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AREAS OF NEW KNOWLEDGE

Some important, even astonishing, developments in our universities — and some thoughts on how to support them

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Any discussion of higher education is so complex that no speaker or author can cover the whole field. I can select only a few topics and draw conclusions based on my own interests and experience. From a different set of relations another speaker may draw radically different conclusions. The poor layman who wants one simple yes-or-no, good-or-bad answer is disillusioned and disappointed.

It may be possible, however, to say a few things that will help us establish some principles on which we can begin to find answers in a multiplicity of special cases. The Pythagorean theorem in geometry, after all, enables us to solve an infinite number of geometric problems. Are there a few Pythagorean theorems we can discover in this field?

Before developing theorems, however, one must always set forth one's axioms or assumptions and attempt, where necessary, to justify these assumptions. The assumptions I am making are these:

1. Science and engineering are of great importance to each other and to our society.

2. American universities play a vital role in advancing our knowledge in the fields of science and engineering.

3. Government and industrial agencies, as well as universities, play a prime role in putting our knowledge of science and engineering to practical use.

4. The progress of science and engineering is so important and so expensive that it is appropriate that both the public and private sectors of our economy participate in their support.

It is no longer necessary—in the year 1965, in America—to attempt to support the thesis that the progress of education and research in science and engineering are vital factors in the growth of our economy and in the improvement of our society. Nevertheless, because other things are important to our society also, there are many people who deprecate the value of extending scientific knowledge, claiming that we should instead devote our energies and dollars to improving the moral, social, political, and economic aspects of our civilization.

I would not for a moment deny the importance of these areas of effort. I would only point out two things:

First, the solution to some of our social, economic, and political problems will surely depend upon further technological advances.

Second, it is not a question of either/or, since the energies and dollars devoted to science and technology need not be subtracted from the energies and dollars devoted to other problems.

As we contemplate some of the problems that modern civilization faces—including overpopula-

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tion, overcrowded cities, unemployment, juvenile delinquency—we are tempted to ask whether modern civilization is any better, after all, than the civilization of the Middle Ages. It is too bad that we cannot turn back the hands of time so that we could all experience briefly what life in the Middle Ages was really like. My guess is that we would return to modern living with great joy and relief.

If, then, we ask the question of what has made the difference between the year, say, 1665 and the year 1965, I think the answer would be that the primary difference lies in the extension of man's knowledge and understanding of the physical world.

We need only recall that the pioneering work of men like Galileo and Newton first led to the idea that man's world and his universe were governed by natural laws, and that these natural laws could be understood and put to effective use. The age of machinery and the Industrial Revolution soon followed. Later, the work of Faraday and Maxwell led to the age of electricity and to the modern age of electrical communications. The work of Bohr and Rutherford and Einstein led to the nuclear age. And the work of Schrödinger, Heisenberg, and others led to the quantum age in which quantum effects are put to use in such things as the transistor, the maser, the laser, and other devices just now coming into use.

Paralleling this development in the physical sciences has been an equally revolutionary development in biology and medicine as men have come to understand more and more thoroughly the evolution of life, the nature of disease, and, in recent years, the molecular basis of life processes, including the molecular basis of heredity.

Elementary particles

At the beginning of the present century physicists were beginning to understand the structure of the atom. A third of a century later they were beginning to understand the structure of the atom's nucleus. Today they are reaching a step beyond and are trying to understand the nature of the so-called "elementary particles" which are involved in nuclear phenomena. The role, behavior, and interrelationships of these elementary particles are still matters of mystery. At one time the accumulation of new facts outran our theories. Now the theories have nearly caught up with the facts and find themselves stymied until new facts can be learned. That is the reason for the present interest in very-high-energy accelerators—200 billion electron volts and above—since only at such energies can some of the basic facts about elementary particles be examined. No one can foresee what the practical results of understanding elementary particles will be.

There is also great excitement today in the fields of astronomy and of the space sciences. Radio and optical telescopes have discovered new kinds of objects in the sky which look like stars but which emit energy at a rate 100 billion times or more greater than previously known stars. There is a real mystery as to the source of this colossal energy. Are we witnessing the results of tremendous thermonuclear or hydrogen-bomb reactions on a grand scale? Or are we getting astronomical evidence for a new kind of energy-release process, possibly involving these same elementary particles themselves? We do not yet know.

The moon and the planets

As we send spacecraft into outer space, we are learning about the moon and the planets, and we are developing spacecraft from which astronomical observations can be made of the most distant objects in the universe. We have taken close-up television pictures of the moon. We have had our first somewhat crude but extraordinarily interesting pictures of Mars. We have measured important properties of Venus. Visits to these objects by both manned and unmanned space capsules will add enormously to our knowledge during the next decade and beyond.

As our eyes are turned to the moon and the planets, and as we try to understand their composition, structure, and history, our interest has also been enhanced in the planet which we call the earth. We are probing the depths of the oceans; we shall in a few years be drilling through the earth's crust to find what lies beneath; we are observing natural and artificial seismic waves bouncing back and forth through the interior of the earth, reading their messages as to its structure, composition, and condition. We shall be learning more about earthquakes and volcanoes. We shall be learning more about the motions of our atmosphere and the storms and weather changes which it carries. Someday we might even be able to do something about the weather.

Biologists and biochemists are untangling the structure, behavior, and properties of the most complex of all chemical molecules, DNA, and the role it plays in heredity and in guiding the development of living things. Those long, coiled, double-helical molecules which appear in fantastically twisted forms can now be unraveled and literally taken apart piece by piece while the structure and function of each piece is examined. We can identify the pieces that govern the manufacture of particular proteins and enzymes in living things and can trace the way in which the elaborate instructions, which come coded in the original DNA molecule, are transmitted cell by cell to guide the development of a living creature, whether it be a bacterium or a human being. We are getting closer to an understanding of the very basic chemical-physical processes in living things, and men are already visualizing the day when life forms can be synthesized in the laboratory.

Just how or when scientific discoveries will come into practical use will depend on the applied scientist (including the medical scientist) and the engineer. In every university and industrial laboratory the applied scientists are watching the new developments in basic science with great care, alert to the possibility of carrying these developments over into practical application. More than ever before scientists and engineers are maintaining close contact with each other. They are maintaining closer contact within our universities, and there is a closer contact between universities and industry and government laboratories.

I recite all this in support of my thesis that science and technology are of vast importance to the progress of our society.

What I have said also supports my second point —that the universities are the seat of these new developments. The universities of America and of other parts of the western world are the most exciting places imaginable at the present time. But they are more than centers for the advancement of knowledge; they are centers for the training of new scientists and technologists who will carry these developments into the future. They are also the centers for the training of our businessmen, our government officials, our professional men and women, our artists and writers. Let us hope that in their university studies these non-scientists are also getting a glimpse of the exciting advances in science and technology, so that their understanding of these can be carried into the professions, into business, into journalism, and into the government.

Supporting science and technology

I think what I have said also supports my final thesis: that modern science and technology are expensive and must be supported by all sectors of our society. Modern instrumentation in physics, in chemistry, in astronomy, in biology, in geophysics, as well as in engineering, has passed far beyond the days of string and sealing wax. Electronic data processing machines, elaborate spectroscopic equipment, space vehicles, nuclear accelerators, expensive radio and optical telescopes, and a host of other essential instruments of modern scientific and engineering research make the million-dollar project the commonplace one rather than the extraordinary one. It will cost $300 million to build a 200-billion-electron-volt nuclear accelerator. It costs tens or hundreds of millions of dollars to send a spacecraft to the moon, to Venus, to Mars—or simply to circle the earth. A modern electronic computer may cost several million dollars, and a host of essential research tools may cost $20,000 to $100,000 each.

It is not that scientists have simply become extravagant in their demands and are using complex equipment where simple equipment would do the same task. Old-fashioned equipment will not do the task at all or, in some cases, would do it only at a thousand or a million times slower rate of production of results. It is said, for example, that Kepler spent nearly a lifetime in computing the orbits of the planets around the sun and proving that these orbits were elliptical. Recently a graduate student decided to perform these same computations on a modern computer and found that, after he had spent a modest amount of time in programing, the entire computational procedure took him but five minutes. Very few men can afford to spend a lifetime making measurements and interpreting them. But when the measurements and calculations can be made in a few minutes or a few days, impossible projects come into the realm of possibility.

Some important developments

The facts I have been outlining have come to be widely realized in this country and have led to some important, and even astonishing, developments in our universities during the past 15 years.

1. There has been a great increase in student enrollment in the colleges and universities. This increase is partly due to the "population explosion" and partly due to the fact that a larger fraction of American high school graduates are seeking to attain some higher education. Rightly or wrongly, nearly everyone wants to go to college. In this exciting and complex world a college education is more and more necessary.

2. There has been a great expansion in the total university research program in the country. The growing interest in scientific and engineering research and the growing support of such research have lifted America into a position of world leadership in the progress of pure and applied science.

Both of these developments—enrollment pressures and expansion of research—have put great burdens on the financial resources of colleges and universities. Although the current financial needs have not been met fully, there has been substantial expansion in the support provided to institutions of higher education for both teaching and research. The sources of these funds are as follows:

1. *Federal funds,* largely devoted to the support of research in science, medicine, and engineering, for building laboratories, for teaching and research in these fields, and for the support of graduate fellowships. Only recently has the government entered the field of undergraduate scholarships and support for the arts and the humanities.

2. *State tax funds,* provided often in very large amounts to the state colleges and universities for expansion of physical plants, expansion of faculty, and the general support of teaching and research and other operating costs.

3. *Private funds,* for endowment, for buildings, and for operating expenses—largely, but not wholly, provided to the private independent colleges and universities. The sources of these funds have been individuals, private foundations, and corporations.

Even if we assume that the sum total of the funds available at the present time is adequate to our needs (which in truth it is not), one can easily grow alarmed as one looks to the future. The expansion in size of our colleges and universities continues. The expansion in the extent and intrinsic cost of research programs is on the increase. Faculty salaries and other operating expenses are rapidly rising. It would be an extremely conservative estimate to predict that the budget requirements for higher education in this country will double during the next ten years. Many experts would predict a higher rate of increase, but the conservative estimate is staggering enough to give us cause for concern and for action. Clearly, all sources of support—private, state, and federal—must participate in meeting this crucial problem.

The role of private support

Let us assume for the moment that state and federal sources will do their share in meeting this problem. While this is by no means a foregone conclusion, it is a useful working hypothesis. What, then, is the role of private support? What critical functions does it play? And what must be its relation to the various public sources of support?

Let me focus my remarks now primarily on the *private* institution—particularly the private university—with particular attention to that handful of institutions, be it 20, or 30, or 50, which have historically played the role of leadership in the progress of advanced education and research in all fields of knowledge and, more particularly, in the fields of science and engineering.

A typical private university in America today is largely or wholly independent of *state* tax funds, and receives its funds from either private or federal sources. The federal sources are confined largely to support of research and graduate education in the sciences and engineering.

In a typical private university, the total federal funds for these purposes may amount to between 30 and 50 percent of the institution's total operating budget, depending, of course, upon the relative size of its scientific research program. While 20 years ago the federal portion of the budget was far smaller than this, it seems to be true that in recent years the federal portion of a typical private university budget has not substantially changed.

Private and federal funds

There are many reasons why this ratio is leveling off. There are also many reasons why it *should* level off, and why future budgetary increases should be provided in approximately the present ratio by private and federal funds. There are three basic reasons for my belief:

1. It is unlikely that federal funds will be available to these universities along the rising trend which characterized the years before 1962.

2. In order to command and use federal funds, a university must have its own funds in at least equal amount in order to build the staff and facilities to support a research program that will attract federal funds.

3. Private funds are needed to maintain and support those activities which federal funds do not, probably will not, or cannot support.

As to the first point, it may seem surprising that one would predict that the major private universities in the country will not continue to receive rapidly increasing federal support in scientific and engineering areas or in other areas which the federal government will soon or may soon enter. The reason is very simple: There is a growing feeling in high circles in Washington that federal funds should be more "widely spread," that it is wrong for a relatively small number of institutions to receive such a large fraction of the total federal funds allocated for support of research and graduate education. Recent directives instruct federal agencies to spread their research support to lesser or "emerging" institutions and to give more attention to wide geographic support. *Thus, even though total federal funds should continue to increase, it is clear that the leadership institutions will receive a declining share of this support.*

Now, I am wholly in favor of placing research support widely throughout the country and in institutions which are sincerely striving for excellence in research and graduate study. However, several facts stand out:

First, the number of brilliant and creative research scholars in the country is limited.

Second, these scholars tend to congregate at institutions with strong research traditions, with excellent research facilities, including laboratories and libraries, where the individual will have many colleagues who can help and stimulate him not only in his own special field of interest but in related fields.

Third, the number of institutions which have built this atmosphere, acquired the staff, and, largely through their own funds, provided the research facilities, is relatively small. There are only a hundred or so institutions that even pretend to call themselves "universities" in the sense of having substantial graduate and research programs. About half of these could be classed as leadership institutions. Half of these, in turn, are private and half are public. Assuming that the public institutions will and should continue to receive state support, the problem remains: What shall be done with the top 25 private institutions in the leadership category and (let us say also) the next 25 institutions with the potentialities of emerging as leaders? Present federal policies will mitigate against a rapid rate of increase of the support of activities in these institutions. Thus, even though they wish to increase their federal support, they will probably have a difficult time attaining such an increase.

Federal support is not enough

On the other hand, there are urgent reasons why the private sources of support in these institutions must continue at least to equal the federal sources. First, for example, federal sources support only restricted areas of scholarship, and the university must support other areas in the humanities, social sciences, arts, business, law, and other fields not eligible for federal support.

Second, even in those areas where federal funds are available, they do not pay the full costs of maintaining the university's activities in those areas. Teaching costs are almost wholly neglected by the federal government; faculty salaries must be paid very largely by the university from nonfederal sources; and the cost of new buildings must come primarily from private sources. Even for science buildings the federal government, if it assists at all, provides only one-third to one-half the funds on a matching basis.

Third, even in the areas of science and engineering, federal support is not uniformly available in various fields. Because much of this support comes from mission-oriented agencies—such as the Defense Department, the Atomic Energy Commission, the National Aeronautics and Space Administration, and the National Institutes of Health—there are broad areas of science and engineering left with inadequate federal funding. Some of these areas which are omitted are most critical to the future progress and prosperity of this country. If funds, personnel, and facilities are largely channeled into those areas of science and engineering which are related to health, atomic energy, space, and defense, the areas of consumer products, housing, building, transportation, air pollution, water supply, public safety, good urban living, and a host of other practical and urgent problems will be neglected.

A Pythagorean theorem

The Pythagorean theorem that I come to as a result of all these assumptions and arguments is simply this: *The present ratio of private to federal support in our leadership universities must be maintained.* That means that private support of operating costs in these universities must at least double during the next five to ten years. Only if this happens can the universities maintain their vital activities in non-science fields, maintain their faculty salary and teaching budgets, support those areas of science and engineering not eligible for federal funds, and generally maintain the health, integrity, vigor, and leadership that the future of higher education and the future of the country so insistently demand. Nothing less is at stake than the continuation of private enterprise in the university world. The growing federal trend toward egalitarianism in higher education is wholly contrary to the meaning and value of higher education. Education and research depend upon a few brilliant people. Only they can carry on these critical tasks, and they must be supported wherever they may be found.

Innovation has always been a characteristic of private rather than of government enterprise. It is true in higher education, as it is true in business and industry.

Private fortunes, private benefactions, private foundations, and private industry have built private higher education in America. They can be proud of the structure they have created. If they abandon the structure to the whims, the controls, the inequalities, the imbalances of federal support —valuable as it may be in itself in its appropriate and proper field—American higher education will be destined to stagnation and decay. I believe no one would wish to see this happen.