adobe and wood-frame building in Valdivia.

A large number of reinforced-concrete elevated water tanks were damaged. Figure 10, a tank in Rio Negro, shows the characteristic pattern of shear failure of horizontal members and bending failure of columns. These tanks were constructed after a design, originating in Germany, which apparently did not provide for the transmission by the supporting members of the horizontal seismic forces between the heavy tank and the ground.

Chile had had a catastrophic earthquake in 1939, in the Concepción region, in which 30,000 people were killed. As a result of that experience, a new building code was put into effect, and major buildings erected since that time have been subject to a design requirement that takes earthquake loading into account. Thus, it was not surprising that the post-1939 construction behaved markedly better on the average than the older buildings. This was particularly noticeable in Concepción, where, though some of the newer large buildings were damaged, the damage to the older structures was much more pronounced. Errors in design or construction, or lack of knowledge about the behavior of soils and foundations in earthquakes, were the causes of most damage to the newer large buildings throughout the afflicted area.

Two examples of damage to modern buildings, from among the cases where soil conditions were not the dominant feature, are illustrative. The first of these buildings is of reinforced concrete, and the second of steel-frame construction, though in fact there were relatively very few steel-frame buildings in the afflicted area. The reinforced-concrete building is a seminary consisting of a three-story and a four-story wing resting on firm high ground in Puerto Montt. The columns proved unable to transfer the horizontal force down to the ground, and many of the columns, especially in the second stories of both wings, were completely shattered, as were many of the masonry partition walls. It appeared that the concrete was of substandard quality. The steel-frame building is a three-story chemistry laboratory at the University of Concepción, on a rigid concrete raft footing resting on deep, soft alluvium. The open first floor contained a number of steel diagonal members with welded joints connecting bottoms of columns with second-floor girders in both longitudinal and transverse directions. The welded joints failed early in the first large shock, but the building was able to ride out the violence of this and the subsequent earthquakes without collapse. There are important lessons to be learned from these and many of the other damaged as well as undamaged modern buildings. The learning of these lessons will require detailed analyses based on the original structural designs.

Conclusion

Both the scientific and the engineering aspects of our knowledge of earthquakes will be significantly augmented as a result of the reports now being prepared by investigators from Chile, Mexico, Japan, and the United States. The wisdom of making full reports and analyses was demonstrated from the comprehensive treatments published after the great earthquakes in San Francisco (1906) and Tokyo (1923); on the basis of those reports and analyses, technical papers are still being written today. Engineers stand to gain valuable information on the suitability of modern antiseismic design methods and criteria, on the currently emerging concepts of dynamic design and limit design, on soil behavior and the action of foundations and earth structures, on characteristics of tsunamis, and on tsunami warning systems. Scientific study of volcanoes, tsunamis, tectonic movements, faulting, earthquake mechanisms, and the character of the earth will be aided. The people of Chile, who are moving with energy and purpose toward reconstruction, may find some comfort in knowing that the world is learning from their tragedy.

Scientific Progress and the Federal Government

The Panel on Basic Research and Graduate Education of the President's Science Advisory Committee reports.

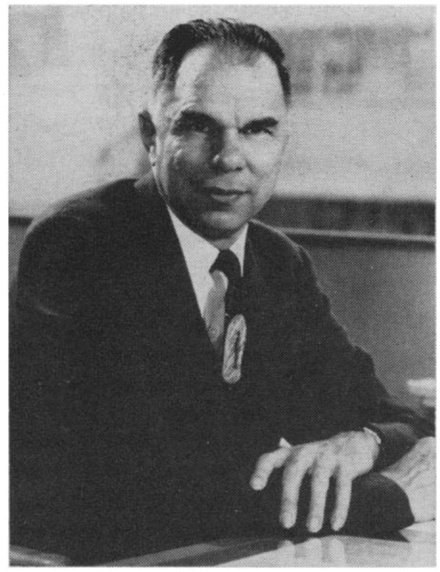
This paper is a brief statement on a large set of problems: the problems which center on the advancement of science by basic research and the making of scientists by graduate education. This is only one part of the complex world of modern American science, but it is a critically important one. We have tried to state clearly the fundamental character of the environment which is required for scientific progress and for the making of good young scientists. We then consider the way in which these requirements should affect the policies of both the federal government and the universities, which are today the two forces in our society whose actions most affect the health and strength of basic research and the training of scientists.

We find much, both in the government and in the academic community, which needs improvement, but we have made no attempt to prescribe detailed policies for either party. The last 20 years have seen a remarkable growth of support of many kinds for basic research and graduate education, and the role of the federal government has, on balance, been highly constructive. On the whole, our universities are much stronger today in science than they were a generation ago. We have great confidence that energetic leadership and constant effort can find good answers to the practical problems of the future. A short statement like this may hope to contribute, not specific solutions, but rather some general ideas about the nature of the task and the principles that should guide us in working on it.

Background

Both the security and the general welfare of the American people urgently require continued, rapid, and sustained growth in the strength of American science. Other reports of qualified bodies, and earlier reports of this committee (*1*), have argued in detail the reasons which make this growth vital to us all. We believe that most Americans are in favor of more and better science. In a general way Americans recognize that scientific understanding is at once highly valuable in its own right and quite indispensable for the sustained progress of a modern industrialized society. We are proud of our great accomplishments, and we become concerned whenever it appears that our scientific effort in any field may be second best. Most of all we have learned to recognize that the defense and advancement of freedom require excellence in science and in technology.

But our acceptance of these quite modern ideas does not mean that we understand fully their consequences for our policy and practice. American science in the next generation must, quite literally, double and redouble in size and strength. This means more scientists, better trained, with finer facilities. Many forces contribute to this urgent need for growth. Our population is rapidly increasing, so that there are more and more young people to be taught, and we have nothing like the number of qualified teachers we need, even now. Science itself is expanding so fast that our efforts would have to be much increased if we were only to keep up with its general international momentum. The training of scientists takes longer than it used to, and the facilities needed in a modern laboratory are usually much more complex and expensive than those that were needed only a few years ago. Science and technology today have a steadily growing, mutual impact, so that the practical man has need of the closest and most immediate access to new results in basic science. Thus, both science and scientists must be more and more widely diffused throughout our society. We need more men doing more things, with more support, in more places. And each of these requirements is better measured by multiplication than by addition. It is the simple truth that if this country is to safeguard its freedom and harvest the great opportunities of the next generation of science, the level of its scientific investment must be multiplied and multiplied again.



Glenn T. Seaborg, chairman of the Panel on Basic Research and Graduate Education of the President's Science Advisory Committee.

Yet the right word is *investment.* What this country spends on excellence in the sciences is not money gone with the wind. It is money that brings us handsome returns, and of many kinds. In immediate economic terms the proposition is clear enough: what we have done in science has brought our society riches many times greater than what science costs us, and this will be true as far in the future as we can see. In economic terms, indeed, scientific investment has quite extraordinary power. Ordinary capital investment puts savings to work on labor-saving machinery that is already known and understood; the increased wealth produced is what separates the developed modern society from helpless poverty. But scientific and technological investments are still more powerful tools, since they invest in the discovery of what we do not yet understand. We are only just at the beginning of the use of scientific investment in this large sense, and the returns it can bring in are literally incalculable. Simply in terms of economic self-interest our proper course is to increase our investment in science just as fast as we can, to a limit not yet in sight.

But we should not emphasize only the material returns of scientific investment. Science yields a return also in the quality and humanity of our civilization. Science is not merely an inducement to progress, it is an affirmation of man's respect for nature and a way to the fulfillment of some of his highest capacities. Science is enriching, but at its best it is much more—it is enlarging to the spirit. This higher value is one we should never leave out of account in our desire to reassure ourselves that science "pays." Indeed, any shortsighted calculation of return on investment is likely to be self-defeating. Scientific progress does not occur in any neatly predictable way; nor can we be sure ahead of time which research project is likely to have particular consequences for our prosperity or security. Moreover, scientific discovery is not easy, and many experiments fail. Nothing could be more unwise than an effort to assign priorities or judge results in basic research on any narrow basis of immediate gain. It is the advance of science as a whole on which we must rely, for material as well as other returns.

Much of this basic argument for the strengthening of American science applies equally to other fields of learning. While this report centers on the needs of science, we repudiate emphatically any notion that scientific research and scientific education are the only kinds of learning that matter to America. The responsibility of this committee is limited to scientific matters, but obviously a high civilization must not limit its efforts to science alone. Even in the interests of science itself it is essential to give full value and support to the other great branches of man's artistic, literary, and scholarly activity. The advancement of science must not be accomplished by the impoverishment of anything else, and the life of the mind in our society has needs which are not limited by the particular

Members of the panel are as follows: Glenn T. Seaborg, chancellor of the University of California, Berkeley, *chairman*; William O. Baker, vice president for research, Bell Telephone Laboratories; George W. Beadle, chairman of the Division of Biology, California Institute of Technology; Henry E. Bent, dean of the Graduate School, University of Missouri; McGeorge Bundy, dean of the Faculty of Arts and Sciences, Harvard University; William B. Fretter, professor of physics, University of California; Caryl P. Haskins, president, Carnegie Institution of Washington; Emanuel R. Piore, vice president for research and engineering, International Business Machines Corporation; Roger Revelle, director, Scripps Institution of Oceanography, University of California; Frederick E. Terman, vice president and provost, Stanford University; Alan T. Waterman, director of the National Science Foundation; Alvin M. Weinberg, director of Oak Ridge National Laboratory; John E. Willard, dean of the Graduate School, University of Wisconsin; and O. Meredith Wilson, president of the University of Minnesota.

concerns which belong to this committee and this report.

We do not, in this report, attempt to consider what direct responsibility and interest the government has for strengthening basic research and graduate education outside the sciences. This is a subject which deserves careful attention, but it is beyond our mission. What we can say, however, is what earlier reports of this committee have regularly emphasized, that neither the government nor the universities should conduct the support of scientific work in such a way as to weaken the capacity of American education to meet its responsibilities in other areas. The costs of scientific progress must not be paid by diverting resources from other great fields of study which have their own urgent need for growth.

Basic Research and Graduate Education

Science is a large field, and in this report we want to concentrate attention on two parts of it: the part in which research is pursued with the purpose of advancing scientific understanding, and the part in which young college graduates are helped to become scientists. Our shorthand terms for these two activities are "basic research" and "graduate education."

Basic research is the cutting of paths through the unknown. As most of us know today, it is the pacesetter for technology and the raw material of invention. Its growth can be assisted, and its general value can be confidently asserted, but it depends, in the end, on the imaginative powers and scientific skills of the men who do it. Basic research is as hard as it is exciting, and while it contributes enormously to the national welfare, what usually moves the scientist is not so much this practical consequence of his labor as the simple but powerful urge to know how nature works. A free society can honor the scientist's curiosity without forgetting his social value.

Because basic research is aimed at understanding rather than at practical results, the layman sometimes assumes that it is entirely abstract and theoretical, and that only when it becomes a matter of industrial development does it "come down to earth." This is a false notion, and its falsity becomes increasingly clear with time. Indeed, one striking characteristic of our scientific age has been the disappearance of the barriers between pure and applied science. Not only are we finding important technological applications for mathematical and scientific knowledge which was formerly thought of as abstract and "useless," but the advance of technology has both generated new problems in pure science and provided new tools with which such science can be advanced more effectively. The development of the techniques and hardware for radar during the war, for example, gave the physicist and the chemist a new and refined tool for investigating the properties of solids and of chemical compounds. Conversely, the extensive use of this tool in basic science has opened the way to entirely new techniques in electronics. Similarly, the development of large-scale electronic computers has led engineers to find practical uses for some of the most abstruse and "impractical" branches of higher mathematics, while the understanding of the techniques of using computers has, on the other hand, given us deeper insight into some aspects of the behavior of complex biological and social systems. Basic and applied science today are distinguished less by method and content than by motivation. Part of the strength of American science stems from close intellectual intercourse between basic and applied scientists. Very often, indeed, the same man can be both "pure scientist" and "engineer," as he works on different problems or on different parts of one problem. We do not believe in any artificial separation between basic and applied research or between science and engineering. The fact that a scientific advance is useful does not make it unscientific.

Graduate education for scientists is usually seen as what comes after the B.A. and before the Ph.D. For us it is this, but also more, and in our view any definition in terms of an interval between two degrees obscures much more than it clarifies. We are using the term here to mean that part of education which seeks to turn a young man or woman into a scientist. By the word *scientist* we mean someone who is fit to take part in basic research, to learn without a teacher, to discover and attack significant problems not yet solved, to show the nature of this process to others—someone, in short, who is equipped to spend a lifetime in the advancement of science, to the best of his ability.

It is a fundamental contention of this report that the process of graduate education and the process of basic research *belong together* at every possible level. We believe that the two kinds of activity reinforce each other in a great variety of ways, and that each is weakened when carried on without the other. We think also that this proposition has substantial implications for the policy of both the federal government and the universities. Because the proposition is so central to our argument, we must try to demonstrate it thoroughly.

In one sense, it is almost self-evident. If graduate education aims at making scientists, and if inquiry into what is unknown is the moving principle of all science, it is not surprising that experience of this kind of inquiry should be essential in graduate education. Clearly, such experience is best obtained in association with others who have had it or are having it themselves. The apprentice scientist learns best when he learns in an atmosphere of active research work. It is true that only a minority of those who receive a Ph.D. in science continue their subsequent careers in basic research. The majority go on to applied research in industry or to teaching in college, where research opportunities are limited. (Even in the universities many scientists are not active in research.) Nevertheless, such experience as all graduate students should have with basic research is highly important. In all forms of scientific work a man's effectiveness is multiplied when he has that depth of understanding of his subject that comes only with the experience of working at a research problem.

But if all this is so, it does not seem to be fully recognized in the standard practices of most universities and federal agencies. For as we are describing it, the process of graduate education depends on "research" just as much as upon "teaching"—indeed, the two are essentially inseparable—and there is a radical error in trying to think of them as different or opposite forms of activity. From the point of view of the graduate student, the teaching and the research of his professor are, at the crucial point which defines the whole, united. What he learns is not opposite from research; it *is* research. Of course many necessary parts of a scientist's education have little to do with research, and obviously, also, for many professors there must be a gap between teaching a standard graduate course and working at one's own problems. Moreover, many good teachers—men who keep up with the new work in their subject and communicate its meaning clearly to their students—are not themselves engaged in research. Yet we insist on the central point: the would-be scientist must learn what it is like to do science, and this, which is research, is the most important thing he can be "taught."

So far we have been arguing that graduate education requires the experience of basic research. What happens when we turn the matter around, and ask whether basic research must be carried on only in conjunction with graduate education? Here the answer cannot be so categorical. Though our general conviction is that a fundamentally reciprocal relation does exist, it is clear that research of outstanding quality is often carried on in isolation from teaching and indeed quite outside the universities. While the great teacher of graduate students is almost invariably a research man too, there are many notable scientists who have as little as possible to do with teaching. First-rate industrial and governmental laboratories with commitments to specific programs are necessarily separated in some measure from teaching of a conventional sort. Thus, basic research can be, and is, carried on without much connection to graduate education.

Yet in the long run it is dangerous to separate research in any field entirely from education. If a research field is to be attractive to good young men, it ordinarily needs roots in the universities. The pool of graduate students in our universities is the pool from which the scientists of the future must come. These young people do not easily study what is not taught; they do not often learn the meaning of research which does not exist in their environment. A scientific field which has no research life in the universities is at a grave disadvantage in recruiting new members. As learning and teaching require research, so research, in the end, cannot be sustained without teaching. Hence it is always important for research installations to maintain effective connections with students. In a later section we note some of the consequences of this rule for both the government and the universities.

Meanwhile it is worth noting that the practical need for connection between a research installation and the source of scientists is not the only reason for doubting the value of any sharp separation between research and teaching. There is also the fact that in the wider sense all first-rate research laboratories are permeated by an atmosphere of learning. Successful research can be defined, indeed, as learning what has not been taught before, and a good scientist is constantly learning from others as a part of his campaign to find out something on his own. It is not an accident, therefore, that in any outstanding industrial or governmental laboratory the atmosphere is reminiscent of the university. In such laboratories, moreover, the scientist's concern with "research for its own sake" is often very strong; much excellent basic work is done in such laboratories, in support of general programs of applied research (*2*). We believe that research, learning, and teaching are deeply connected processes which should be kept together wherever possible. Not all basic research should be —or could be—performed in our universities, but where it is done separately, special efforts should be made to take advantage of its educational value.

Role of the Federal Government

Basic research and graduate education, together, are the knotted core of American science, and they will grow stronger together or not at all. Let us now consider the consequences of this principle, first for the government and then for the universities. The federal government, by its varied missions and the size of its financial commitments, is the most powerful single force in this whole field, while the universities are the natural holders and custodians of the knotted core. Both have done much to strengthen, and something to weaken, the common enterprise in recent decades. Both must do better in the years ahead.

The federal government, through many agencies, is now by far the most important source of funds for research in the universities. In 1957–58 the federal share in all such research was about 70 percent. This astonishing expansion in federal activity is the product of several forces, all of them initially related to specific needs of specific branches of the government. The two most important purposes of the government in supporting research have been defense and health; more than three-fourths of all federal funds for such research in 1959 came from agencies with one or the other of these two missions.

The government's first interest in its relations with universities was to obtain the practical advantages of research. Historically, the earliest large-scale relations were those in the field of agriculture, which connected the government to the land-grant institutions. Then, during World War II, American science conclusively demonstrated its practical value, and in the years after the war, first the defense agencies and then those related to health developed large-scale research relations with the universities. At first these relations were based on contracts allowing compensation for services rendered. Government contracts have supported a great deal of research of high quality; they have, for example, paid for almost all of our remarkable postwar effort in nuclear physics. Nor has this support been limited narrowly to the fields with high practical significance or political appeal.

Yet in its essence the concept of "purchase of services," which is implied in any government contract, was and is a doubtful one when applied to basic research. Basic research, almost by definition, has no clearly predictable practical result, and so the Congress and the federal agencies involved have had to interpret very broadly the notion of "value received" in return for sums spent on research contracts. But conversely, the support of university research has been hampered by contract rules which strictly limit the ways in which universities can be compensated for their costs. The whole framework is somewhat arbitrary and unrealistic. The wonder is that it works as well as it does.

From the point of view of this report, a particularly grave difficulty in the support of research by government contracts is that by its very nature support given through such a mechanism tends to separate research from education. In the research contract the one recognized "product" is "research"; yet if the government has an interest in basic research in any given field, it inevitably has a related interest in graduate education in the same field. Thus, the government is almost forced to work against its own interest as well as that of the university when it uses an instrument whose formal concern is with research results alone. It is greatly to the credit of many able public servants that this inherent difficulty has often been overcome by imaginative and farsighted administration. Many graduate students have been helped by contract funds in a fashion that is both constructive and proper. But the research contract, with its concept of services purchased, remains an imperfect instrument. Even for the advancement of basic research as such it is awkward, because first-class research is really not a service to be contracted for. And for larger purposes it is wholly inadequate.

All government agencies are now empowered to use grants instead of contracts in supporting basic research; the National Science Foundation and the National Institutes of Health, particularly, have used this form extensively for some years. The use of grants sometimes has the regrettable consequence of failing to provide for the full cost of the research that is supported, and sometimes the complexities of application and processing for even a small project grant compare unfavorably with the best practice of contracting agencies. But on balance and in the long run, the grant is a better instrument than the contract—it is more consistent with the nature of basic research.

Grants and contracts are both used to support specific research projects. This is good, in and of itself—especially when such support is provided, as it often is, with a minimum of red tape and for broad objectives, with relatively long time schedules (three-year terms were recommended in an earlier report). Support of good men or groups in specific projects can be particularly effective in ensuring that excellent scientists and excellent problems are identified wherever they may be. While the process of evaluation and award is time-consuming both for government officials and for outside scientists who serve on advisory panels, it is well done, on the whole. But project support, in and of itself, does not fully meet the needs of the federal government.

We can understand this matter better if we consider for a moment the federal government's larger purposes in relation to basic research and graduate education. In addition to the research interests of particular agencies, the government has two other, more general, responsibilities. One is its concern for the development of fields of basic and applied science which may be of general importance for the national security and the general welfare; the other is its concern for the strength of American science and higher education as a whole.

There are many fields of science in which the United States could well become stronger and more active, both from the point of view of the national defense and from that of the public welfare. It is unfortunately not true that scientists always and automatically sort themselves out into the most relevant and productive fields of work. Science, like any other human activity, is subject to the distortion of human frailty, and scientific fashion is not always sound. Moreover, even when individual scientists spot promising untilled fields (and it is scientists who do spot them), it is often hard to find funds and facilities for the new undertaking from within hard-pressed universities.

We think it plain that the federal government should act in such areas of scientific promise. No other agency in our society is responsible for the national security, and a large field full of new problems, such as space science or materials research, is potentially vital to our safety. No other agency in our society is responsible for the general welfare, and all major fields without exception can be expected to contribute to the general welfare. No other agency, finally, has the financial strength to provide the necessary support—and incentive—for work in expensive new undertakings. It can be said without qualification that our society will be endangered and impoverished if these things are not done, and that only the federal government can take the leadership to get them done. We do not mean, again, that only federal action will be needed; we do mean that it must play a large initiating and sustaining role.

When we construe the matter in this way, it becomes clear that no narrow or single-instrument method of action will serve the government's purposes. For example, if oceanography is urgently important (as it is), if good oceanographers are scarce (as they are), and if oceanographic facilities—especially modern sea-going vessels—are almost nonexistent (as is also the case), the federal government cannot discharge its responsibilities by signing a research contract with any one institution. It has to look at the whole subject and all its needs. It may be more important to buy some university a ship—as the National Science Foundation has recently done—than to execute a research contract for work under one of its professors. It may also be important to offer fellowships or to assist in the initial expense of a new set of courses. The government will not be able to serve its own interest if it cannot put its money freely wherever it sees an urgent need.

In speaking of new fields of need and opportunity, we are seeking to emphasize the things that now need doing. We could also call attention to the many things that have already been done, above and beyond the standard research contract. The federal government has, of course, already built major research facilities when no one else could—most notably in the field of nuclear physics. It has also begun to make grants for research facilities as well as for research—most notably in the field of health. The National Science Foundation, with the broadest charter of any agency in the field, has granted fellowships both directly to students and indirectly through universities, and recently it has planned to make unrestricted research grants to institutions receiving funds on a project basis from its hands. Nor should we neglect the imaginative use of training grants in medicine and health, the fellowship program of the Atomic Energy Commission, or the special help made possible by the National Defense Education Act. Still, all of these are limited *ad hoc* programs which only partially meet the government's own interest in graduate education and basic research; we have hoped, by discussing a new topic like oceanography, to show how general and unlimited that interest can be.

The government has one still greater interest in these matters. It is, quite simply, that university science should be as strong as possible. This blunt statement does not arise from sentimental affection, or from professional affiliation, though most of us must confess to both. It is rather that the function of the universities is one of absolutely critical importance to the national welfare. As our scientific efforts have expanded in many industries and government installations, the universities have naturally lost their near monopoly on scientific work. But it is essential that this process should not go too far. For the universities are the source of tomorrow's scientists, as they are the natural centers for jointly thriving basic research and graduate education.

Obviously this proposition has meaning for many others besides the federal government. The universities themselves are not without resources, and they have a particular and urgent obligation to spread the word of their high mission wherever they have friends who can help. State governments, graduates, generous private citizens, and foundations all have a part to play in strengthening the American university. Moreover, as we shall presently see, the American university has a special opportunity and obligation to see to it that its responsibility for judgment and leadership in basic research and graduate education is well discharged.

But when all these things have been said, the first and greatest of responsibilities comes back to the federal government. No matter how many diverse elements of our society may join in their support (and the more the better), basic research and graduate education are in the end, by their very nature, a problem for the nation as a whole, and so for the national government. There is not one physics for California and another for Texas. A first-rate program in Massachusetts or Connecticut must not be limited to New Englanders. Science flourishes by honorable rivalry, but not by any effort to consider only narrow or local interests. Both basic research and graduate education must be supported in terms of the welfare of society as a whole. It is in this large sense that the role of the federal government is inevitably central.

The truth is as simple as it is important: Whether the quantity and quality of basic research and graduate education in the United States will be adequate or inadequate depends primarily upon the government of the United States. From this responsibility the federal government has no escape. Either it will find the policies—and the resources—which permit our universities to flourish and their duties to be adequately discharged, or no one will.

It is much easier to state this general interest of the federal government than it is to delineate its consequences. Indeed, in the largest sense the consequences are too many for numbering, because in essence this general proposition should color every action of every federal agency in all its dealing with our universities. With all their irritating faults, universities are essential agencies of our national hopes, and they must be treated accordingly.

The Job of the Universities

American universities are far from perfect, and their best spokesmen are the first to admit it. In a sense they do not have the excuse of government, which has entered the field only recently; their very reason for being is that they should support the high purposes we are concerned with here. Basic research and graduate education—as we have said and as all will easily agree—are of the very essence of the fundamental purposes of the American university. Yet many do much too little, and none does all it should, in these great areas.

In the first place, it is often as hard for the university as for the government to keep it clearly in mind that *basic research and scientific education* go together. The first and simplest temptation, we fear, is the neglect of research. Most American universities have their origin in a public need for education—for instruction, for teaching—and in most of them there is still maintained the same artificial and fundamentally wrong division between research and teaching that bedevils the government's relations with universities. But while the government finds it easier to pay for research than for teaching, the university, too often, budgets for teaching as a matter of course, and for research only when special circumstances permit. The result is that in all but a few American universities the standard teaching assignment of the professors (significantly called his "teaching load") is such as to make it difficult for him to carry on any serious program of investigation of his own.

On the other hand, the university itself sometimes allows favored individuals to play no teaching role whatever, as a means perhaps of attracting and keeping men of particularly outstanding reputation. The danger in such a practice is obvious, since it appears to suggest that the very best men deserve exemption from teaching. While in any individual case such an arrangement may be justified, it is of the first importance that universities, and scientists themselves, should sustain the value of teaching as well as research. This is not a rigid matter of splitting every man's time in equal but separate parts. In the best departments there will be men whose time is spent mainly on research and men who are mainly teachers, and it is foolish to hold any individual to any arbitrary standard that cramps his style. What is essential is that the environment as a whole should be an environment of learning, investigation, and teaching—all together. Only too often the universities fail to understand and support this image of their nature.

More broadly, our universities have been slow in finding effective ways of encouraging scientific research and training at all the new levels and in all the new ways which the age of science makes possible. Graduate education is not as good as it should be. Outmoded rules of study too often impede the student's access to the experience of modern science. Research programs are too often kept in isolation from the mainstream of student life. Special research installations are too often not imaginatively used as a source of learning and teaching. New fields of study are ignored because they inconveniently cross departmental barriers. Strong understanding of the meaning of the age of science is too rarely found among university administrators. The universities themselves have much to do.

Perhaps the most important single task of the universities is to see to it that their own standards of freedom and excellence are maintained in a period of growing connection with government. While we do not share the notion that government money is necessarily subversive of university freedoms, it is obvious that large-scale federal spending, like any other form of patronage, has its hazards. In the record of the last 15 years there is much more ground for hope than for fear, but occasionally government action has distorted the direction of research or unwisely discriminated against particular scientists on irrelevant grounds. It is to the credit of the government that such cases have been the exception, not the rule, and we commend the good sense which has led the Administration to oppose discriminatory and useless affidavits of disbelief as a condition for fellowship aid.

But the first and greatest responsibility for keeping our universities free and self-reliant rests with the universities themselves—with their faculties, their administrators, and their trustees. What they do not defend, others will not find it easy even to understand, while, when they are staunch in their principles and vigilant in their practices, the record suggests that neither the federal government nor any other source of support is an overwhelming threat to them. Courage and vigilance are essential, but there is no ground for a timid mistrust of government in and of itself. The right concept is that of partnership, with each partner respecting the rights and responsibilities of the other. For this there is need for a constant effort of communication and understanding, and we repeat that the first responsibility here rests with university people.

Yet the main trouble in the universities is not a failure of understanding or communication; it is lack of means. Typically the American university is trying to do too much with too little. Its salaries are low; its teaching assignments are high; its scientific buildings and equipment are cramped or out of date, or both. Modern science does not flourish in such circumstances. Dedication and talent are still the first requirements for scientific achievement, but in most branches of science today there is no escape from the need for expensive facilities and substantial numbers of colleagues. No university in this country today is doing what it should in science; none could be doing even as much as it is without the federal support which has developed in the last 15 years. Thus, partnership between the universities and the national government is the indispensable basis of first-rate university work in science.

The partnership is a fact. It has done much more good than harm. It seems certain to grow in importance unless the American people decide to accept a second-rate standing in terms of power, of comfort, and of knowledge. The broad problem which faces the government and the universities is to make the partnership fully fruitful. The remainder of this report is devoted to a number of specific issues on which it seems possible to make useful comments at this time. But particular issues are subject to change from year to year, and we do not wish to put our main emphasis on any one question in itself. In a sense these comments are illustrative rather than exhaustive or definitive; the main thing, once again, is to think of basic research and graduate education together.

Excellence Deserves Strong Support

In the advancement of science the best is vastly more important than the next best. Mediocre research is generally worse than useless, and the same may probably be said of teaching. It is, therefore, of first importance that national support for both activities should aim at sustaining and reinforcing outstanding work wherever it may be found. Both the federal government and university administrators should be firm in their support of what is first-rate, even when such support requires hard choices.

In this respect, the programs of the government since the war deserve considerable praise. In its support of basic research the government has usually relied on the advisory judgment of respected scientists, and in the main this advice has ensured that, in those areas of research in which federal support has been available, outstanding men have been able to attract substantial support. In this respect the project method of research support has real values which should not be forgotten in our proper concern for additional methods of action. As federal activity expands and broader objectives are included, we should never lose sight of the need for qualitative judgment. Nor should we ever suppose that those scientific centers which have achieved outstanding quality are somehow, by that reason, self-sustaining and free of need.

Centers of Excellence Needed

Equally with the importance of sustaining what is already outstanding, we urge the importance for the country of an increase in the number of universities in which first-rate research and graduate teaching go forward together. The growth of science requires more places with superior faculties and outstanding groups of students. Existing strong institutions cannot fully meet the nation's future needs. It is true that experience is casting doubt on some conservative notions about the optimum size of the university, and the universities which are already great are larger than they expected to be ten years ago. But there is a limit to such growth, and we must hope that where there were only a handful of generally first-rate academic centers of science a generation ago and may be as many as 15 or 20 today, there will be 30 or 40 in another 15 years. Timely and determined support to the rising centers will be repaid many times over in service to society.

Graduate Education Needs Expansion

While we believe that the basic structure of graduate education is sound, we are sure that university faculties can do much to improve it. We believe that the most important graduate degree for scientists will continue to be the Ph.D. Obviously, it is the substance of graduate training and not the formal title "Ph.D." that counts, but in our opinion there is not much point in denying the dominance of this particular degree as the outward symbol of advanced scientific capacity.

As our whole report emphasizes, we believe that graduate education leading to the Ph.D. should include a genuine experience of research. It is experience of research that makes a man a scientist. We think this kind of graduate education is needed not only for those who go on in university science but also for college teachers and, increasingly, for the more important scientific and technological positions in industry and government.

Thus, we need more men and women with the advanced training the Ph.D. symbolizes. No fixed projection of exact numerical needs seems convincing to us, and there is a sense in which we can always make do with what we have. But in terms of return on an investment, again, we believe that a steady and rapid growth in our national output of scientists, in all fields, will be well worth while.

Attracting Talented Students

If we are to have more good scientists, the first necessity is that more of our talented young people should want scientific careers. It is here that our colleges, whether or not they are parts of universities, can contribute largely. We believe that both colleges and the federal government should give urgent attention to the quality of collegiate instruction in the sciences. The first and greatest need is to extend to the college the connected concern with teaching and investigation which we have emphasized throughout. This does not mean that every college must be a university, or that every college teacher must be a dedicated research man, but it does mean that the opportunity and practice of scientific inquiry should be a part of the life of the college laboratory. This is not an easy goal; even in universities the teaching of undergraduates is often sharply separated from the research life of the institution. But once the problem is squarely recognized, much can be done. Decent salaries, time for research, facilities for good scientific activity, and modernization of curriculum can all be helpful. Indeed, the short way of saying it is that most of the comments and conclusions we offer with respect to graduate education can be applied with only moderate adaptation to scientific work in the undergraduate liberal arts college. We repeat that nothing can do more for the supply of talent to the sciences than a general renewal of life and energy in collegiate science (*3*).

Other ways and means of strengthening the attraction of science as a career have been discussed in earlier reports and need only brief reference here. Exposure to the fascination of science should begin long before college, and at every level, and it is time for an end to the separation that has developed between college and university scientists and school teachers. We enthusiastically commend the steps toward reunion which have recently been taken by agencies of government, by school teachers, and by university scientists. There are many urgent reasons for this general course of action, but one important consequence of a new and lively connection of leading scientists to what is done at school can be a major reinforcement of the number of scientists in the next generation.

Graduate Education Needs Modernization

Our basic acceptance of the Ph.D. degree does not imply any similar acceptance of all that is now done in its name. We think it urgent that graduate education be constantly revised and improved. As science itself rapidly advances, we need new ways of teaching and learning both traditional and emerging subjects. Many university departments are more rigid in formal requirements—and more lax in insistence on real achievement—than they ought to be. Many traditional programs for the Ph.D. are now a poor preparation for serious contemporary research, and too few university scientists have given proper thought to the ways in which the learning of science can be improved at all levels by imaginative changes of method. We are at the edge of great advances in our scientific knowledge of what the process of learning is, and it would be an irony if science itself were to lag in the application of its own achievements. Fortunately, there appears at present to be a marked revival of interest among scientists in the improvement of both teaching and learning.

Financing Graduate Education

Graduate studies leading to the Ph.D. are very expensive, both for the university and for the student, and neither party is adequately supported. Great improvements have occurred in recent years, but a great deal still needs to be done. Lack of financial means is probably the greatest single difficulty faced by the American graduate student. It is lack of means, for example, that is mainly responsible for the undue length of time so often consumed in achieving the Ph.D. degree. Too many students simply cannot find the money for sustained full-time study and drop out, or take part-time jobs that delay their progress and flatten their spirits (*4*).

Fortunately, the general need for improvement in this situation is now widely recognized. The universities themselves, the major private foundations, and the federal government have all taken a hand here. But once again, because of the size and urgency of the need, we believe that the level of federal support should steadily increase.

The best and most direct form of support for graduate education is the graduate fellowship. The government has a number of such programs, and on balance they have been highly constructive. We believe that these programs—and in particular the well-designed and effective fellowship programs of the National Science Foundation—should be expanded just as fast as truly promising candidates can be found. A properly designed fellowship program is highly rewarding in its eventual return on every dollar invested.

Fellowship programs have another special value in that they can readily be designed not only to support excellence where it already exists but also to encourage new centers of outstanding work. When such fellowships are awarded directly to individuals who are free to work wherever they choose, the winners do tend, on the whole, to register in departments of established quality. On the other hand, the establishment of fellowships at a particular promising place can be a powerful reinforcement of its efforts to establish itself securely. We favor both forms of fellowship, and again we call attention to the use of both by the National Science Foundation. The various activities of the Department of Health, Education, and Welfare, especially the programs of the National Institutes of Health and the provisions of the National Defense Education Act, also serve both these ends. Thus, our double insistence on the support of existing excellence and the encouragement of new centers has sound precedents.

The natural selection and selective reinforcement which can be supported by fellowships seem to us to constitute a strong argument for including in every fellowship a substantial additional grant for the support of the institution itself. The cost of graduate education to the university always far exceeds the tuition charged to the individual, and therefore university authorities have regularly pointed out that without a supplementary grant they must expect to "lose money" on each fellowship winner. This in itself may not be a wholly persuasive argument, since the university's other resources are at least partly aimed at this same educational purpose. But we believe that fellowships are a good instrument for effective distribution of general support to universities where it will do the most good. We therefore recommend that, as a general rule, graduate fellowships supported by the federal government should include a substantial supplementary grant for the general support of the related work of the university. Since the average graduate student in science costs his university not less than $3500 a year (*5*), grants which provide this amount to the institution would not be excessive. (Where tuition is already covered by the basic fellowship grant—the usual case—the supplement should of course be reduced accordingly.)

Fellowships are of course not the only means of supporting graduate education. Research projects provide legitimate part-time work for many degree candidates, and in many universities part-time teaching is also an effective means of serving the interests of all parties. These instruments are not without hazard; it is possible to do much harm to a young scientist either by subordinating his need for a lively research experience to the requirements of a large organization or by exploiting his first enthusiasm for teaching by assignment exclusively to routine pedagogical tasks. In a properly designed graduate education, these legitimately remunerated forms of experience should be designed and administered with a steady eye for their effect on the graduate student as well as on his pocketbook. This is an urgent issue in many departments which otherwise have very high standards.

But once the emphasis is placed squarely on the student's need for the best possible experience in graduate school, assisting in the research of others and sharing in the work of teaching can both be intensely valuable parts of a good education, and in our eagerness to prevent abuse we should not make rules which cut students off from such opportunities. In particular, fellowship programs should not exclude the student from part-time assignments in research or teaching, and unless the fellowship is so large as to make any additional stipend unreasonable, there should be no obstacles to an appropriate payment for such services.

Ideally, perhaps the best way of financing graduate education would be to take the dollar sign off each of its separate component elements, entwined as they are, and give full support to the student from a general pool of money, while arranging his work in research, learning, and teaching so that in part it would meet the needs of others beside himself. As we work gradually toward such a result we can at least make sure that separate programs, each good in itself, are administered with full respect for the general purpose of graduate education.

Need for Improved Facilities

The dramatic expansion of science in this country has outrun our ability to provide up-to-date space and equipment for either research or teaching; still less can we provide for the two together. While, in the end, men are more important than facilities, the immediate bottleneck today, in many fields and in many universities, is in buildings and equipment. In part this backwardness is the result of a widespread and quite erroneous notion that it is less fruitful to pay for a building or for its maintenance than for research or teaching in themselves. Very little good laboratory work can be done without a roof, and in experimental science the best equipment is usually the true economy.

These propositions carry a moral both for universities and for the government. Neither side should expect to develop first-rate programs without appropriate space and equipment, and on both sides an increased emphasis on investment in facilities is desirable. We warmly approve the recent general endorsement of facilities grants by the executive branch, and we particularly commend the initiation of programs in this area by the National Institutes of Health and the National Science Foundation. While we do not believe there is any permanent magic in the matter, we see considerable practical advantage, for the present, in the practice of sharing the costs of such facilities between the federal government and other sources. Grants contingent upon some degree of "matching" tend to encourage other sources of support, and to ensure that the receiving institutions have a serious commitment in the field concerned. The heavy overapplication for funds available under these programs suggests that, for the present at least, federal money will be most productive if it is used in this way. Obviously, when the government has a particular interest in a particularly expensive installation of more than local importance, it must expect to meet all or nearly all the cost of the undertaking. There may also be other circumstances in which a particularly good opportunity for progress would be lost if "matching" were insisted on, and we believe that unmatched grants should be made in such cases.

New Fields of Research and Education

As we have already said, the national interest demands particularly rapid growth of research and training in a number of fields. The identification of these fields is a job for scientists, universities, and the government, all working together, but since the national interest *is* involved, particular responsibility for their support rests on the government. In such efforts the government must at times be willing to concentrate its support in relatively few places, and universities must avoid a log-rolling insistence on dispersion of efforts in many places at once. Moreover, in its support of these new subjects the government should place its bets where there is clear evidence that the institution concerned is prepared to establish and encourage programs of graduate education fully connected with new research.

This is no place for an exhaustive discussion of the particular subjects that are urgent today. The government has already recognized the existence of special needs in a number of fields; general examples are the sciences closely related to health and to nuclear physics (including high-energy physics and other subjects only distantly related to military strength). More recently and more specifically there has been a proper special concern for such large fields as materials, meteorology, and oceanography. These newer interests frequently have the important characteristic that they are interdisciplinary. Often this overworked word means nothing except that existing departmental divisions do not recognize a subject which has itself all the intrinsic qualities of a separate discipline. But there are also topics which really do require cooperative attack from many branches of science, and studies of materials, the oceans, and the air have this broader and truly interdisciplinary character. In such cases both the universities and the government must be particularly energetic and imaginative in seeking effective ways of encouraging basic research and graduate education together, though in a really new field, research will necessarily precede any large-scale teaching program.

The fields we have mentioned are merely illustrative. Well within sight, but in areas not yet closely studied by the federal government, are opportunities just as striking. Because the government can often be a source of stimulus to academic institutions wearing the blinders of existing departments and divisions, we think that particular attention should be given to such new topics. Again for illustration only, we suggest that there is great promise in such an emerging subject as the general study of complex systems of action, within which such very large questions as the communication sciences, cognition, and large parts of biology itself might conceivably be treated as special cases.

Avoiding Research Installations

The central proposition of this report is that science and the making of scientists go best together. This means that when it can be managed, basic research should be done in, or at least in association with, universities. Exceptions to this rule are numerous, of course. Some problems, by their nature, require attack in ways that are not suited to university life; work of the Geological Survey, for example, can hardly be divided among the universities, yet it requires science of high quality, and basic research is essential to the whole undertaking. The same thing is true of many other enterprises of government and industry. Yet we hold to the view that in the absence of special considerations the university is the best place for basic research, and we note that the separate installations which do the best work are, as a rule, those which have a close and effective connection with academic centers. The Geological Survey, in its intimate relation to academic geology, is an excellent case in point.

When a new field of interest becomes urgent, there is always a temptation to believe that a new and separate research installation is the easy answer. In basic research, at least, such a conclusion is usually questionable, and this temptation should be resisted. As a general rule such new undertakings should be made working parts of universities—or of groups of universities, if the size of the enterprise justifies the additional administrative trouble involved in such joint ventures.

The Universities and New Laboratories

Since the beginning of World War II there have developed a number of major research installations which are supported by federal money and operated by universities or groups of universities. At their best these installations have greatly contributed both to research and to education; we believe that this particular form of partnership between government and universities deserves encouragement and improvement.

We specifically reject the view that such large operations as those of the Ames Laboratory of the Iowa State University are inevitably alien to the university. We believe that great fields of research like nuclear physics simply must not be cut off from universities just because they now require very large instruments and correspondingly large staffs of specialists and technicians. The very difficulties of such large laboratories, in our view, are an argument for strengthening their connection to the universities.

In the best cases these laboratories have derived the following advantages from their university connection: they have had the active participation of outstanding university scientists; their own ability to attract first-rate research men has been strengthened by the university's sponsorship; they have been stimulated to high standards of excellence by the standards of the university itself. At the same time the university has benefited from opportunities for research and for the advanced training of graduate students, and its own ability to attract first-rate scientists has been strengthened.

It is true, however, that all such installations have their dangers, and none of them now is perfect. It is essential that the mission of such laboratories be appropriate for university sponsorship. Development as distinct from basic research, and the training of technicians as distinct from graduate education, usually belong outside the university framework. Moreover, the large laboratory confronts the university with problems of policy that are new, and there is a real danger that there will be a destructive separation between university men and laboratory men. When that happens the university loses the opportunity for a great enrichment of its graduate education, and the laboratory loses the stimulus and the support of the university's scientific staff.

We believe that members of such research installations should be more fully associated with teaching in the universities than is now usual, and conversely we think the installations themselves should always be full of learning students. All concerned should guard against the dangers of bureaucratized "team research," and the installation should be directed with a steady sympathy for new ideas. Government must avoid policies which make such flexibility difficult, and university faculties must work hard to make members of the laboratories members of the university community as well. We have no sympathy with the academic snobbery which occasionally treats as "outsiders" the members of a large special laboratory. New levels of connection and understanding are needed if we are not to have two mutually repellent races of men in our universities—the teaching faculty and the research staff. It is not enough that a small number of senior professors should preside over both sides of life; the two can be, and must be, connected in many other ways.

Nonacademic Research Scientists and Graduate Education

In spite of the basic line of argument we have set forth in this report, American science is and will continue to be much more than the work of universities and directly affiliated laboratories. Great government-supported or government-operated installations like those at Argonne and Bethesda are national assets of high scientific importance, and the same is true of many an industrial laboratory. In some fields of science leadership is no longer clearly in the universities, and basic engineering research often requires kinds of activity that do not fit easily into them. Thus there is a large and growing sector of American science which is not directly included in our central analysis, and the question arises whether in this sector there is anything that can be done to advance the fruitful connection between basic research and graduate education.

We believe that in this area there are indeed important opportunities that require exploration and exploitation by industry, by government, and by universities. Perhaps the simplest notion, and one of the best, is that it should be possible for research scientists in governmental or industrial laboratories to contribute to the graduate programs of nearby universities. This happens now, of course, but it should happen much more often; all parties should be eager to expand the practice. Government and business will serve their own interests by facilitating such teaching even to the extent of helping to pay for it, and universities for their part should be hospitable to qualified men even though they have chosen to pursue their research outside the academic fold.

There are many other avenues of fruitful interconnection between universities and government or industrial scientists: graduate students can learn much from a summer in an industrial laboratory (although such work should not be part of the degree requirements); academic scientists can and do serve with distinction as consultants; a year back at the university can refresh a government scientist; postdoctoral study can often be done as well at an outside installation as in the university itself. We believe that the interpenetration of academic, governmental, and industrial science is only in its opening stages, and we are sure that those who bravely press the effort to find better connections will be well rewarded. In this effort all concerned must of course protect their own standards and purposes. The university cannot become the servant of a particular company or agency. The industrial research laboratory cannot neglect its own mission. Any good thing, like associating industrial scientists with universities, can be overdone. But once again the right note, we think, is one of hope, not fear.

Supporting Postdoctoral Studies

One major element in strengthening both graduate education and basic research can be the postdoctoral fellow, who is ideally equipped to combine research with learning, and both with a share of teaching. We believe that the nature of modern science makes it necessary that there should be many more members of this rapidly growing class; both universities and the government should recognize that such postdoctoral work is as necessary, and at least as expensive, as any other form of advanced training. Postdoctoral fellowships may have particular value in the development of new interdisciplinary fields; regular and rigorous exposure to a standard doctoral discipline is often an excellent preparation for entry into subjects which apply the tools of such a discipline to specific problems. The postdoctoral fellow is free to make this important and difficult transition.

It makes no sense to accept responsibilities for other levels of preparation and then to ignore this increasingly important higher level of work. Universities, in particular, should seek ways of budgeting for the cost of postdoctoral education, just as they budget for undergraduate and graduate instruction. Tuition can as reasonably be charged for one as for the other, and state governments which have accepted the responsibility for meeting the costs of other kinds of teaching will serve their own interests well by making explicit provision for this new and growing form of higher education.

Strengthening University Faculties

The growth of science depends on good facilities and good students, but most of all upon good scientific faculties. The professor is the heart of the enterprise. Without professors the universities quite simply cease to exist. They are, indeed, so essential that we often tend to take them for granted. In recent years much good work has been done in calling attention to the shockingly low level of faculty salaries, and improvement is visible. But neither universities nor the federal government have yet recognized fully the absolutely focal role of the professor both in research and in graduate education. Both sides believe they understand the point, but both continue to tolerate policies that make it difficult for the country to have the services of an adequate number of adequately supported university scientists.

The characteristic error of most universities is to pay professors too little and to load them unwisely with specific teaching assignments. Of course lack of resources is a main cause of this error, but equally plainly part of the trouble is in a failure to understand the nature and value of a professor. Universities which pay no more than the market minimum and which make no adequate provision for research will never move into the front ranks, and will not deserve to.

And there is more to it than money and time for research. The really great scientific faculty cannot be the servant of other men—it has to be secure in its own freedom and responsibility. Too many university administrators suppose that faculties can be bought and managed like baseball teams. It is not so. Universities need brave trustees and strong administrators, but in the end they are what their faculties make them. That the United States today has a number of first-rate faculties is our greatest single scientific asset. To sustain them and to provide the conditions for the growth of more is the greatest single task of American university administrators.

In placing first and central responsibility upon the universities here, we do not mean to underestimate the importance of what government does or does not do—quite the contrary. In our judgment the general pattern of federal support for science has so far developed with very little regard for the problem of building strong faculties, and we think it urgent that careful thought be given to changes in policy that may help the universities discharge this great responsibility. The basic difficulty at present is that most federal funds are tied to specific research projects in a way which makes it hard for universities, in making long-term appointments, to rely in any way on federal funds. This difficulty is compounded in some agencies by policies which discourage the use of federal money to pay the salaries of senior faculty people. We believe that these practices and policies need to be revised in the light of the proposition that nothing is more clearly in the general interest of the federal government than a rapid increase in the quality and quantity of the nation's teaching scientists.

We do not venture to prescribe the ways in which the government and the universities can best serve their common interest at this sensitive and highly important point. Experience is a powerful teacher, and so far we have no knowledge of what can happen when the government and the university become jointly concerned with strengthening the ranks of senior scientists in our universities. There are many instruments that can be used here. At one extreme is the relatively simple practice of paying an appropriate share of the salaries of all faculty members engaged in a federally supported project; we think that this policy should in general be adopted as an interim measure, even though it often has the disadvantage of perpetuating the misleading distinction between "teaching" and "research." At the other extreme is the method, now used in Great Britain, of making large general grants for all purposes to all universities; we doubt if any such pattern could or should be accepted here. In between are such devices as the training grant, which can often be used for professional salaries, and the so-called "institutional" grant, in which broadly inclusive support is offered for a relatively large sector—say, "biological science"—over a relatively long period of time. We believe that the government and the univerisities should take energetic measures to put into effect programs in this middle ground, with the specific objective of making federal money not simply a reinforcement of scientists already holding tenure but a stimulus and a support in the appointment of more such men. We repeat that, in the general interest, a rapid increase in the number of such permanent professorial scientists is needed.

We recognize that many university scientists are strongly opposed to the use of federal funds for senior faculty salaries. Obviously we do not share their belief, but we do agree with them on one important point—the need for avoiding situations in which a professor becomes partly or wholly responsible for raising his own salary. If a university makes permanent professorial appointments in reliance upon particular federal project support and rejects any residual responsibility for financing the appointment if federal funds should fail, a most unsatisfactory sort of "second-class citizenry" is created, and we are firmly against this sort of thing. A variant of this same abuse is the practice of permitting extra pay to faculty members from grants or contracts during the regular academic year. It seems to us fundamental to the spirit of a university that a man's salary from the university itself should not be supplemented by extra term-time payments for work that is properly part of his professorial responsibilities. (Summer compensation for research work is a separate matter, since most academic appointments plainly leave the summer months free for other activities at additional compensation.) Just as a professor should not be responsible for obtaining the funds to pay his regular salary, so also there should be no bonus payment for "landing a contract."

But in our judgment the possibility of abuse is not a good argument against action. We are convinced that when a university is firm in accepting institutional responsibility for payment of all senior salaries and protects its staff from improper pressures or incentives, it can and should seek federal support for salaries as for other needed elements in basic research and graduate education.

The nation's universities urgently need to improve their own ways of giving attention to the matters described in this report. In general, university administrators need to pay much more attention to the meaning and requirements of the age of science. In particular, both administrators and faculty members need to improve their methods of dealing with the federal government. Many of the limitations and weaknesses we have found in government programs are the result of failures within the university. There is an urgent need for a stronger and clearer voice of higher education in Washington, and in particular there is need for more effective representation of those who are concerned with excellence in basic research and graduate education. Either existing agencies of representation should be greatly strengthened or new patterns of action should be sought. The choice of means belongs to the universities themselves, but in any event we believe that the leading men in our university faculties and administrations should clearly recognize that a significant investment of their own time and effort will be continuously needed in this process.

Government Policy in This Area

Today, when many separate agencies are deeply involved, when large national interests are at stake, and when programs not carefully coordinated can easily produce waste and even conflict, it is self-evident that the government should have the means for a well-coordinated and powerfully directed general policy. In our judgment, the final executive authority in this great field must necessarily lie in the office of the President, where policy can be developed with the aid of the Special Assistant to the President for Science and Technology, the Federal Council for Science and Technology, and the President's Science Advisory Committee.

A specific issue which requires resolution on a government-wide basis is that of patent policy regarding inventions that may be of practical value and which have been made while the inventors were working on government-financed projects. At present the policies of the different agencies supporting basic research vary greatly, and this creates problems both for the government and for the universities.

Under the President's policies, first reliance for designing and operating effective programs in basic research and graduate education in the sciences clearly should rest upon the National Science Foundation and the Department of Health, Education, and Welfare. But there is also a need for greater uniformity in the general practices of the many government agencies which support research in the nation's universities. The Federal Council for Science and Technology can usefully serve this end.

We do not presume to define the administrative organization that will best serve to strengthen basic research and graduate education in the nation. We do believe, however, that the President should establish, in whatever way he finds most effective, clear general policies to govern the practices of executive agencies in these areas. Any policy should, of course, be undertaken with full fiscal responsibility, but just as no university can be great if its final decisions are made by the business manager, we believe that in order for the government's programs for the support of science to flourish they must be determined by longer-range objectives as well as by budgetary considerations. Moreover, the development of federal programs to strengthen two such productive national resources as basic research and graduate education should allow for early and careful discussion with university leaders as well as for advice from research scientists outside the universities. The basic requirement is a policy of general and growing federal support both for basic research and for graduate education. Nothing less will do, if we mean to keep the position of world leadership in basic science which we now enjoy.

Private and State Support

We have urged in this report that the government should accept growing responsibility for effective support of graduate education and basic research. Our reasoning is pragmatic, not doctrinaire: government must do these things because, in view of their size and nature, no other agency can. But there is no reason to suppose that it will be good for the government to act alone, or for the rest of the forces in our plural society to stand aside. On the contrary, there is every reason for private and state funds to be sought, as eagerly and urgently as ever, and the very fact of increasing federal support makes such other help an important safeguard against the possibility of undue government influence. In the same way, the government's own plurality of agencies is valuable, in spite of the occasional confusion and duplication it can cause. Even in the best of worlds there will be things which government money cannot or does not do, and private philanthropy will always be greatly needed in the whole field of scientific research and teaching.

Conclusions

The following recommendations grow out of the preceding parts of this report; they indicate the lines of development which we think urgent in the immediate future. But for the reader who may turn only to the recommendations, we wish to emphasize that the record of this country in basic research and graduate education is not one of failure. American science is second to none in the world, and the federal government, on balance, has played a highly constructive role in supporting it. Most of our specific recommendations are based on our respect for the best existing practices of particular agencies of government or particular universities. These recommendations are intended not as criticisms of what has been accomplished but as proposals for still greater accomplishment in the future.

General Recommendations

1) In view of the growing importance of scientific reseach to national security and welfare, all parts of the national community should assume a greater responsibility for supporting, strengthening, and expanding basic research and graduate education.

2) In science the excellent is not just better than the ordinary; it is almost all that matters. It is therefore fundamental that this country should energetically sustain and strongly reinforce first-rate work where it now exists.

3) It is of equal importance to increase support for rising centers of science. Over the next 15 years the United States should seek to double the number of universities doing generally excellent work in basic research and graduate education.

4) It should be a general basis of policy and action that basic research and the education of scientists go best together; that they are inseparable functions of universities; that in graduate education the training of scientists involves research; and that the strength of scientific research grows out of research training in institutions of higher education.

5) To attract more talented young people to science as a career, both undergraduate colleges and the federal government should give urgent attention to the quality of collegiate instruction in the sciences. Here again research and teaching need to be connected wherever possible, so that both teachers and students may have the opportunity for learning by scientific inquiry. Better salaries, increased time for research, rising support for facilities and equipment, and modernization of curriculum—all are needed in undergraduate colleges.

6) Both the universities and the federal government should be energetic and imaginative in seeking effective ways of identifying and supporting new fields of basic research and in supporting the training of scientists in such fields. Many research opportunities are emerging in new fields that are essentially interdisciplinary; these require special efforts by universities to encourage new programs. The federal government should stimulate and support such programs where there is clear evidence that the institutions are prepared to establish programs of graduate education fully connected with the new research.

7) State, local, and private resources are needed on a large and growing scale to meet the needs and opportunities in basic research and graduate education. While this report emphasizes the responsibilities of universities and the federal government, the very fact of growing federal activity makes it urgent that state, local and private efforts also be increased, for, especially as concerns private efforts, there will always be much that the government either does not or cannot do.

Recommendations for Universities

1) Universities must continue to expand their efforts to pay proper salaries, provide adequate time and opportunity for research, and maintain an atmosphere of free learning and investigation.

2) Universities should recognize that graduate education in the sciences needs constant modernization.

3) University programs in graduate education should ordinarily include experience in both research and teaching, whether the student is headed for academic work or for industrial or governmental research. Such experience should be of a sort which advances the scientific effectiveness of the graduate student; it should not be limited to drudgery in support of the research or teaching of senior faculty.

4) Universities should give increased recognition to postdoctoral opportunities for promising students. Appropriate budgetary arrangements should be made for this form of education.

5) Universities should make full educational use of affiliated research installations. These installations should always be available to students, and members of research staffs should, wherever possible, be associated in the teaching processes of the university itself.

6) Universities should strengthen their faculties for both research and graduate teaching by accepting and using federal as well as nonfederal support for faculty salaries.

7) The university community as a whole has a duty to inform the government clearly and in detail of the nature and needs of basic research and graduate education. There is urgent need for strengthening the quantity and quality of representation of universities before both the Congress and the executive branch.

8) Universities should accept primary responsibility for ensuring that their growing partnership with the government reinforces their freedom and excellence.

Recommendations for the Federal Government

1) Federal support for basic research and graduate education in the sciences should be continued and flexibly increased so as to support excellence where it already exists and to encourage new centers of outstanding work.

2) The federal government should continue to enlarge the practice, now followed with great success in a few agencies, of providing research support over long terms and for broad objectives.

3) Once support is granted, the federal government should not seek to supervise technical operations directly. Complete scientific responsibility for all phases of a research operation should remain with the universities. Here again the best practice of the most effective agencies is a good model for the government as a whole.

4) We repeat the recommendation of

an earlier report, that "government departments and agencies concerned should uniformly modify the grant and contract provisions to permit universities and non-profit research institutions to charge full cost of research performed for the government—including overhead—and to amortize capital expenditures as an allowable cost" (*6*). This recommendation has been implemented to some extent but still requires further attention if we are not to undermine the strength of the institutions which perform the needed research. Unless research is to be cut back, the recommendation does imply increased expense; as funds increase, the further implementation of this recommendation should have very high priority.

5) Since the federal government has a deep interest in a rapid increase in the quality and quantity of the nation's teaching scientists, its agencies should in general seek forms of support for basic research and graduate education which will permit universities to enlarge their permanent faculties. In particular, the government should allow charges against all federal grants and contracts for time spent by faculty members on work so supported. (However, no such charges against grants and contracts should be permitted for extra compensation to individual faculty members during the regular academic year.)

6) Federally supported fellowship programs should be expanded when truly promising candidates can be found. Fellowships should be provided directly to talented graduate and post-doctoral students and also to selected universities for allocation to promising applicants. They should include a supplementary grant based on the full cost of such education. Such programs should not exclude the student from part-time assignments in research or teaching or from payment for such services when it is appropriate.

7) Federal support of facilities and equipment should be provided for both basic research and graduate education so as to increase the quality and quantity of research results and the number of trained scientists. Since the need for buildings and equipment is urgent, these should have high priority for the present. When the federal government has a particular interest in an installation of more than local importance, it should expect to meet all or nearly all the costs of the undertaking. In other cases, the practice of sharing the costs of facilities and equipment between the federal government and other sources should be encouraged, for the present at least, since it stimulates other sources of support and ensures that the receiving institutions have a serious commitment in the field concerned.

8) In the assignment of funds for basic research, the government should seek to promote the essential connection between the conduct of research and the training of scientists. Where it is feasible, new undertakings should be established in, or in close association with, universities, and the great influence and effectiveness of basic research in existing government installations should be increased where possible by improving its connection with graduate education and with university scientists.

9) The government should strengthen its ability to establish general policies governing its support of basic research and graduate education at universities. These policies should be formulated under the leadership of the office of the President, through appropriate advisory machinery. The planning of federal programs in these areas should allow for early and careful discussion with university leaders.

References and Notes

1. See, for example, *Strengthening American Science*, a report of the President's Science Advisory Committee (Washington, D.C., 1958); *Education for the Age of Science*, a statement by the President's Science Advisory Committee (Washington, D.C., 24 May 1959); and *Basic Research—A National Resource*, a report (NSF 57-35) by the National Science Foundation (Washington, D.C., 1957).
2. That basic research is an important element in the quality of any mission-oriented laboratory in the government was argued earlier in *Strengthening American Science* (President's Science Advisory Committee, Washington, D.C., 1958), pp. 18, 32. Nothing in the present report should be taken as a modification of that position.
3. Of course college education in the liberal arts and sciences has many other values beyond what we here emphasize; it is only in the present context that we limit ourselves to the particular and urgent topic of attracting talent to the sciences.
4. For extended discussion on this point see B. Berelson's important study, *Graduate Education in the United States* (McGraw-Hill, New York, 1960).
5. This figure is based on recent estimates collected by the U.S. Office of Education; the estimates relate to all fields of learning, and it seems most probable that scientific education is in general the most expensive kind. Estimates of cost in this field are very uncertain, but we feel confident that our figure is conservative.
6. *Strengthening American Science* (President's Science Advisory Committee, Washington, D.C., 1958), p. 34.