed been realized, as has his prediction that with politicization would come a decreasing disposition of the public to support higher education. As Patrick Moynihan noted in a talk before the American Council on Education last fall, the dogmatic nihilistic doctrine which Podhoretz called "a barbaric hostility to freedom of thought" (*12*), accompanied by what Wildavsky described as "a will to believe the worst with a compulsion to make events speak to the necessity of revolutionary change" (*13*), have combined to diminish the common will to support what had been one of the most remarkable expressions of American life—a university system, from which no qualified student was to be barred regardless of family circumstances, and the heart of our science enterprise. Wildavsky's statement aptly describes those who usurped this platform earlier tonight.

Science of the Academic Community

Nevertheless, while retreating from provision of graduate student stipends, the unprecedented Higher Education Opportunity Act of 1970 (*14*), proposed by this Administration, offered a mixture of loans and partial subsidy such that, in effect, all prospective students would have the resources available to families with an annual income of $10,000 or more. That measure received strong backing from a few sources such as the Carnegie Commission on Higher Education but, receiving no support from the academic community, students, faculty, or administration, it languishes in committee to this day.

Nor did I hear much response from college presidents, faculty, or students to my proposal, last spring, that we bring into being a National Youth Service Program (*15*). Briefly, the thought was to provide full support to *all* qualified students who undertake education beyond the baccalaureate in exchange, subsequently, for 2 years in a National Youth Service Program—a domestic Peace Corps, if you will, but composed of our most educated, most talented young people, undertaking service in the public interest. Other than a few laudatory editorials, the silence has been deafening.

The Administration also offered to create a National Foundation for Higher Education empowered, inter alia, to make block grants to the universities and, presumably, in some measure mitigate their current fiscal plight (*14*). But again, few voices were heard in its support. Presumably, university presidents were so caught up in the task of maintaining peace on campus that they failed to respond.

A year before, the National Science Board issued a report (*16*) which warned that the universities had come to rely too much on funds appropriated in the name of research to provide salaries for the faculty, the administration, and the nonprofessional staff as well as stipends for students. The report proposed to substitute block grants to universities and to their departments, while recommending that research

grants be limited to those funds which the individual faculty investigator need expend for the immediate conduct of research itself. But again, the academic and scientific communities remained silent. Neither the cognizant congressional committees nor the White House detected any significant support and these proposals vanished into the limbo of reports which are rendered when the time is not right.

Patently, the politicization of the campus has not yet extended to the sophistication necessary to support constructive proposals to strengthen academia even when there is a receptive Congress and President. If you believe —as I do—that the proposals of the National Science Board have genuine merit and represent a wise set of constructs for the long-term national interest; if you believe that the President's proposals for the support of higher education represent a significant step forward; if the proposal of a National Youth Service Program is commendable, please do say so. One day, when reason returns to the campus, we can surely regenerate the national resolve to maintain and extend the system of higher education and research—but only if there is a sufficiently vocal and numerous constituency.

Federal Research Support

It is unlikely, however, that we can realize the dream of a first-rate university within easy access of each major population center. There are already more than 200 Ph.D.-granting institutions and there is grave doubt that the nation has either the manpower or continuing financial resources to bring all of them to the level of "excellence" to which they aspire. Nor is it in the national interest to distribute available manpower or financial support uniformly among them. Surely, we must soon emulate the British in making deliberate decisions with respect to the academic strength and resources of the nation, achieving substantial geographic distribution but recognizing that most institutions will be fortunate to attain excellence in even a few disciplines (*17*).

Even to maintain such distribution will require greater financial support of disciplinary academic science than we now know. If current trends continue and disparity between resources and opportunity increases, responsible federal research administrators must use investigative excellence as the overriding criterion in judgment-making; unless funding improves, this could reverse the dispersing efforts of the last decade, once again concentrating federal funds in a limited group of institutions, lest the entire enterprise fall into mediocrity. Deliberate institution building must be accomplished with funds in excess of those necessary, minimally, to support excellence in being in the older established centers—and that requires an act of public will.

The system, then, is in partial decline, but not because government has ever made any explicit decision to allow the scientific effort to decay. Current difficulties are not the consequence of absolute reduction in support but rather attrition due to inflation, the rising costs intrinsic in the increasing sophistication of science itself, and the continuing inflow of new young investigators at a rate such that the entire endeavor would double in qualified manpower about every 8 years. Failure of appropriations to match both scientific opportunity and our current national capability has not been for lack of voices explaining the consequences of budgetary decisions.

I confess that I do not know in detail what happened to the financing of American academic science this year. Merely adding the figures shown in the budget is insufficiently informative if funds for systematic biology or theoretical chemistry were replaced by funds to study the delivery of health care or employment opportunities in the ghetto, worthy as such studies may be. We badly need such analysis, as we badly require some means of establishing appropriate levels of funding, by discipline and by "mission." For many of our public sponsors, our task is not to establish that science is worth supporting, but how much should be provided. No magic formula related to the gross national product or other gross parameters seems to me to be a worthy response. Nor can we, in conscience, condone the knowing support of the trivial, the pedestrian, or the unnecessary. Support of fundamental research should surely suffice to assure that new horizons are being explored and that truly talented, competent investigators are fully engaged. Less demanding criteria may suffice in judging applied research which offers promise of early societal return. By these gauges, it is not clear where we presently stand.

To be sure, some advocate that the academic and scientific endeavors should share in the currently reduced national income. However, others argue that this is one channel through which government expenditures can maintain the vigor of the economy in a socially useful way, as do I.

Recall that gross federal expenditures for all of science represent the sum of a large number of decisions most of which are taken to assure progress toward various societal missions and only incidentally advance scientific understanding and engage the services of scientists. Only in the appropriation for the National Science Foundation is the balanced strength of the national science endeavor the primary consideration. That distinction is surely true in Congress, perhaps less completely so in the Office of Management and Budget. The current fiscal circumstances of science, then, are largely the secondary consequences of decisions made concerning allocation of resources to the mission agencies but, we may assume, with some appreciation of the consequences to the scientific endeavor. That the total level of support is less than required to fully engage the scientific community is not due simply to the cost of the Vietnam war, the pause in the economy, or a perceived lesser requirement for mission-related science, although all surely contribute. At least equally important is the growing public disenchantment with science, failure of the American public to share the values of the scientific community, or, perhaps more realistically, failure even to understand what those values may be.

Is Science "Relevant"?

Undergraduate enrollments in the hard sciences decline as students declare science to be irrelevant to their view of a better world. Graduate students now reject research whose ultimate application to human affairs they cannot foresee, as if guided by the statement by Karl Marx to the effect that, "Philosophers seek to study and understand the world, the point is to change it." Is it not our responsibility to make it clear that, while change may be necessary and desirable, if it is to be beneficial, then one must first understand that world and that in no small measure such understanding is possible only in the language of science?

Those who reject science charge that, through technology, science has engendered our environmental problems, degraded the quality of life, limited our

personal freedom, and has been the willing servant of the military. Each is perhaps a partial truth. Yet the fact remains that there is no tool but additional science-based technology, appropriately regulated by an understanding society, with which yet further to improve the human condition.

One hears much of a need for a "humanistic science." Yet, surely, much of science in the past has also been used for humanistic purposes. The machines that once freed us from the need for "human power," live "horse power," and child labor were humanistic. The lowly tin can, the frozen foods, and mechanical refrigeration which liberated the female half of the race from the thralldom of the kitchen while so remarkably enriching the American table were humanistic! The advances in medicine which permit us to live out our lives free of pain or serious illness were surely humanistic as have been abolition of malaria and typhus by DDT as well as our agricultural abundance. What can be a more powerful instrument in the search for a lasting peace than live satellite television communication around the globe? The detailed ethical codes governing animal and human experimentation have long been notably humanistic.

I deny that my life has been made wretched or my freedom reduced by science. Rather do I believe that technology has made the lives of about three-quarters of all Americans richer, more comfortable, more enjoyable, and more healthy, than that of humanity in any other period of history. The challenge is to extend those boons to the remaining quarter. While recognizing the dangers ahead, I believe that, with judicious use of applied science, those dangers can be averted and humanity freed as never before for what Norbert Wiener called "the human use of human beings." To be sure, we have been dangerously exploiting the planet's natural resources and too rapidly despoiling the environment. But only by much improved technology can we avoid the first danger and prevent the second, far preferable to returning to the "good old days" that never were.

The Environment

Appallingly exaggerated statements have been made by some scientists with respect to the immediate seriousness of those problems but let us be glad of the opportunity, thus engendered, to take public action in these regards. Our most acute environmental problems can be managed even now by appropriate regulatory measures which require utilization of technology either already available or readily devised. I consider our air pollution concerns to be rather temporary and, at least in a historic sense, readily solved. Water pollution is decidedly more complex and solid waste disposal is still without a real solution; but both can be markedly alleviated even now if we are but willing to pay the costs. It has been estimated that pollution abatement by industry to achieve standards of water and air which now appear both desirable and feasible may increase production costs by as much as 10 percent, costs which must be paid by the consumer, and which, in effect, would decrease the real gross national product by the same amount. We may rejoice in growing public willingness to accept those costs.

What I find strange is the intense emotion elicited in students by water and air pollution when they express so little concern for the possibility of nuclear war, for the hopelessness of our millions of rural poor, and for the 30 million Americans whose health is stated to be adversely affected by inadequate nutrition. That figure is undoubtedly grossly exaggerated and we urgently need reliable, hard data. But even if exaggerated by two orders of magnitude, it is unacceptable in a nation that already produces far more than it needs to eat well. How remarkable it is that we have a national determination to avoid damage from what emanates from the tailpipes of automobiles—unpleasant but rarely if ever serious in a medical sense—while we remain apathetic to the fact that last year the front ends of those vehicles killed 56,000 Americans and maimed hundreds of thousands more (*18*). Nor do our students seem deeply concerned by the fact that in about half of those fatal accidents, one of the drivers was intoxicated, while a third of all drivers in such accidents were under 25 years of age.

I would not minimize the seriousness of our environmental problems—they are huge and require large-scale measures for their abatement. But if such are to be undertaken, we first require systematic acquisition of data which would permit evaluation of risks versus benefits—where such exist—in all instances where man's intervention threatens the environment. For example, we need to know much more than is known today concerning pesticides, food additives, drugs, diverse industrial practices, radiation hazards, atmospheric phenomena, or the alleged fragility of ecosystems if we are to make sound judgments and establish rational public policy. I share the concern for the possible hazards of DDT—but not the hysteria of those who demand an absolute prohibition against its use before an acceptable substitute is available. The predicted death or blinding by parathion of dozens of Americans last summer must rest on the consciences of every car owner whose bumper sticker urged a total ban on DDT.

A New Profession

No human has yet been known to be damaged in consequence of normal usage of DDT; its untoward effects on bird and fish life appear to reflect heavy overdosage rather than proper use. In this connection, may I direct your attention to a constructive suggestion—the invention of a new profession. Had we a corps of specialists trained in entomology, insect and other pest physiology, and the properties and proper usage of pesticides, their attendant disadvantages could be minimized. Perhaps some safer pesticides could still be obtained—over the counter as it were—but society could be protected if the others could only be used by licensed, certified specialists who would know what uses were legal, adhere to maximum dosage schedules, and treat the agents they use with proper respect until such time as they can be replaced by suitable biological control measures. Creation of such a corps is an appropriate function of the university.

Multidisciplinary Research on Campus

Which leads me back to the campus. Fused to complaint from industry that the products of our graduate schools are overspecialized and complaint from students that their educations are irrelevant, there is a growing demand for revamping of both undergraduate and graduate education. Some graduate students request an abridged, multidisciplinary experience in science without the extensive experience in independent research normal to the Ph.D., but adequate for addressing one or another

of the ills of our time as members of an appropriate team. I find myself sympathetic. Others, however, demand that universities extensively restructure themselves, replacing the classical disciplinary structure by multidisciplinary units engaged in research and education, at all levels, oriented about current societal problems.

Yet, universities can boast few significant multidisciplinary accomplishments. Organized multidisciplinary teams have been successful in government and industry, but not on campus. I do not mean to deter the natural alliances which spring up among groups of faculty with temporary common interests. But wholesale reorganization of the university so as to focus upon multidisciplinary consideration of problems of the environment, population control, and drug abuse, urban redevelopment or ethnic problems, and so forth, important as these are, seems inimical to the central life of the university, the only guardian of scholarly disciplines, and should be undertaken only with great caution. The frontiers of the disciplines are the frontiers of our civilization, and disciplinary specialization has accelerated societal progress. Patently, there is too much which is archaic, irrelevant, or, worse still, uninteresting in conventional college curricula. But, while undertaking their reformation, it should be clear that the university must continue to be dedicated to the "life of the mind," through transmittal of classical values, through preservation, presentation, and expansion of the essential core of the natural and social sciences and the humanities.

Only if we continue to maintain such disciplinary strength can we hope to provide adequately trained individuals to work in yet other, multidisciplinary structures. If leadership in some areas of sciences passes to other nations, only by continued substantial efforts in those areas can we be positioned to take advantage of the accomplishments of their scientists. In this game, the "second best hand" is unlikely to be much cheaper than the winner; it offers small solace to a government seeking to reduce expenditures. Pursuit of science at the disciplinary frontiers as well as in multidisciplinary institutes will necessarily become increasingly expensive—but the nation can make no better investment.

Multidisciplinary research *can* be encouraged on campus—but in separate structures, separate administrative units deliberately created to such ends, each with a core multidisciplinary staff, each concerned with one major aspect of society such as crime, the system of justice, urban life, domestic housing, educational reform, violence, the drug culture, transportation, the search for a lasting peace, or some aspect of the environment. As the government undertakes large social action programs, numbers of universities must both assist in their design and learn to participate in their evaluation, or we shall never profit by experience.

I hope that some universities will give attention to the macroenvironment. Serious as our domestic microenvironmental problems may be, those of the macroenvironment are yet more scientifically mysterious, and outside our control. Recent disasters in East Pakistan, those along the west coast of South America, and our own Gulf Coast far exceed in human costs the relatively trivial damage yet done to man by the microenvironmental deterioration which concerns so many. Efforts to understand and predict the behavior of the macroenvironment, such as movements in the earth's crust, undersea currents, the air-sea interactions and atmospheric processes that determine our climate including its most violent aspects, all seem to me to be highly human challenges worthy of the best efforts of our talented young people. If members of the disciplinary faculties, undergraduates, graduate students, and postdoctoral fellows were free to flow through such units, largely on a temporary basis, they could contribute to the success of such organizations while strengthening their own disciplinary qualifications.

Biomedical Research and the Public Health

Recently, I was shocked to be told with a straight face that it is the environment which is "relevant" this year; research on heart disease, for example, was last year's concern. Even medical students now reject medical research, stating that those so engaged must be cold and inhuman else they would devote their efforts to care of the sick. Some of these students are now earnestly concerned with improved delivery of health care to the American people. So am I. We urgently need to understand the limitations on the national ability to provide health care, to learn whether they derive from the number of physicians or paramedical personnel, the availability of clinics, hospitals, or whatever. And when that understanding is in hand, as it is not today, it behooves us to design and implement a national system for health care to which all citizens have access, regardless of means, and for whom the standard of care is the best we know how to deliver. That will surely require training of decidedly increased numbers of medical and paramedical personnel.

Meanwhile, assuming that the supply of physicians is the bottleneck in the delivery of health care, some of the public, some congressmen, and too many medical practitioners demand that medical schools devote themselves to the production of "ordinary practicing doctors" in substantially greater numbers, at the expense of research activity, somehow forgetting that virtually every useful procedure available to modern medicine is the product of the research effort of the last few decades. Further, they demand that even this diminished research effort be more directly addressed to the problems of disease rather than free exploration of the nature of life. Worse still, they approve diversion of the already limited federal resources from biomedical research to direct improvement of the delivery of health services. They could not be more wrong.

As Ivan Bennett has noted, what is really meant by "medical care" is the mobilization of resources of manpower and facilities to bring to bear inadequate "half-way technologies" (*19*). When research provides a basis for truly definitive prevention or therapy, invariably the resultant control of a disease is far simpler and cheaper than the palliative halfway technologies which were utilized before. Moreover, it has usually been the consequence of fundamental insight into underlying disease mechanisms provided by basic biological research. Consider if you will a partial list of diseases, each of which was, at one time, a major drain upon the then extant health-care system but is now of little consequence in this sense: infectious diseases such as tuberculosis, typhoid fever, infantile diarrhea, epidemic meningitis, typhus, trachoma, scarlet fever, poliomyelitis, cholera, yellow fever, bacterial endocarditis, syphilis, gonorrhea, lobar pneumonia, measles, rubella, whooping cough, diphtheria, smallpox, tetanus, or

puerperal sepsis; nutritional diseases such as pellagra, rickets, scurvy, iron-deficiency anemia, and pernicious anemia; or such diverse syndromes as Addison's disease, hyperthyroidism, goiter, juvenile diabetes, glaucoma, erythroblastosis fetalis, and Parkinsonism. In every case, today, their control or prevention is relatively simple and cheap. It is not these diseases, now under control, that pose the great problems of logistics, manpower, and costs for the current health-care system.

In contrast stand those only partially understood diseases which can be somewhat mitigated by major efforts—but for which we lack definitive cures or preventive measures. It is these which now demand the most complex technologies research has yet made available to the modern hospital, but which, nevertheless, constitute only palliative or physiologically corrective measures. These disorders engender large human and financial cost and frustrate the health care system *not* because of shortage of professional manpower or of hospital facilities, but primarily because there is so little truly effective medical technology available even in the very best of circumstances. This is true for most forms of cancer, stroke, coronary thrombosis, myocardial infarction, hepatic cirrhosis, glomerulo- and pyelonephritis, rheumatoid arthritis, osteoarthritis, acute rheumatic fever, disseminated lupus, bronchial asthma, multiple sclerosis, the senile psychoses, schizophrenia, mental retardation, emphysema, most genetic disorders of metabolism, muscular dystrophy, cystic fibrosis, and virtually all the virus disorders which are not preventable by early immunization.

There are promising avenues of research with respect to practically each of these disorders. None are regarded as hopeless by those engaged in their study; the atmosphere of confidence, in large measure, is the consequence of the rapidly developing understanding of normal structure, physiology, and metabolism in molecular terms, permitting rational, penetrating questions concerning etiology and pathogenesis. Indeed, virtually everything important now understood about cancer, and the most promising clues to future chemotherapy were provided by investigators who did not know that they were "working on cancer." Elimination or effective therapy of the major lethal and incapacitating diseases which now afflict mankind is not a hopeless dream. Whereas, if this nation foreswears research progress, in view of our population growth, we must plan for no less than 50 percent more hospitals, more doctors, more nurses, more sanitariums, and more suffering by the turn of the century—scarcely a brave sight.

Public Understanding and the Scientific Endeavor

The facile national belief that if we can put a man on the moon we should be able to deal with pollution, cancer, or housing fails to recognize the great differences among these problems. Until last year, the Space Agency had a single articulated goal and, in effect, a blank check on the Treasury for its achievement. Similarly, the Department of Defense has a huge budget, deals with industrial contractors for whom government is the principal if not the only customer, and provides defined and unique goals, for example, new weapons systems. These situations differ vastly from the widely distributed, small science base which underlies our efforts to understand disease, to understand and alleviate environmental deterioration in each locality, to improve the national transportation nonsystem, to predict and control the weather, to replace millions of substandard homes, to rejuvenate the cities, to curb drug abuse, to combat crime, and so forth, goals most of which are never attained as we change our perceptions of what is to be achieved. The respective agencies of government appear to have been less successful in attaining these rather diffuse goals than have the Space Agency, the Atomic Energy Commission, or the Department of Defense. But, the latter simply cannot serve as adequate models for our efforts in other areas. Conceivably, the time has come to rethink the style of operation and the mechanisms available to such agencies. Alternatively, perhaps we need only fund them more generously than in the past. In any case, I have little confidence that the large corporate entities of the injured aerospace industry can successfully adjust to a domestic role, for example, in the field of economically acceptable pollution abatement, but I do hope their released scientists and engineers can learn to engage these problems in other settings.

In retrospect, a multitude of causes, competing demands for the public purse, and uncertain priorities have conspired to cause both political parties to renege, in part, on a series of commitments which, I believe, truly did reflect our national aspirations when they were made. In defaulting on these commitments the political apparatus has expressed, not thwarted, the will of the American people who can only be expected to vote the huge sums required to support the colleges and universities and their students, to support scientific research in all disciplines and in both old and newly emerging applied areas if they are adequately informed—a responsibility which devolves upon the scientific community, not upon the members of the science press. The latter have made it clear that science reporters can be expected to be only our translators or interpreters. The scientific community—if such there be—must learn to be its own advocate and must find opportunity to make its own case.

While believing deeply in the intrinsic nobility of the intellectual structure of science, and in attainment of scientific understanding as one of the very purposes of our society, we must repeatedly persuade others of the unpredictability and the long time constants involved in the applicability to human affairs of scientific understanding, of the futility of closely targeted applied research and development when such understanding is not at hand, of the vital significance of a scientifically informed citizenry, and of the essentiality of advancing science to our security, public health, general welfare, economic vigor, and the conservation of our environment and its resources—in short, to our national future.

Unfortunately, there are few public platforms available to us which permit understandable documentation of that "case for science" before attentive nonscientists. Moreover, to do so is to invite charges of self-service, of conflict of interest. But it is the national interest we serve and I hope that many of you will join me in this endeavor. Should we succeed, we will enhance the possibility that the philosophy espoused by President Nixon in 1968, when he was campaigning, will guide him, the Office of Management and Budget, and the Congress as they address themselves to the federal budget for fiscal 1972 and subsequent years. Candidate Nixon said (*20*)

Science has served mankind faithfully and well, it has dramatically extended the

average lifetime, shortened geographical distances, increased industrial productivity, reduced poverty and in the long trial of war contributed significantly to the cause of freedom. . . . If science and technology were to founder or stagnate many of our hopes would collapse. To the extent that we neglect this source of our greatness and to the extent that we fail to preserve the conditions of openness and order that made our progress possible, we are living off the land of civilization without refertilizing it. . . . Instead we must bring about a new dawn of scientific freedom and progress.

I could not agree more.

References and Notes

1. Democratic Platform, 1968, p. 40.
2. Democratic Platform, 1968, p. 52.
3. Republican Platform, 1968, p. 9.
4. Memorandum from the President to the Heads of Departments and Agencies, 14 September 1965.
5. Republican Platform, 1968, p. 22.
6. Democratic Platform, 1968, pp. 39–40.
7. "Health Research Facilities Amendments of 1965," President's remarks at the signing of the bill, 9 August 1965.
8. Republican Platform, 1968, p. 12.
9. Democratic Platform, 1968, pp. 49–50.
10. M. A. Farber, cited in *The New York Times*, 4 December 1970, from "The new depression in higher education," Carnegie Commission on Higher Education.
11. I. Kristol, "American intellectuals and foreign policy," *Foreign Affairs* **45**, 608 (1967).
12. N. Podharetz, "Issues," *Commentary* **50** (4 October 1970).
13. A. Wildavsky, cited by D. P. Moynihan before the American Council on Education.
14. S. 3636, Higher Education Opportunity Act of 1970.
15. P. Handler, hearings before Subcommittee on Science, Research and Development, Committee on Science and Astronautics, No. 23 (1970), p. 97.
16. "Toward a Public Policy for Graduate Education in the Sciences," National Science Board (1969).
17. B. H. Flowers, "Science in universities," lecture at Nottingham University, 6 March 1970, and "Science on a tight budget," *Science* **170** 1361 (1970).
18. Accident Facts, July 1970, National Safety Council.
19. I. Bennett, private communication.
20. R. M. Nixon, speech on 5 October 1968.

Addiction as a Necessity and Opportunity

Edwin H. Land

Last Christmas, while riding through London, I found that in spite of my delight in the galleries, libraries, and concerts, there was within me a deep and insatiable need. I found myself saying to our driver, "Green, did you know that I am an addict?" He is of the old school so that he did not turn his head. "No, sir, I did not know that." "I am addicted to at least one good experiment a day—sometimes I can arrange it by telephone. When I cannot, the world goes out of focus, becomes unreal." Possibly somewhat disappointed, but clearly relieved: "I see, sir."

And then last month I was participating in a student seminar at one of our great universities. We were in the professor's room. We sat on the floor, and the boys and girls sat in a circle around me. The men, including the professor, wore magnificent long hair and, of course, the whole variety of handsome beards. It was rather hard for the women to compete with the colorfulness of the men. Furthermore, the women seemed somewhat restive, with an inner concern about the relationship to reality of the new world they were all trying to create together. As we all talked, I found myself describing the wonders of the scientific experience. I told of the way in which one yearns for a deep insight in some domain; of the strange intuitive program of collecting observations; of the mystery of formation of hypothesis within one; of the competence of the mind-body system to select the crucial experiment; of the excitement of interaction between experiment and hypothesis; of the sense of relief and even of nobility when the hypothesis is proven true by the experiment and the stage set for the next hypothesis. I remarked on the sense of awe that one could be the instrument of this process, as if input had flowed into one and significant outputs emerged from one. I was pleased to note the comprehension on one of the bearded faces. He turned to the neighboring girl and said with firm conviction, "Why, it's just like heroin, isn't it?"

And, finally, a few weeks ago, sitting with the board of a foundation, I shared in the sense of helplessness and impotence, confronted with the problem of how to use money to block the sweep of drugs across our nation. As an inveterate hypothesis maker I had an insight into the nature and function of addiction, and it is that insight I should like to examine with you tonight.

Some years ago, talking to a group of brilliant high school students about the life of a scientist, I said, "My own recollection of your age is a curious alternation which, I think, goes on through life for the scientist. It is alternation between the one mood and attitude of feeling part of the race as a whole, part of the family, part of the neighborhood; the mood of being in love with friends, women, men, people all over the world; the mood of being in love with what is great in music and art—all that on the one hand and then, quite suddenly, a separateness from all that—a separateness that comes during the preoccupation with a particular scientific task. There is a need, a transient need, a violent need for being just yourself, restating, recreating, talking in your own terms about what you have learned from all the cultures, scientific and non-scientific, before you and around you. During that period you want to be almost alone, with just a few friends. You want to be undisturbed. You want to be free to think not for an hour at a time, or three hours at a time, but for two days or two weeks, if possible, without interruption. You don't want to drive the family car or go to parties. You wish people would just go away and leave you alone while you get something straight. Then, you get it straight and you embody it, and during that period of embodiment you have a

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