losses. With minor modification, the same model (Figs. 1 and 4) can be used to evaluate the effects of forest fertilization (*37*), on land waste-water and sewage sludge disposal (*38*), and other land management practices on nitrate production and loss in forests and on downstream water quality.

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Basic Research in the United States

Philip Handler

In the years immediately after World War II, basic science in the United States was supported by the Department of Defense, the Atomic Energy Commission, and the infant National Institutes of Health. The Bureau of Standards, the Geological Survey, and the Department of Agriculture functioned much as they do today, although on a smaller scale. The scientific enterprise grew in consequence of our national perception of the requirements to assure our national security; our desire to pursue peaceful uses of the atom and, later, to assure a continuing energy supply; a vision of what scientific advance might do to improve the public health; recognition of the role of science in enhancing agricultural productivity; the sense of adventure and enhancement of our prestige among nations as we sought to place man on the moon; recognition of the innumerable applications of space platforms for observational purposes; appreciation of the dwindling resources of the earth's crust, particularly that portion that underlies the United States; awareness of the fragility of the natural environment; general acceptance of the view that scientific and technological advance brings social and economic progress; and a perhaps less widely but no less firmly held belief that understanding of man and the universe is, in itself, a national goal.

In 1950 the National Science Foundation (NSF) was established as the special means to assure the balance of the national program in basic research and education in science; it was then thought that most basic research as well as applied research and development would be funded privately and by appropriate mission agencies.

Since then, Congress has created the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, and the Department of Energy, and has proliferated institutes at the National Institutes of Health (NIH). Nevertheless, the NSF is no longer merely a gap filler; it has become the primary vehicle for government support of basic research in a variety of scientific fields, while fulfilling several other missions as well. Its appropriation has grown almost 40-fold over the last 25 years, and the President's budget request for fiscal year 1980, with its total of about $32.5 billion for research and

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development, includes $1 billion for the NSF.

Today, the NSF is clearly the lead federal agency for support of such areas as systematic biology, astronomy, chemistry, solid-state physics, environmental science, and various social sciences. It is second only to the NIH in total funding of research at universities. It seems to have become the agency to which academic scientists naturally turn in seeking support of their research, as indicated by the fact that last year NSF received about half of all applications to the federal government for the support of basic research.

The return of this investment over the years has been stupendous. There has been no comparable period in the history of mankind. In the next section I will touch briefly on some recent findings in diverse scientific disciplines. I will then discuss the present status and future prospects of basic research in the United States.

Some Highlights of Recent Science

In the brief life-span of the NSF there have been profound insights into the interior of the atomic nucleus and into the special properties of matter in the solid, liquid, and gaseous states as well as in hot plasmas. Much has been discovered concerning the basic processes that shape the earth's crust and operate in its interior, and we have been staggered by new concepts of the nature, origin, and possible future of the cosmos. I will return to these exciting findings shortly.

Living cells have proved to be vastly more complex than we surmised two decades ago. The major metabolic pathways (the chemical processes that constitute much of the life of the cell) have been mapped; we have learned a great deal about the nature and mechanisms of the enzymes that make metabolism possible; and we have learned how energy is made available and utilized in the cell. Subcellular entities that accomplish specialized functions in the cell have been described, and insight has been gained into the nature of genes and the mechanisms by which genes find expression. We have begun to glimpse the manner in which gene function is controlled, and increasingly appreciate but do not fully understand the workings of evolution. Current knowledge of molecular genetics derives largely from studies of viruses and bacteria. Our few glimpses into the mechanisms operative in eukaryotic cells suffice to indicate that these are far more complex and subtle.

Many specialized biochemical aspects of such tissues as liver, connective tissue, bone, kidney, blood cells, and muscle have been elucidated, and we discovered that among us are persons afflicted with just about every possible genetic defect still compatible with life. And we now have a detailed understanding of the photochemical apparatus of the plant cell and the events that make possible nitrogen fixation in the microbes on which all life depends.

Several biological fields have virtually exploded in the last decade—notably immunology, endocrinology, and neuroscience. Our earliest acquaintance with the immune system was as a defense mechanism against viral and bacterial invaders. Later we came to appreciate its role in allergic phenomena, more recently as a surveillance and scavenger mechanism when our own cells are altered inappropriately. Most recently, there have come to light autoimmune diseases in which the immune system fails to recognize some normal tissue as self, thereby causing such diseases as myasthenia gravis and multiple sclerosis. In endocrinology, the great advance has come from recognition of the receptor proteins to which hormones bind on target cell surfaces, and of the events triggered thereby, as well as identification of a multiplicity of hormones quite unanticipated a decade ago.

If I could share with you my enthusiasm for only one field, it would be for what has recently been learned about the nature of a nerve cell, how it conducts the nervous impulse, the events by which it conveys information to another cell, and the beginning of an understanding of the biological basis of behavior. The astonishingly detailed current knowledge of nerves enables us to understand the mechanism of action of classical drugs and poisons such as curare, bee venom, and snake venoms; of cardiac glycosides such as digitalis and ouabain; of tranquilizers such as reserpine; as well as of chlorpromazine and other drugs empirically found to be useful in the treatment of schizophrenia. Indeed, there is now hope of a new and effective pharmacopoeia for the management of mental disorders.

A beginning has been made in understanding the process of perception—of what happens, for example, when light strikes the cells of the retina and how that information is processed, conveyed to, and "displayed" in the brain. The regions of the brain responsible for various types of perception are being mapped, and we are discovering how closely akin physiologically are pleasure and pain, and where and how opiate compounds affect the brain. Particularly exciting are the compounds made in the brain that serve as our own "opiates" under ordinary circumstances. Most information is signaled by "hard-wiring" of nerve to nerve, while "mood" is affected by the equivalent of endocrine mechanisms, in which certain regions of the brain secrete hormones that affect other areas relatively nearby.

Science at Home and Abroad

Perhaps 80 percent of all of science has been learned since the birth of the National Science Foundation. This era had as its point of departure the end of World War II, when much of the world was in ashes. The United States has since contributed disproportionately to the growth of scientific understanding. But that era is drawing to a close.

While our scientific enterprise is healthy, vigorous, and productive, science abroad is coming into its own. The totality of the scientific endeavor in Western Europe more or less matches ours. The research and development effort in Japan is perhaps half that in the United States, with almost none of it addressed to military ends and an incommensurate effort in basic research. The Soviet endeavor may be as large as ours, albeit not yet as innovative and productive. The research effort in these countries, like their industry, is younger than ours, and they have been acquiring the latest, most powerful instruments of science while our instrumentation lags. And there is more competition to come. Modern scientific endeavors are just beginning in countries such as Brazil, Argentina, Mexico, India, and China. I hope that when the NSF is twice its present age, U.S. science will be as productive as it is today. But even then, we cannot expect to retain the dominance we have enjoyed in the recent past. I hope that our science will be preeminent, but it is certain to have serious competition. That is not necessarily cause for concern: scientific understanding garnered anywhere will be available to us—but only if we maintain a front-line scientific capability will we be able to utilize fully others' science for our purposes.

Basic Research in the Near Future

As we turn to the subject of science in the next few years, it should be no surprise that our principal harvest has been to learn what questions to ask next.

These questions will be more difficult to address than were those we tried yesterday. They will deal with phenomena more remote from our senses, requiring more elaborate and sophisticated instruments and facilities. Science tomorrow will be intrinsically more expensive than was science yesterday.

Physics and Astronomy

It now seems likely that inside the nucleus there are only a few truly indivisible particles, those now called leptons: the electron, the muon, the tau particle, and the neutrinos associated with them. More than 200 other particles, called hadrons, have been seen under special conditions. The forces between hadrons are very strong and these particles are thought not to be elementary but to be built up of quarks, although the latter have never been seen as separate entities.

Particle physicists are driven by the idea that there is a simplicity and symmetry to nature that is waiting to be revealed. Of the four principal physical forces—gravitation, electromagnetism, and the weak and strong interactions of the nucleus—the relation of the weak interactions of electromagnetism appears to have been established, and the next few years will be devoted to tying together weak, electromagnetic, and strong interactions. There will be a major effort to search for the W particle—the quantum of the weak interaction force, which is believed to be about 75 times the mass of the proton. No existing machine is capable of providing the energy necessary to confirm its existence. Through clever experimentation it may yet prove possible to get around this difficulty; otherwise, there will be required a machine so expensive that it can probably be built only under international auspices.

A great deal is still to be done in understanding the physics of the solid and liquid states. Synchrotron radiation, high-intensity ultraviolet and x-radiation, and neutron sources, particularly high-intensity pulsed neutron beams, will contribute powerfully to this field. Since the science of condensed matter serves as the base for other fields of science and for diverse technologies, it behooves us to get on with these tasks.

It has been said that astronomy is every scientist's second science. Most of us have followed the progress of astronomy with a never ending sense of wonder. The detection of the 3°K radiation has provided strong support for the big bang concept of the origin of the universe, the finding of neutron stars confirms theories of stellar evolution, and the ever stronger suggestions indicating the existence of black holes tend to confirm one of the more remarkable predictions of the general theory of relativity.

An ensemble of powerful new astrophysical instruments is now becoming available. Infrared and gamma-ray observations from space platforms have just commenced. When the Space Shuttle permits, we hope to launch the large space telescope at about the same time the new ground-based large multiple-mirror telescope goes into operation and the full Very Large Array begins to gather data. Collectively, these will permit astronomical observations to much greater distances and in more detail than ever before. What wonders await, no one can say.

Chemistry

A new armamentarium of tools has become available for studying the structure of atoms and molecules. Synchrotron radiation sources, intense neutron sources, nuclear magnetic resonance and electron paramagnetic resonance, and sophisticated instrumentation for light microspectroscopy permit ever closer approach to the detailed structure of organic molecules. Tunable lasers now make it possible to observe the intermediates in chemical reactions in time intervals as short as 10^{-12} second. We look forward to the application of these techniques to the macromolecules of living systems, such as chlorophyll and heme. In quite another direction, continued exploration of the prospects for isotope separation with lasers could yield huge economic payoffs.

In our time, chemists have become veritable wizards, able to synthesize almost any molecule at will. But there are classes of molecules as yet unexplored (it was just such exploration that led to nylon and Dacron); and as we learn more about the architecture of the macromolecules of living systems, chemists should be able to tailor new drugs with unprecedented precision and success.

Earth Science

Cores retrieved from a few hundred shallow holes drilled in the vast expanse of the world's oceans have, in one decade, demolished all older hypotheses concerning the nature and behavior of the earth's crust. From these relatively meager data has emerged the concept of a protocontinent, Pangea, which broke up hundreds of millions of years ago, with subsequent continental drift. Seafloor spreading and plate tectonics then account for the earth's major features and, in part, explain ore body formation. But the data base remains meager; many more and much deeper holes are required if the earth's history and future are to be understood.

Space-based platforms that permit observation of the earth will increase our knowledge of geodesy, enable us to test the predictions of plate tectonics, and facilitate the detection of mineral resources and the observation of crops. An inventory of our mineral resources will be critical to our future economy and enable rational planning for substitution when necessary. Seismic research will continue, and reliable earthquake prediction may become a reality. But we have no acceptable mode of social response to such predictions. Hence, while we improve the science, we should also emphasize earthquake-proof engineering.

With continued progress in collecting information about the atmosphere, the sea, and their interactions, we should be better able to understand climate and, perhaps, make more reliable long-term weather predictions. An effort will be made to follow the buildup of atmospheric carbon dioxide and its effects on climate; the outcome of that effort will be critical for energy policies the world over. It is noteworthy that these matters are intrinsically global in nature; effective international cooperation is a condition of success.

Life Sciences

I have long been chary of making predictions about what will be learned in the field of biology or what can be done with the information. The only certainty seems to be that we shall be surprised. Consider, for example, two recent findings concerning DNA.

As you are aware, DNA is an unbroken strand in which there occur all the three-letter words possible with a four-letter alphabet. But, with no spaces between the words, if the reading frame is shifted by one letter, it reads as an entirely different message. Remarkably, in at least one family of viruses, stretches of the genetic message are indeed read in all three possible reading frames, giving rise to three entirely different proteins necessary to the life cycle of those viruses. That remarkable cryptography is extraordinarily useful to a virus, for which there is a premium on packaging a maximum of information in a minimum of solid material.

In mammals, the opposite occurs. The DNA message that spells out the amino acid sequence of a protein may be interrupted several times with long passages that go untranslated. The meaning of this is not entirely clear, but it almost certainly bears on the control of protein synthesis, on evolutionary mechanisms, and on how it is that we can make so many antibodies.

There is immensely more to be learned about molecular genetics as well as about what a single living cell is and how it functions. Sooner or later, we will gather the right clue to the intrinsic nature of the transformation that converts a normal cell into a cancer cell, perhaps be able to relate that mechanism to the bizarre diversity of chemical structures of known carcinogenic materials, and understand what fraction of all cancer is the unavoidable consequence of our own biology as compared with that due to diverse forms of environmental insult. If we are very lucky we may get a clue to how that transformation may be reversed.

Fairly soon we should have more insight into the nature of differentiation, the basic process of development of an organism—for example, the genetic programming of specific cell types, the signals that cause embryonic cells to migrate to new locations and to settle down. When we learn how cells in the developing nervous system find each other, recognize their appropriate partners, and link up in the billions of right connections, how a growing nerve finds the correct muscle or nerve with which to make linkage, then we may have some understanding of why it is that an adult lobster can grow a new arm but we cannot, and perhaps a rationale for research seeking means to stimulate regeneration in severed nerves in the spinal cord and peripheral nervous systems.

Only a small part of research on the nervous system will be done with human subjects; most of it must be done with species that afford special experimental opportunities, such as squid, lobster, electric eels, or chickens. Clues to the physical basis for memory are just beginning to come from studies of learning in relatively primitive nervous systems, but the task of understanding memory and recall will be with us for a great many decades. Rather sooner we should learn the intrinsic physical defects that must underlie the major psychoses, and perhaps know better than we do today how to go about the task of mitigating the human waste they cause.

I hope that equivalent boons will derive from advancing understanding of plant biochemistry and physiology. Agricultural productivity has been leveling off for some years. Little additional improvement is possible by conventional techniques—breeding, irrigation, fertilization. It remains to be seen whether our growing understanding of photosynthesis and nitrogen fixation and the ability to transfer genes will enable us to produce higher-yielding strains of crop plants or plants that can flourish with less light, water, or fertilizer. What is clear is that such strains will surely not become available unless we have sufficient understanding and try to produce them.

Environment

Concern for the quality of the environment will continue. The basic processes involved—photosynthesis, denitrification, mineralization, gas absorption, volatilization, and so on—are scientifically understood at the primary level but not in the gross dimensions of real concern, the large-scale exchanges and fluxes that may be beneficial or injurious to the environment. Some of the major subjects demanding examination are the following.

- Cleansing of the atmosphere by forests and other natural and managed vegetation
- Impoverishment of soils caused by acid precipitation
- Influence of precipitation on the quality of lakes and streams, and the alterations in aquatic vegetation and fauna caused by deposition of acid substances
- Increases in the abundance of heavy metals in food crops and natural food chains as a result of direct deposition from the atmosphere and mobilization in soils due to acid precipitation.
- Fate of volatile pesticides and other chemicals used in agriculture and forestry, and their effects on humans and the environment
- Substances and processes involved in atmosphere-biosphere exchange

The effort to establish acceptable standards and devise acceptable control technologies will continue for years, as will the effort to understand the nature and magnitude of threats from man-made pollutants. For pollutants, as for food additives and other materials, it is time we acquired credible dose-response curves, down to more realistic low doses. Surely we should not quarrel indefinitely about the probable shape of a curve that no one has seen.

No problem of environmental concern seems as immediately urgent as that of formulating a sound plan for long-term management of radioactive wastes. My colleagues and I are still confident that a suitable geologic host can be selected to isolate hazardous radionuclides. Until recently, waste isolation studies and planning concentrated on such a geologic barrier, but newer studies have indicated that engineered barriers are also feasible. By analyzing the radionuclide isolation mechanism in terms of an overall waste isolation system—which includes, in addition to the geologic barrier, the form and composition of the waste, the container, the overpack, and the interaction, over time, between the waste and the surrounding environment—it should surely be possible to design a suitable system. With data from laboratory experiments, credible predictions of long-term repository performance should be possible.

Another critical problem is the future of our water resources. Again, much of the understanding required for rational policy formation is obtainable only from suitable studies. For example, we need to know what extreme departures from normal rainfall (droughts and floods) can be anticipated, whether they are predictable, and what technological responses can be developed. Groundwater is still an uncertain resource in many areas, and factors that affect it could be elucidated by case studies of particular basins. The effect of nonpoint sources of pollution on water quality in streams and lakes is not well understood, and the trade-off in funding between further reductions in point sources and attention to nonpoint sources remains a critical question. Technology for water recycling and reuse and possibilities for reducing water consumption must be investigated to assist in meeting future demands.

Social Science

It is almost a truism that the pace of natural science and technology has considerably exceeded the growth of knowledge of social processes and their management. Consider such "buzz words" as population, crime, poverty, alcohol and drug abuse, child and family development, education, employment, aging, cities, sex, discrimination, conflict. Patently, research in much of social and behavioral science is shaped and defined by our times. That understanding comes slowly and with difficulty, if at all, reflects not the competence of the investigators but the intrinsic difficulty of the problems, the lack of useful nonhuman models, and our reluctance to experiment with people as subjects.

Still, we may expect improvements in the quality and utility of econometric models. Nonmarket indicators of the quality of life should be sought so that we can gauge the effects of government intervention on our sense of well-being. Estimates derived by using market surrogates and multiple regression analysis will be looked at askance by most of us until some more direct measures are available—as of the value we really place on nonpolluted air if the health effects of the pollutants are unknown.

Our society must decide whether it is as risk-averse as it has acted in recent years. In view of the fact that the age-corrected incidences of only two forms of cancer have altered significantly in recent decades—an increase in lung cancer due to cigarette smoking and a marked decrease in stomach cancer for unknown reasons—is the current cancer phobia and resultant regulation a reasonable process? Is there an acceptable means to assess the relative benefits and costs of the interventions on which we have been intent? Have we, as alleged, been placing a dead hand on the throttle of the economy, seriously affecting productivity and innovation? What will be the effect on our national well-being of inflation, an aging population, intractable unemployment, markedly increased energy costs? Can we come to terms with the increasing interdependence of the world economy? Can we learn to minimize international tensions and avoid armed conflict? The list of such questions seems endless; their answers seem imperative to rational national policy. I can offer only the hope that the social and behavioral sciences will find proximate answers in time to help.

Instrumentation

Turning now to some institutional facets of the U.S. scientific enterprise, there is first the matter of instrumentation. From 1967 to 1976 basic research was insufficiently funded to support the enterprise already in being. Available funds were streteched as far as possible, used largely for salaries and consumable supplies while instrumentation requirements languished. Meanwhile, a remarkable assortment of new techniques, technologies, and instruments were developed which can spare not only manpower for other tasks but also enable measurement of phenomena that are otherwise inaccessible.

Too few of these new instruments are currently at work to meet urgently sensed needs. They include nuclear-magnetic-resonance spectrometers, electron paramagnetic resonance spectrometers, synchrotron radiation sources, scanning electron microscopes, high-voltage electron microscopes, high-resolution mass spectrometers, medium-size computers, and a variety of others. The cost and small numbers of such instruments will revolutionize the manner of conduct of much of science.

A new mode of instrument use began with the large, expensive machines of high-energy physics, astronomy, and oceanography. Since there are only a few of each such instrument, investigators come substantial distances to utilize them, not infrequently bringing along auxiliary apparatus, postdoctoral fellows, and graduate students. That style—sharing—extended to the space program and now will be extended to the use of the medium-priced instruments of chemistry, biology, and physics. But there must first be instruments to share. Science is paced by ideas and instrumentation; it is wasteful and unwise to fail to provide adequate instrumentation if it is our society's intention that our scientific cadre shall be as productive as possible.

Manpower and Universities

This country never made an explicit decision that the university should be the primary locus for the conduct of basic research. That it became such was the consequence of a multitude of lesser decisions, while, in parallel, industry reduced the fraction of its own resources that it allocated for basic research in-house. In any case, universities now conduct perhaps three-quarters of all basic research. But, because universities are organized and budgeted primarily to discharge their formal educational obligations, the academic research endeavor is remarkable in that (i) the number of potential investigators is a function of the size of the teaching faculty, and (ii) because the labor force for this enterprise consists of individuals who think of themselves as graduate students and postdoctoral fellows, their stipends are modest compared to their contributions, and the entire enterprise is funded "on the cheap."

However, we are heading into a period that will differ strikingly from the last few decades. Thanks to the decline in the birthrate that began in 1961, enrollments in colleges and universities will begin to decline in a year or two and will reach a minimum around 1995. The resulting decreased requirement for faculty has already been recognized by those responsible for hiring at the universities. It seems clear that there will be relatively few opportunities for newly trained young people to embark on careers combining teaching and research, but we do not know, quantitatively, just how bad this situation will be. It is possible that we stand in danger of losing much of an entire generation of young minds who might have engaged in science.

A number of predictions of the effect of declining college enrollment are available, but their reliability is uncertain; at the request of the NSF, the National Research Council is about to address this question. (These problems will be even more acute for the humanities, since there are other meaningful outlets for the talents of trained scientists, but not for those trained in the humanities.) If we want to be sure of having a nucleus faculty in 1995, and if we want the scientific enterprise to continue at a rate at least as great as at present, it will be necessary to invent some new, perhaps temporary, arrangement whereby trained young people will be enabled to pursue their science. If, as a nation, we are serious about science, we probably have to loosen somewhat the coupling between teaching and research at universities. Six or eight months from now we should know more about what to expect. What seems entirely clear is that the severe reduction in the postdoctoral fellowship program proposed in the NSF appropriation request for fiscal 1980 is a step in exactly the wrong direction.

Because of these demographic circumstances, for some years the industrial research world will presumably have improved opportunities to employ the brightest products of the graduate education system. That may prove useful in itself. Some of us are disturbed by the fact that the connection between academic research and industrial research in this country is now rather tenuous. We might be able to capitalize on the demographic changes I have described to build stronger working ties between industrial and academic science. I cannot be sure that this would mitigate the falloff in industrial innovation that has been the subject of so much discussion in the last couple of years. But it might be of assistance in that regard.

The University-Government Relationship

I suppose that university presidents have always known that he who pays the piper will, one day, call the tune. When NSF and NIH were young, there seemed to be fewer strings attached to federal research grants and contracts than to money from private sources. How that has changed! Universities are now expected to be models of equal employment opportunity, models of how to manage an animal colony, models of how to provide seemingly endless statistics concerning themselves, their financial circumstances, and their arrangements of a dozen kinds, and models of arrangements to minimize the disadvantages of the physically handicapped. They are to respect privacy but provide information that the Privacy Act, in spirit, was certainly intended to protect. They are efficiently to use federal funds in support of research, but are also, for example, to comply with guidelines for research on recombinant DNA that require that protocols of every experiment be reviewed by a committee which can only meet after sufficient notice, leaving the investigators to fill their time.

A substantial fraction of the indirect costs component of research grants arises from the burdens imposed in meeting federal regulations. I do not mean that the university should be exempt from legislation that was intended to apply to all of U.S. society, but it is a place to observe just what that costs. What is important is that those costs are being defrayed from funds appropriated in the name of research.

One could wish that the federal government and the universities could clarify the terms of the bond between them. The government defrays as much as 50 percent of the total cost of university activities in some instances, but denies any responsibility for the universities' continuing welfare. While avowedly only purchasing research services, the government uses the threat of withholding payment as the means of enforcing laws concerning matters unrelated to those services. For their part, the universities argue their independence, yet have become very largely dependent on federal funds to support one of their primary functions. They press for "full indirect costs," while balking at the requirements for accountability that necessarily follow. They are uncomfortable in the knowledge of their long-term commitments for physical plant and faculty salaries, when the goernment makes only annual commitments for its share of costs. The universities believe themselves ensnarled in a web of bureaucratic regulations from which there seems no retreat. This state of affairs is patently undesirable, if not intolerable. One must hope that the groups now addressing these problems—sponsored by the Sloan Foundation and by the American Association of Universities and the Conference Board of Associated Research Councils—will point the way to a more harmonious future for this enterprise.

Inadequacy of Total Available Research Funds

As a result of policies set in motion by the government, U.S. graduate schools have been turning out new Ph.D.'s in science and engineering at a rate that increased the total number of scientists by about 8 percent per year for about two decades. Between 1967 and 1976, when there was an actual decline, in constant dollars, of federal funds available for basic research, the total national science community competing for research support nearly doubled, indirect costs rose steadily, and the intrinsic costs of doing research increased by 4 to 5 percent per year because of the increased sophistication of research itself. Hence, the sense of a considerable shortfall. The federal agencies, to stretch their resources, shortened the period of the average grant and reduced the fraction of their resources allocated to acquisition of instruments—a situation that someone has described as 10-year ideas supported by 2-year grants based on 1-year appropriations.

And there has been one other noteworthy manifestation. With pressures for accountability from Congress and the White House, program officers at federal agencies, including NSF, have demanded that grant applications be submitted in ever greater detail. At the same time, applicants, aware of the ever increasing competition, have attempted to enhance their chances of success by submitting the most detailed applications possible. When I was an active investigator, 1 week easily sufficed for the preparation of a multiyear research grant application. Today, closer to 1 month per year appears to be par. This is a massive waste of scientists' effort. The recipient agencies are obliged to find qualified reviewers to read it all, thereby tying up yet more scientists in peer review—which has become an endurance contest as well as an analytical procedure.

National Science Foundation Appropriation Request

In view of the stringency in other aspects of his budget request, I was doubly pleased that the President asked for a substantial increment in the appropriation for basic research to the NSF. To be sure, that increment is not quite as large as it might seem; the 11.8 percent increase requested for basic research includes significant expenditures committed in prior years for at least two large, nonrecurring items. If those are deleted from the calculation, then the requested increment is, I believe, about 9.8 percent—2 or 3 percent above the expected inflation rate—if we are lucky.

It is not unknown for Congress to depart from the budget request, even occasionally to make significant additions to some favored items while holding the total appropriation constant. I hope that, should the appropriation be increased for any specific item in the NSF budget, that will be done as an add-on, rather than at the expense of some component of the basic research budget. To the extent that I have been able to study the President's budget request for NSF, I fully support it. I know that that much—and considerably more—can be put to good use.

The primary mission of the NSF is to extend the body of useful knowledge, not to solve social problems, not, directly, to expand the economy, protect the public health, or assure the national defense, for example. We have a battery of mission agencies; if any of these is found wanting in its uses of science, I trust that the cure will be applied where the disease is rather than by distorting the mission of the NSF. The record of the Foundation for integrity and excellence is unsurpassed in the federal establishment. Its accomplishments should be much more widely known among the American people so that they may join in our pride in this remarkable expression of our national purpose.