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# But Is the Teacher Also a Citizen?

Alvin M. Weinberg

My subject is the connection between the university, particularly the scientific university, and society. Insofar as this connection affects the university's interests and its manner and style of teaching, I am concerned with the question, "But is the teacher also a citizen?" The tensions and contradictions I see in the relation between the modern scientific university and society are much the same as those described by others, but I describe them in a slightly different language, a language that comes from my own nonuniversity world.

Perhaps I should explain what this language is. I come from a large government laboratory. The laboratory is organized into 16 scientific divisions, each of which is concerned with a particular scientific discipline—that is, each is "discipline-oriented." But the primary purpose of the laboratory is to accomplish applied missions—desalting the sea economically, or providing an inexhaustible, cheap, energy source, or alleviating radiation disease. The laboratory as a whole is "mission-oriented." Thus our laboratory, like so many other institutions, has a dual structure—organizationally it is "discipline-oriented"; functionally it is "mission-oriented." To accomplish each mission we establish projects which cross divisional, disciplinary lines. A large project can involve a dozen divisions. This "mission-discipline duality" is evident in many social structures, not only in large laboratories. I see the relations between the university and society in terms of this duality.

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### The Mission-Discipline Duality

Our society is "mission-oriented." Its mission is resolution of problems arising from social, technical, and psychological conflicts and pressures. Since these problems are not generated within any single intellectual discipline, their resolution is not to be found within a single discipline. Society's standards of achievement are set pragmatically: what works is excellent, whether or not it falls into a neatly classified discipline. In society the nonspecialist and synthesizer is king.

The university by contrast is "discipline-oriented." Its viewpoint is the sum of the viewpoints of the separate, traditional disciplines that constitute it. The problems it deals with are, by and large, problems generated and solved within the disciplines themselves. Its standards of excellence are set by and within the disciplines. What deepens our understanding of a discipline is excellent. In the university the specialist and analyst is king.

The structure of the discipline-oriented university and the structure of the mission-oriented society tend to be incongruent. Moreover, as the disciplines making up the university become more complex and elaborate in response to their own internal logic, the discrepancy between the university and society grows. The university becomes more remote; its connection with society weakens; ultimately it could become irrelevant. The growth of this discrepancy appears to me to be a central problem in the relation between the university and society. It poses major difficulties for the university professor, especially in the natural sciences, who views his responsibility as a citizen broadly.

Harvey Brooks, dean of engineering and applied physics at Harvard University, put the matter with his usual incisiveness (*1*):

> The . . . issue is the relationship between science and technology in education. The original concept of an engineering school, as of a medical school, was an association of practitioners who used the benefit of their varied experience to teach young people. This tradition is somewhat maintained to this day in the field of architecture, but in both medicine and engineering the importance of the underlying sciences has become so great that medical and engineering faculties are increasingly populated with basic scientists who do research or teaching in sciences which are relevant to but by no means identical with the practice of medicine or engineering. The old form of teaching primarily by practicing physicians or engineers was found wanting because practical knowl-

edge was too rapidly being made obsolete by new scientific developments which could not be fully absorbed or appreciated by the mature practitioner. Yet in the process something of the spirit and attitude of the skilled practitioner was lost, particularly *his willingness to deal with problems whole rather than in terms of the individual contributing disciplines*. . . . In medicine this problem has been partially met by the teaching hospital, but in engineering the analog of the teaching hospital is the big engineering development laboratory in industry. How, then, is the spirit of applied science and engineering to be retained in engineering education? The intellectual foundations of engineering lie increasingly in the basic sciences; inevitably engineering faculties will contain large numbers of people whose way of thinking is more akin to that of the scientist than the engineer. It is these people who will develop many of the techniques which will be used by the engineer of the future. And it is their knowledge, not that of the current engineer, which the student will be using ten years from now. The reconciliation of these two necessary attitudes of mind in the process of engineering education is the central dilemma of the field today.

## The Trend toward Purity

Though Brooks's critique is directed mainly at the engineering school, what he says has wider relevance. The university's disciplinary viewpoint and even organization create many points of tension between the university and the society in which it is embedded.

One is the tendency toward increasing purity, especially in the sciences and most notably in mathematics. I would measure "purity" of a branch of science by the degree to which the phenomena studied are of intrinsic interest to that science or are of extrinsic interest. In the first instance the science is more pure; in the second, where the motivation is to understand phenomena which lie outside the branch, the science is less pure. Thus I would divide science into "pure" or intrinsically motivated, and "applied" or, more broadly, extrinsically motivated. For example, applied science (in the usual sense of the term) seeks to clarify some aspect of, say, engineering or medicine: we study the chemistry of molten fluorides at Oak Ridge because we wish to build a reactor that uses molten fluorides; or we study certain viruses because these viruses are implicated in certain kinds of leukemia.

Extrinsically motivated science also includes those sciences that are pursued in order to deepen our understanding of some other branch of even pure science. For example, those parts of nuclear physics that are studied primarily to elucidate the origin of the elements rather than the structure of the nucleus would, in my usage, be termed "extrinsically motivated." On the other hand, the study of elementary particles, originally motivated by our desire to understand the nuclear force, now develops with a logic and urgency of its own dictated by the intrinsic interest and beauty of the phenomena occurring at very high energy. I would therefore call elementary particle physics "pure." Of course it is in the nature of "pure" science that the light it eventually will shed on other branches of science or technology is to some degree unpredictable; yet at any given time I believe one can often make a judgment of relevance on the basis of the motivation of those practicing the science. Thus, many nuclear physicists who measure capture cross sections make no bones about their primary motivation—it is to help the astrophysicist understand stellar nucleosynthesis better, rather than to help themselves understand the nucleus better.

At its inception nearly every science is extrinsically motivated—that is, it seeks to explain questions that were originally part of some other branch of human interest, usually, though by no means always, some practical matter. Mathematics originated because men had to measure, weigh, and count to maintain an organized economic system. The study of thermodynamics started from Carnot's interest in steam engines. Pasteur's science of bacteriology began when he tried to prevent French beer and wine manufacturers' products from turning sour. Group theory was invented by Galois as a means of studying the properties of algebraic equations. So to speak, nearly every "pure" science starts as an "applied," or at least as an extrinsically motivated, science.

And, indeed, in previous generations the distinction between pure and applied science was less pronounced than it is today. The three greatest pure mathematicians—Archimedes, Newton, and Gauss—were also great applied mathematicians; to these one can add the three greatest pure mathematicians of the 20th century—Poincaré, Hilbert, and von Neumann—each of whom was also a great applied mathematician. Pasteur, the founder of bacteriology, was an applied scientist. Lord Kelvin was equally at home in applied and basic physics. Similarly, the distinction between theoretical and experimental science was much less sharp two generations ago than it is now. Maxwell did experiments as well as construct theories.

But daughter sciences, once they bud off the stalk of the parent science, acquire a separate existence, grow, and luxuriate. In the process these offspring generally become purer and narrower. The parent stalk had closer roots in the original questions posed by some urgent need: in chemistry, the need to extract metals, or to find the elixir of life; in mechanics, to build more accurate missiles; in astronomy, to predict the seasons. But, today, many pressures compel the daughter science to become purer, especially when the science is pursued within the university.

To understand how this comes about, I remind you that every scientist or, for that matter, any intellectual creator, in plying his trade, tries to choose for himself problems that are both soluble and important. The importance of a problem is judged, by the scientist, by the breadth of added understanding its solution affords. The discovery of the second law of thermodynamics was important because it organized so many otherwise disjointed elements of physics and chemistry. Its discovery was much more important than, say, the discovery that light reflected at the Brewster angle is completely polarized, since the latter discovery affects a much narrower segment of related science or technology. The "important" questions often tend to be posed as much from without as from within a given narrow field of inquiry. The solution of an "important" problem tends to reinforce the relation between a scientific discipline and the disciplines to which it is related. In this sense, the "important" questions are broad—they tend to be extrinsically motivated.

Unfortunately, the "important" questions are often the most intractable ones, and therefore most of science is concerned with "soluble" problems, not "important" problems. We do not know how to create a controlled thermonuclear plasma; we therefore study aspects of plasmas that are tractable rather than necessarily relevant in the hope that our added general knowledge will eventually help us make progress toward the goal of controlled fusion. But in the process the science of plasma physics becomes "purer." So, in general, the strategy of pure science is always to deal with soluble problems which, by their nature, tend to be narrow in impact. The "important" problems are skirted until enough soluble problems have been solved to permit a successful attack on the important problems.

The social structure and purpose of the university accentuate the pressure toward purity. For the university's purpose is not to solve problems that are set from outside a discipline. The university is not mission-oriented. Its purpose is to create and encourage the intellectual life per se. If a scientific discipline sets off on an independent course, separate from its original applied parent, it tends, in the university, toward greater purity and remoteness simply because there are few countervailing pressures there. In the university it is improper to ask of the scientist, "What is the relevance of what you are doing to the rest of the world or even to the rest of science?" The acceptable question is "What do your scientific peers, who view your work with the same intellectual prejudices as you, think of your work?"

The process leading toward greater purity and remoteness was described with exquisite perception by John von Neumann, though it had been discussed previously by David Hilbert (*2*). Speaking of the development of mathematics, von Neumann put it (*3*):

> As a mathematical discipline travels from its empirical source, or still more, if it is a second and third generation only indirectly inspired from 'reality' it is beset with very grave dangers. It becomes more and more pure aestheticizing, more and more purely *l'art pour l'art*. This need not be bad if the field is surrounded by correlated subjects, which still have closer empirical connections, or if the discipline is under the influence of men with exceptionally well-developed taste. But there is a grave danger that the subject will develop along the line of least resistance, that the stream so far from its source will separate into a multitude of insignificant branches, and that the discipline will become a disorganized mass of details and complexities. In other words, at a great distance from its empirical source, or after much abstract inbreeding, a mathematical subject is in danger of degeneration. At the inception the style is usually classical; when it shows signs of becoming baroque, then the danger signal is up. . . . whenever this stage is reached, the only remedy seems to me to be the rejuvenating return to the source: the reinjection of more or less directly empirical ideas. I am convinced that this was a necessary condition to conserve the freshness and vitality of the subject and that this will remain equally true in the future.

Von Neumann's plea for greater unity in the mathematical sciences has been taken up by others, notably Mark Kac and Richard Courant, who see grave danger in the trend toward superpurity, abstractness, and remoteness. Kac speaks of the professional purist in mathematics; Courant speaks of the "isolation that threatens every pursuit of science—certainly very much the pursuit of mathematics—this isolation can be very stifling." The trend toward isolation that has marked modern mathematics seems to me to have invaded the empirical sciences, and possibly even the social sciences, and for the same reasons. For example, the nuclear structure physicist today concerns himself with subtler, more delicate questions about nuclear structure than he did 20 years ago. And just because the questions are subtler, and more detailed, they tend to have less relevance to the fields of science and technology that surround nuclear structure physics. The language of the nuclear structure physicist becomes more sophisticated, his techniques more specialized. His ability to communicate with his colleagues in surrounding fields becomes impaired; and, insofar as what he studies becomes of less relevance to the fields in which his own field is embedded, his own field becomes purer.

## The Denial of Science as Codifier

The other major danger I see in the development of science in the university is the tendency to downgrade science's role as codifier of human knowledge. Science traditionally has two aspects: it is on the one hand a technique for acquiring new knowledge; it is on the other hand a means for organizing and codifying existing knowledge, and therefore a tool for application. Both aspects of science are valid. The discovery of $SU_3$ symmetry does not in the slightest detract from the importance of the second law of thermodynamics. This law, with its enormous power as an organizing principle for much of existing chemistry, though discovered more than a century ago, is as much "science" as the *search* for new unitary symmetries.

The modern university tends to emphasize science as search at the expense of science as codification, and for many of the same reasons it drives science toward fragmentation and purity. The codified parts of science are often most useful in the neighboring sciences, not in the science in which the codification originally took place. X-ray crystal analysis sprang up in physics; most x-ray crystallographers nowadays work as chemists, metallurgists, or even biologists. Thus the university's disciplinarity, its tendency to deal with pure problems that are intrinsically motivated, reduces its concern for science as codification; such science has already been by-passed by the researcher in the field.

The pressure to do research rather than teach accentuates the denial of science as codification. Much has been said about the conflict between research and teaching in the university. As I see it, at least part of the conflict amounts to a philosophic judgment as to whether science is the search for new knowledge or the organizer of existing knowledge. In emphasizing research at the expense of teaching one is implicitly valuing the one above the other.

One by-product of this trend is the waning of the tradition of scientific scholarship. As our sciences become more and more fragmented and narrowly specialized, and as their connection with earlier, more general phases of science weakens, the relevance of what came before for the pursuit of current research decreases. For example, it is possible to carry out research on elementary particles without knowing much about nuclear structure. The taste for knowing the historical origin and development of a science wanes, partly because such knowledge is unnecessary for prosecuting current research, partly because there is too little time and energy left over after learning what is needed to do the research at hand.

## Implications: For Education

These two tendencies—toward purity and fragmentation as opposed to application and interdisciplinarity, and toward research and away from scholarship—seem to me to portend trouble in the relation between the university and society.

First, I speak about the great curriculum reforms, especially in the sciences. These reforms started in the high schools but have now been extended, particularly in mathematics, downward to the grade schools, and in many instances upward to the colleges. They are relevant to my discussion, because the reforms have been instigated by the university, and they certainly reflect the intellectual spirit of the university. With certain of the aims of the curriculum reform, one can have no quarrel. The new curricula try hard to be interesting, and in this I think they succeed; also, they demand more effort and present more challenge than the old. But, insofar as the new curricula have been captured by university scientists and mathematicians of narrowly puristic outlook, insofar as the curricula reflect deplorable fragmentation and abstraction, especially of mathematics, insofar as the curricula deny science as codification in favor of science as search, I consider them to be dangerous.

The danger I worry about was brought home to me by a distinguished physics professor. According to him, the mathematics department at his university no longer teaches the kind of calculus course which develops power and skill in handling simple integration. Such skills are apparently too lowbrow, and in any event are no longer needed by one who wishes to pursue a career as a research mathematician. As a result, many physics students are unable to do the mathematics which still is important for physics, even if not for mathematics. This physics professor has therefore written a book on calculus which presents the traditional parts of the subject that have been by-passed by the professionals. I think this anecdote illustrates both what is wrong with, and what might be done to remedy, the situation. The professional purists, representing the spirit of the fragmented, research-oriented university, got hold of the curriculum reform and, by their diligence and aggressiveness, created puristic monsters. But education at the elementary level of a field is too important to be left entirely to the professionals in that field, especially if the professionals are themselves too narrowly specialized in outlook. Instead, curriculum reform should be strongly influenced by disciplines bordering the discipline being reformed. The mathematics curriculum should receive strong cues from the empirical sciences and from engineering; the physics curriculum, from engineering as well as from the neighboring sciences; and so on. There is nothing wrong with physics professors writing calculus books, or engineering professors writing physics texts, as long as the physics professor knows calculus or the engineering professor knows physics. And, indeed, seeds of the counterrevolution in curriculum reform seem to be sprouting. In physics a group at Harvard under Gerald Holton is trying to devise a curriculum which views physics as a more broadly cultural activity than some of the other curricula do. In mathematics a counterrevolution also seems to be taking place; for example, a group of 75 leading American mathematicians stated: " . . . to offer such subjects to all students as could interest only the small minority of prospective mathematicians is wasteful and amounts to ignoring the needs of the scientific community and of society as a whole" (*4*). And the American Council for Curricular Evaluation has been organized to maintain "the intellectual integrity of our schools"—that is, to scrutinize some of our newer curriculum reforms.

Related to the trend toward purity in curriculum reform is the relatively poor place of applied science in the universities. This matter has been emphasized by Edward Teller (*5*, pp. 257–266). He points out that most of the money our government spends for research and development goes for applied research; yet most of the prestige and emphasis in the university goes to basic science. The best scientific minds go into basic, not applied, science; and the social hierarchy of science, reflecting the discipline-orientation of the university as much as it does the intrinsic logic of the situation, places pure science above the interdisciplinary applied science. Hans Bethe, in speaking of the social responsibility of the scientist, has also noted this denigration of the applied sciences in the university. He exhorts the university scientist to overcome his prejudice against application and especially urges him, as part of his social responsibility, to reaffirm the dignity of applied science (*6*).

## Implications: For Government

What are the implications of these trends for government and society? Our society increasingly is a product of the university. As the university degree becomes more and more common —it may be nearly as common, eventually, as a high school diploma is now—the outlook and point of view of our society and of our government becomes the outlook and point of view of the university.

I want to make perfectly clear that on balance I believe this to be enormously good. The university is rational, and its outlook is basically tolerant and knowledgeable. For example, I believe our whole enlightenment in race relations would be unthinkable if anthropological and psychological doctrines, developed largely in the university, had not penetrated society as a whole. One must never forget that the Supreme Court, in justifying its 1954 decision on school desegregation, invoked a psychological doctrine (psychic damage to the segregated child) that catches the spirit of and was certainly nurtured by the university.

But my purpose is to point out the dangers to government, to society, and to the university that lie in the latter's narrow disciplinarity. Thus university's picture of science as research and denial of science as codification or as a tool deadens its taste for action. Let me illustrate with the views of *Growth of World Population*, released by the National Academy of Sciences in 1963, to which I subscribed at the time (*7*). The report concluded that the overall task was to achieve "universal acceptance of the desirability of planning and controlling family size." The report then made four major recommendations, which I paraphrase:

1) Support graduate and postdoctoral training in demography.

2) Expand research laboratories for scientific investigation of human reproduction.

3) Cooperate in international studies of voluntary fertility regulation.

4) Train more administrators of family planning.

With none of these recommendations can anyone concerned with the population problem take issue. Of course we need more research and more studies, as well as more administrators. But such recommendations are, it now seems to me, tangential to the main issue. They substitute research about the problem of family planning for action on the problem. Complicated social problems such as control of family planning must be attacked with the information at hand even as we learn more about them. And, indeed, the distinguished biochemist, William D.

McElroy, who chaired the panel that issued the report, said recently: "Although I am still in full agreement with these recommendations, I think the time has come when we must move ahead even without the additional biological knowledge" (*8*).

Nor is this instance an isolated one. Panels that advise government, especially on matters having scientific implications (and what affair of government these days does not?), are usually dominated by university people, especially those active in research. What is more natural than to recommend more research as a kind of magical talisman that will solve profound and complex social problems? I was therefore much impressed with the contrast between the recent study on heart, cancer, and stroke, which proposed specific concrete action on the basis of the knowledge at hand, and the many other studies, such as the NAS study on population, which display an inclination to study rather than to do.

Even the choice of what things our government decides to spend its research funds on is now deeply influenced by the puristic university. In earlier, and simpler, times the government's attitude toward science was unsophisticated and inexpensive. First, the nonscientific goals of the society were ascertained by the political process; these goals by and large transcended the goals of the university. Thus, we had long since decided that national defense was a necessary goal; or good public health; or better navigation; or adequate physical and chemical standards. We then decided to support the science that scientists believed would help achieve these goals. How much we spent on the relevant science was determined by how important we regarded the goals themselves to be, and this was a political decision. It is true that in recent years we have become very relaxed over how relevant a science need be to warrant support; nevertheless, the mission-oriented agencies support basic science per se largely as a justified overhead expense charged against achievement of the overall mission. Just as a good applied laboratory does a fair amount of related basic science, so an enlightened government agency supports a large amount of related basic research. But the ultimate justification of this basic research, as far as society at large is concerned, was the achievement of some nonscientific goal. If one examines the original basis for establishing the National Science Foundation one finds that an eventual tangible and palpable pay-off of science was strongly in the minds of those who conceived the NSF.

The current active debate on scientific priorities bespeaks a change in our viewpoint. Whereas in previous times government support of science was justified by its contribution to the achievement of some nonscientific end, we seem now to have accepted the view that science deserves large support solely for its own sake; with this development no scientist can quarrel. However, to my mind, the same professionally puristic viewpoint that has captured the elementary mathematics curriculum seems to be prevailing in the present debate on scientific priority. The debate at the moment centers on the support given high-energy physics relative to that given other fields of science. Now, high-energy physics is at once the most elegant and, in a sense, the most fascinating branch of physics. The new unitary symmetries are beautiful to behold and astonishingly unexpected. The high-energy physicists themselves are brilliant and dedicated. Because the field is rich and exciting in itself it certainly deserves support. I cannot, however, understand the argument that high-energy physics commands an *urgency* of support simply because, as Robert Oppenheimer puts it, it is "the conviction of those who are in it that, without further penetration into the realm of the very small, the agony may this time not end in a triumph of human reason" (*9*). The agony Oppenheimer refers to is surely not shared by all of society, nor even by all scientists. The question is why the intellectual agony of this generation of physicists needs to be relieved as quickly as possible rather than being resolved, at a slower place, by succeeding generations.

To me urgent support of a field is justified only if that field is likely in some way to solve a pressing human need. The biomedical sciences merit urgent support because out of them come means of alleviating some of man's most primitive suffering—illness and premature death. The social sciences would merit urgent support insofar as they are aimed at helping solve man's social problems; unfortunately, in my opinion, they do not at this time seem ripe for great expansion. By contrast, high-energy physics offers little prospect of satisfying any *urgent* human need.

The emergence of high-energy physics among our country's highest-priority basic scientific enterprises is a manifestation both of the university's deification of purity in science and of its influence on what our society does. High-energy physics is the purest branch of physics. In the university community it towers above most sciences in prestige and in the caliber of the students it attracts. That it should be placed so high on our society's list of things to be done attests at once to the pervasiveness of the university's influence on the society and to the way in which fragmentation and concern for disciplinary purity of the university, when imposed on the "mission-oriented" society, diverts the society from its real goals. Our society is not a university; the goals of our society are not the same as the goals of the fragmented and discipline-oriented university. For the university to persuade the society that at this stage in history the university's own intellectual goals and aspirations—remote, pure, and fragmented—deserve the highest place among the goals of the society is hardly tenable.

## Recapitulation:

## The Imbeddedness of Values

My remarks have been a fugue on a single theme. I began by pointing out that the university and society are incongruent in that the university is discipline-oriented and fragmented, the society, mission-oriented and whole. I tried to show how the ecology of the discipline-oriented university encourages the rise of purism and specialization and the denial of scholarship and application in science. I then argued that these trends in the universities are affecting our elementary curricula; are giving us poorer people to get on with the applied work of the day; are substituting research for action; and are tending to impose the scientific values of the fragmented university upon society.

In every one of these trends I discern the same underlying issue: a failure to realize that no judgment of the relative value of a universe can be made from the narrow base of that universe. Values are established from without a universe of discourse; means are established from within. Thus, our science tends to become more fragmented and more narrowly puristic because its practitioners, harried as they are by the social pressures of the university community, have little time or inclination to view what they do from a universe other than their own. They impose upon the elementary curricula their narrowly disciplinary point of view, which places greater value on the frontiers of a field than on its tradition, and they try to put across what seems important to them, not what is important when viewed in a larger perspective. The practitioners have no taste for application or even for interdisciplinarity since this takes them away from their own universe; and they naturally and honestly try to impose their style and their standards of value upon society, as when they insist on research instead of action, or when they claim urgency for matters whose urgency—that is, importance—is largely self-generated.

For the universities, and for the members of the universities, I have some recommendations though I put them forward diffidently. The university must accord the specialist of broad outlook the status and prestige it now confers solely upon the specialist of narrow outlook. Granted that specialization is "blessed" in the sense that only the specialist knows what he is talking about; yet, if only the specialist knows what he is talking about, only the generalist knows why he should talk at all.

Can the university combine the point of view of the specialist with that of the generalist? Can it acquire some of the mission-orientation of the large laboratory, yet retain its discipline-orientation intact? Can it truly become interdisciplinary and whole, and thus become congruent with society?

Several possibilities suggest themselves, though I do not pretend that these possibilities are panaceas. The university could convert itself into the National Laboratory. This is surely going too far, even though mission-oriented institutes are springing up on university campuses, largely I believe in response to the contradictions that I have outlined. The university certainly should not give up the freedom and the individual autonomy of the professor—the freedom and autonomy he cannot enjoy when he enters the mission-oriented institute. Thus, much as I approve of the mission-oriented institute, I value the professor's stubborn freedom even more, and so I would hate to see the university become the National Laboratory.

I would go farther. Many of the shortcomings I find in the university are intrinsic characteristics of the university and are hardly susceptible to change. The university loses something unique and precious when it submerges the professor's independence to achieve a common scientific mission conceived by administrators. But this means, simply, that some things are not properly done at the university. For example, the "important" problems even in pure science that transcend in difficulty the capacity and style of the university, like studies of genetics involving 200,000 mice, or modern plasma physics, must be done outside the university. Moreover, the basic research that goes to support such activities is properly the business of institutions having such responsibilities. Thus my plea amounts to reasserting the validity of the National Laboratory, with its shortcomings that I know so well, as a home for certain kinds of basic and applied research, even as I emphasize the place of the university, with its shortcomings, in the scientific society. The view that federal support of basic research is the university's inalienable right and that if competition with the mission-oriented institutions arises then the university's is the prior claim (as implied in the recent Wooldridge report on NIH, *10*) to my mind ignores the shortcomings of the university in basic research. There is an appropriate analogy here between the two kinds of institutions: the university and the mission-oriented laboratory. Basic research is supported in the mission-oriented laboratory to help the laboratory accomplish its mission. As Harvey Brooks suggested (*5*, pp. 77–110), it ought to be looked upon as a reward for achievement of the laboratory's mission, especially since the basic researcher is thereby given a stake in achievement of the laboratory's mission. Similarly, a case can be made for giving the university, as an institution, support for basic research as a reward for excellence in teaching, since one thereby gives the research professor a stake in the university's mission.

For in a sense the university, no less than the laboratory, is already mission-oriented if only it will accept and recognize its traditional mission—education of the young. And just as the mission orientation of the National Laboratory adds point and wholeness to its scientific activity, so pregraduate education ought to give wholeness to the university. Education at the undergraduate level should properly be less professionalized and puristic than it is at the highest levels. Just as ontogeny recapitulates phylogeny, so elementary education properly should recapitulate the historic path of a discipline: its connections with other disciplines and with practical purposes, its origin, its scholarship—in short, its place in the scheme of things. If the university takes undergraduate education seriously, and does not look upon it simply as attenuated professional education, the university community will be forced to broaden its outlook. The university professor would, by enforced contacts with young people whose backgrounds are diverse, surely be obliged to relate his narrow professional interest to the rest of the world. And in the process, as he becomes part of the interdisciplinary real world, the teacher ought once more to become a citizen.

**References and Notes**


1. "The dean's report, 1963–1964," *Harvard Engineers and Scientists Bull. No. 45*, (1964), p. 6. The italics are mine.
2. Von D. Hilbert, "Mathematische probleme," in *A Collection of Modern Mathematical Classics: Analysis*, Richard Bellman, Ed. (Dover, New York, 1961), p. 248. Translated from the German by E. Guth, Oak Ridge National Laboratory. See Hilbert's lecture before the Mathematical Congress, Paris, 1900: "In the meantime, while the generating force of the pure thought acts, the external world enters again and again; it forces upon us new questions through the actual phenomena; it opens new topics of mathematics, and while we try to incorporate these new topics into the realm of pure thought, we find often the answers to old unsolved problems, and advance this way best the old theories. Upon this repeating and changing interplay between thought and experience are based, as it seems to me, the many and surprising analogies and that apparently 'prestabilized harmony' which the mathematicians so often notice in the questions, methods, and concepts of different fields of science."
3. J. von Neumann, "The mathematician," in *The Works of the Mind*, R. B. Heywood, Ed. (Univ. of Chicago Press, Chicago, 1947), p. 196.
4. L. V. Ahlfors *et al.*, "Mathematics curriculum of the high school," *Amer. Math. Monthly* **69**, 189 (1962).
5. *Basic Research and National Goals*, a report to the House Committee on Science and Astronautics, submitted by the National Academy of Sciences (March 1965).
6. H. Bethe, "The social responsibilities of scientists and engineers," a lecture at Cornell University, 6 Nov. 1963, published subsequently in *The Cornell Engineer* and excerpted in *SSRS Newsletter* (Gambier, Ohio, Feb. 1964), p. 1.
7. Committee on Science and Public Policy, "Growth of world population," *Nat. Acad. Sci. U.S. Publ. 1091* (Apr. 1963).
8. "The need for action," in *Population*, panel discussion held at the Pan American Union (Planned Parenthood/World Population, New York, 1964), p. 43.
9. J. R. Oppenheimer, in *Nature of Matter*, L. C. L. Yuan, Ed. (Brookhaven National Laboratory, Upton, N.Y., 1965), p. 5.
10. *Biomedical Science and Its Administration, A Study of The National Institutes of Health, Report to the President*, D. E. Wooldridge, chairman (Government Printing Office, Washington, D.C., 1965).