TOWARD A PUBLIC POLICY FOR GRADUATE EDUCATION IN THE SCIENCES

NATIONAL SCIENCE BOARD
1969

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REPORT OF THE NATIONAL SCIENCE BOARD

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NATIONAL SCIENCE FOUNDATION
1969

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We have come to know that our ability to survive and grow as a Nation depends to a very large degree upon our scientific progress. Moreover, it is not enough simply to keep abreast of the rest of the world in scientific matters. We must maintain our leadership. The National Science Foundation will stimulate basic research and education in nearly every branch of science, and thereby add to the supply of knowledge which is indispensable to our continued growth, prosperity, and security.

Harry S. Truman

May 10, 1950

. . . the process of basic scientific research and the process of graduate education in universities must be viewed as an integrated task if the nation is to produce the research results and the new scientists that will maintain the leadership of American science. In this great endeavor, the partnership between the Federal Government and the nation's universities will assume growing importance in the future.

Dwight D. Eisenhower

November 17, 1960

Expansion of high quality graduate education and research in all fields is essential to national security and economic growth. Means of increasing our supply of highly trained professional personnel to match the rapidly growing demands of teaching, industry, government, and research warrants our interest and support.

We need many more graduate centers, and they should be better distributed geographically. Three-quarters of all doctoral degrees are granted by a handful of universities located in 12 States. The remaining States with half our population produce only one-fourth of the Ph.D.'s.

New industries increasingly gravitate to or are innovated by strong centers of learning and research. The distressed area of the future may well be one which lacks centers of graduate education and research. It is in the national interest to encourage establishment of these critically needed centers of advanced learning, especially in parts of the Nation now lacking them.

John F. Kennedy

January 29, 1963

. . . The prosperity and well-being of the United States—and thus our national interest—are vitally affected by America's colleges and unversities, junior colleges and technical institutes.

Their problems are not theirs alone, but the Nation's. . . .

We depend upon the universities—their training, research and extension services—for the knowledge which undergirds agricultural and industrial production.

Increasingly, we look to higher education to provide the key to better employment opportunities and a more rewarding life for our citizens.

As never before, we look to the colleges and universities—to their faculties, laboratories, research institutes and study centers—for help with every problem in our society and with the efforts we are making toward peace in the world. . . .

Lyndon B. Johnson

February 5, 1968

Science has served mankind faithfully and well. It has dramatically extended the average lifetime, shortened geographical distances, increased industrial productivity, reduced poverty, and in the long trial of war, contributed significantly to the cause of freedom. . . .

If science and technology were to founder or stagnate, many of our hopes would collapse. To the extent that we neglect this source of our greatness, and to the extent that we fail to preserve the conditions of openness and order that made our progress possible, we are living off the land of civilization without refertilizing it. . . .

Instead, we must bring about a new dawn of scientific freedom and progress. As the world's investment in science expands, the impact of technological progress will be more profound. Scientific knowledge doubled between 1750 and 1900; again between 1900 and 1950; yet again between 1950 and 1960. By 1970 it is expected to double again. In twenty years the world may be as enormously different from today as 1968 is different from 1900.

Richard M. Nixon

October 5, 1968

LETTER OF TRANSMITTAL

January 24, 1969

My Dear Mr. President:

It is my high privilege to transmit to you this Report, the first to be prepared pursuant to Section 4(g) of the National Science Foundation Act, as amended by Public Law 90-407, which directs the National Science Board to assess the status and health of science, including such matters as national resources and manpower, in reports to be submitted to the Congress.

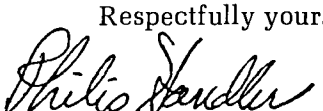
Since creation of the National Science Foundation in 1950, five consecutive Presidents have directed attention to the significance of science and science education to the national welfare. Because the research intrinsic to graduate education is a major contributor to the national research endeavor, while producing the young scientists vital to our national future, the Board considers it especially appropriate that this first Report be addressed to matters of national policy for the support and strengthening of graduate education in the sciences and engineering.

Several thoughtful efforts to formulate national goals for higher education generally have recently been reported or are presently in train; due consideration has been given by the Board to those relevant reports available at this time.

The National Science Board, necessarily concerned primarily with national policy affecting the sciences, believes however that the recommendations of this Report are as applicable, in general, to graduate education in the arts and humanities as to that in the natural and social sciences and engineering.

It is our hope that this Report will contribute significantly to planning for graduate education by the Congress, the Executive Branch, and all other public and private bodies so concerned.

Respectfully yours,



Philip Handler
Chairman, National Science Board

The Honorable
The President of the United States

ACKNOWLEDGEMENT

The National Science Board has been greatly aided by the contributions of several former Members whose participation in the early discussions and decisions was invaluable in arriving at the present report. These individuals include Dr. Henry Eyring, Dr. Katharine E. McBride, Dr. Edward J. McShane, Dr. Edward L. Tatum, Dr. Ralph W. Tyler, and the late Dr. Rufus E. Clement.

The Board is also grateful to three consultants who joined with the Board Committee, charged with this report, in the many discussions that resulted in the final document. These consultants are Dr. Allan M. Cartter (Chancellor, New York University), Dr. Frank W. Putnam (Director, Division of Biological Sciences, Indiana University), and Dr. Charles P. Slichter (Professor of Physics, University of Illinois).

In preparing this report the assistance of many individuals has been essential. The help and cooperation of many persons in the National Science Foundation, the Office of Education, the National Institutes of Health, the National Academy of Sciences - National Research Council, the American Council on Education, and other organizations in providing important information is gratefully acknowledged. In particular, the Board is indebted to Dr. Lawton M. Hartman, who served as the staff director for this report, and to Dr. Charles E. Falk (Planning Director, NSF), Dr. Louis Levin (Executive Associate Director, NSF), and Dr. William E. Rosen (Special Assistant to the Director, NSF) for their advice and counsel.

SUMMARY

American science and engineering have achieved a position of great strength, the maintenance of which is vital to the future of the Nation. Yet a major source of this strength, the institutions of graduate education, has developed without the guidance and focus of an explicit national policy directed to its distinctive character, needs, and opportunities. The necessity for such a policy is evident in the challenge of the next decade:

> Graduate education will be the fastest growing element of the educational process, with the number of graduate students expected approximately to double and to reach 1.3 million by 1980.
>
> The cost of graduate education is increasing even more rapidly and is expected to quadruple by 1980, possibly attaining an annual rate of $20 billion.
>
> Rapidly growing enrollments and increasing costs are already over-straining the resources of most colleges and universities; substantially increased funding from the Federal Government, unrelated to the present period of budgetary retrenchment, will be required if these institutions are to meet the expectations of American society.

The responsibility for implementing a national policy for graduate education is shared by the educational institutions, State and regional organizations, and the Federal Government. Major recommendations to these three sectors include the following:

EDUCATIONAL INSTITUTIONS

The paramount obligation of the educational institution is the maintenance of sound programs of education and research.

> Institutions moving for the first time into graduate work, either at the level of the master's or doctoral degrees, as well as those considering the formation of additional graduate programs, should base their decision on strong academic depart-

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ments, already in existence, and on the availability of adequate resources to be committed to the graduate program.

Programs which lead to the master's degree in both liberal arts colleges and universities should be strengthened and enriched.

Encouragement should be given to the development of multidisciplinary graduate programs at both the master's and doctoral level, adapted to the problems of a changing society, combining various of the natural, social, and engineering sciences, and, when appropriate, leading to the award of new types of advanced professional degrees, designed for the preparation of practitioners rather than research-oriented specialists.

The expected general increase in graduate student enrollments, while a challenge to institutional capacity, constitutes an unique opportunity for substantial enhancement of the quality of graduate education in many institutions currently operating at subminimal levels.

The institutional characteristics of high quality graduate education are presented in this report in some detail.

STATE AND REGIONAL PLANNING

The markedly increased demand for graduate education expected in the next decade **could** be satisfied entirely by selective expansion of the programs of institutions already engaged in graduate education.

However, each State and each metropolitan area with a population in excess of 500,000 should have graduate educational resources of high quality and of sufficient capacity to ensure full contribution to cultural, social, and economic development.

Those metropolitan communities and those States that are inadequately served today by graduate institutions should plan either the significant expansion and improvement of existing institutions or the creation of new graduate institutions of high quality.

The geographic distribution of Federal academic funding is heavily influenced by the geographic distribution of graduate educational quality. A significant contribution to a broader distribution can and should be achieved by the strengthening of existing graduate institutions and, where specifically needed, the formation of new institutions of high quality.

THE FEDERAL GOVERNMENT

Federal support for the funding of higher education is especially important at the graduate level. The Federal Government should accept a continuing responsibility for a significant, perhaps the major, share of the total support of graduate education. Such support should be made to graduate education, in its own name, as a distinctive educational process.

Federal support should supplement, not replace, non-Federal sources of funding.

Academic research at the frontiers of knowledge, in its own right, is certainly in the national interest. It is, however, inseparable from the process of graduate education. For this reason, although research grants and contracts have played an unique role in bringing United States science to its present eminence, a major restructuring of the instruments of Federal support of graduate education is both timely and necessary for the major expansion expected in the next decade. Further, were appropriate mechanisms in operation, responsive to the character of graduate education, review by the Federal Government, especially at times of fiscal constraint when reductions of budget are inevitable, would be made in full awareness of the consequences of its decisions both to American science and to the educational programs of the Nation.

Six types of grant programs are proposed, in all but the first of which grants should be awarded on the basis of appropriate national competition:

1. **Institutional Sustaining Grants**—formula-based grants, including factors related to quality, to provide for faculty salaries, a moderate base of student stipends, and

general institutional expenditures related to graduate education.

2. **Departmental Sustaining Grants** — to assist especially with student stipends, the research needs of young investigators, and the on-going expenditures of the academic department or organized multidisciplinary program.

3. **Developmental Grants** — to assist with the formation, expansion, or improvement of graduate institutions or programs.

4. **Graduate Facilities Grants** — to assist in providing the general facilities, specialized research facilities, and libraries required by graduate education.

5. **Graduate Fellowships** — prestige fellowships awarded competitively to a select group of graduate and post-doctoral students to assist in setting standards for undergraduate and graduate performance.

6. **Research Project Grants** — to provide for those direct expenditures for research that are not included in the types of grants summarized above to support the research efforts of individual investigators or appropriate groups thereof.

Specific Federal agencies should be authorized to administer the first five of these grant programs, each of which should receive specific appropriations annually. All Federal agencies should be encouraged to engage in programs of Research Project Grants.

These recommendations are made in the firm conviction that no instrumentality of society can contribute more importantly to the future strength and well-being of the Nation and its citizens than does graduate education. To realize this potential, however, will require the timely, vigorous, and informed efforts of all who can affect the process. Difficult decisions by legislators, administrators, trustees, and planners are needed if the goals and opportunities with which this report is concerned are to be achieved. But the rewards attainable during the years ahead amply warrant the expen-

diture of energy and funds that the undertaking will entail. Graduate education has served the Nation well; yet its opportunities for important service are just beginning.

Graduate education is interpreted in this report as including all provisions for formal education beyond the baccalaureate, usually leading to the award of master's or doctoral degrees, with the arbitrary exceptions of work leading to professional degrees in such specialties as medicine, dentistry, veterinary medicine, nursing, law, and theology. These fields would appropriately be examined in other studies, and the present report has been prepared with the knowledge that many such efforts have been completed or are in progress.

The conclusions and recommendations contained in this report reflect the statistical and other evidence, available in many quarters, concerning the status of graduate education in the United States. Important features of this information and its interpretation are summarized in a publication entitled *Graduate Education —Parameters for Public Policy.*

This report is primarily addressed to graduate education and academic research in the natural sciences, the social sciences, and engineering. However, many of the conclusions and recommendations here presented also appear to be applicable to the arts and humanities.

CONTENTS

Graduate Education in American Life

Science and engineering in the United States have attained a position of unprecedented strength. From fundamental research to the development of new technology, this Nation is today at the forefront of most major lines of endeavor. Important contributions are made daily to man's knowledge of man, his social institutions, and his universe, and to his ability to utilize this knowledge and understanding to secure a better world for his children, to improve his economic lot, to conquer disease, and to ensure a richer life for all citizens.

Understanding of the animate and inanimate worlds has expanded at a prodigious rate. A gene is no longer an abstraction but a chemical entity of defined structure. The innumerable chemical reactions which constitute the life of a living cell are being revealed. The chemical basis for the wondrous process by which a single fertilized egg becomes an integrated mammalian organism is being unraveled. Efforts to understand that most resistant of all objects of scientific study, the human brain, are increasing in sophistication and are gradually revealing the physiological bases of behavior. Powerful tools are being brought to bear to illuminate the intricate relationships within a biological community. The phenomena which govern the productivity of a lake or a farm, or which control populations of plants, invertebrates, vertebrates, and of man himself are every day better understood.

Meanwhile, chemists gain more detailed insight concerning the atomic and molecular basis for chemical reactions, while they create new and more complex molecules whose properties are used to synthesize new fabrics, food, structural materials, drugs, and fuels. Physicists achieve increasingly penetrating understanding of the atomic nucleus and of matter in the liquid, gaseous, solid, and plasma states. Other physical scientists are concerned with the earth's interior and with the forces that determine the nature of the earth's surface, its weather, and its atmosphere, while their col-

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leagues conduct experiments to reveal ever more clearly the nature of the solar system and the universe.

In parallel, there has burgeoned an increasingly sophisticated effort in the social sciences, broadly concerned with man, his welfare, his behavior, and his interactions with his fellowmen and his environment. Analytical tools have been refined, quantitative considerations have become more frequent, and predictive capabilities more reliable, thus laying the foundation for major advances toward the solution of many of society's problems.

All Americans can well be proud of the scope and success of this diverse undertaking and of the contributions of the United States to scientific understanding.

While much of this impressive endeavor occurs in academic institutions, it is scarcely an academic exercise. From observations and experiments, large and small, conducted in universities and research institutes, and in Federal and industrial laboratories, have come developments that have enriched and transformed daily life, mitigated the age-old struggle for existence, prolonged life, and contributed to the national security. Indeed, the products and consequences of American science and its associated technology are to be seen at every hand. And there is ample reason to expect even greater benefits to come. Technological advance underlies each new expansion of the economy, as witnessed by the spectacular growth of the electrical, electronics, chemical, communications, transportation, and other industries. The general stability of the economy reflects the growing understanding of society in modern economic terms, while the ever-growing labor force of trained scientists and engineers, whose efforts are responsible for the great success of the Nation's scientific and technical enterprise, attests to the strength of the American system of graduate education.

Not all of this activity has occurred without penalty. Nor have all citizens benefited in like measure. The pollution of the environment, the blight of the cities, and the plight of disadvantaged citizens across the Nation are reminders of the inadequacies of societal mechanisms and of incomplete understanding of society. They are reminders, also, of the limited ability to predict the consequences of changing technology and to plan accordingly. A major

factor in future capability to undertake such planning will be the strength, scope, and success of graduate education in the relevant disciplines and in multidisciplinary programs.

Many of the contributions of science are being made in the institutions of graduate education; virtually all are the work of the scientists and engineers who are the products of these institutions. Today, as man's problems and his awareness of these problems multiply, there is an ever increasing need for the highly trained scientists and engineers that graduate institutions provide. The position of the United States in the sciences and engineering is not static; it must continually be strengthened and enriched by the creative efforts of those who build on past accomplishment.

Ever greater numbers of highly trained individuals are required to staff the expanding educational system, to man the industrial, government, and nonprofit laboratories and hospitals, and to take positions in the engineering, manufacturing, marketing, and administrative functions of industry. Increasingly, those trained in the natural and social sciences and engineering are finding appropriate places in the diverse activities of government, communications, journalism, recreation, public health, and foreign relations. Particularly striking is the appearance of practitioners of these disciplines in endeavors which have not, traditionally, employed them, e.g., physiologists in the aircraft industry, anthropologists in public health teams, sociologists and psychologists in the laboratories and personnel offices of large industry, and biologists and psychologists in the communications industry. While the front pages of the newspapers reveal the frustrations of the undereducated segment of American citizenry, the pages of employment advertising reveal both a diminishing market for unskilled and semiskilled labor and a shortage of highly trained scientists and engineers.

The enviable position of the United States in the sciences and engineering is relatively recent. Throughout the history of the Nation, important contributions have been made by many notable scientists and engineers. The remarkable development of scientific agriculture, created in concert by the agricultural schools of the Land Grant Colleges and by the U.S. Department of Agriculture, ranks among the greatest of American triumphs and has freed millions to take their places in the labor force which operates American industry, thereby also accelerating the urbanization of the Nation with all of its attendant benefits and ills. Although scientists and

engineers have traditionally responded to opportunities for public service, it was not until World Wars I and II that they were called upon to make massive and concerted efforts in defense of the United States. Since World War II, a matter of a little more than 20 years, American science and engineering have grown to their present unparalleled position of strength. This flourishing is due to a threefold wisdom: that of the American people who brought into being and nourished a diversity of public and private institutions of higher learning; that of the institutions themselves in sustaining a rapid rate of development; and that of the Congress in establishing such Federal agencies as the Office of Naval Research, the Atomic Energy Commission, the National Science Foundation, and the National Aeronautics and Space Administration, in encouraging the support of research and development by the Department of Defense, in strengthening the National Institutes of Health, and in sponsoring the support of research and development by many Federal agencies.

Before World War II, the costs of graduate education and its associated research were largely defrayed from the general resources of each university, with occasional critical assistance from philanthropic foundations. In the postwar period of dramatic growth, the support of graduate education has increasingly been accomplished through the judicious use of research grants or contracts from Federal agencies. Although addressed to the performance of defined research tasks, these contracts and grants have, in fact, been the major source of support of graduate education in the sciences and engineering. Without them, without the active, mutual involvement of Federal agencies and educational institutions, the development of American science and engineering to its position of present eminence could not have occurred.

Support of this endeavor by means of the research grant or contract has served American society well during this period when total costs of graduate education and academic research increased by almost twentyfold and the Government itself was viewed as the major potential user of the information to be secured, as well as a major ultimate employer, directly or indirectly, of the students to be trained. Such research contracts and grants to the institutions of graduate education are now awarded by the tens of thousands annually. Experience has been gained in their administration, in their strengths and weaknesses, and in their relationship to the educational process at the graduate level. Today, as the focus of research broadens to encompass the full utilization of the sciences and en-

gineering for the welfare of individual Americans, the improvement of health, the structure of cities and their environs, and the operation of the economy and society, it is also possible to look forward to a doubling of the graduate student population by about 1980 with, perhaps, an attendant quadrupling of the total costs of graduate education. The time seems opportune, therefore, to adopt such policies as may be required to assure that this growth occurs in a manner appropriate to the national interest, and to assure that the mechanisms for the financial support of this huge enterprise are appropriate to the national purpose.

Several specific circumstances prompted the selection of graduate education as the subject of this report.

(1) Although American civilization is increasingly dependent upon the institutions and the products of graduate education, and although present strength in science and engineering is due in large measure, directly and indirectly, to the contributions of graduate institutions, no clear national policy exists today to serve as a guide for the development and strengthening of graduate education, as such, in the United States.

(2) It has long been a *de facto* American goal, and is now a stated national policy, to provide to all citizens the educational opportunity to develop their individual capabilities to the fullest. Approach to this goal has gradually resulted in the formation of institutions of higher education, and in particular graduate programs, in every State of the Union. The pattern of this latter development, represented by the date of the first award of the doctorate in each State and the District of Columbia, is seen in Table 1. Adherence to this goal, however, will present graduate education with a severe test during the next decade when, as in each preceding decade, graduate enrollments are expected approximately to double. This projected growth, at a rate significantly greater than that for higher education as a whole, is shown in Figure 1. The magnitude of the total graduate enterprise is further illustrated by the patterns of growth of the production of doctorates and master's degrees in the United States, as shown in Figures 2 and 3. Graduate enrollments in science and engineering today exceed 200,000. The next doubling of enrollments, therefore, will represent a far larger proportion of the popu-

Table 1

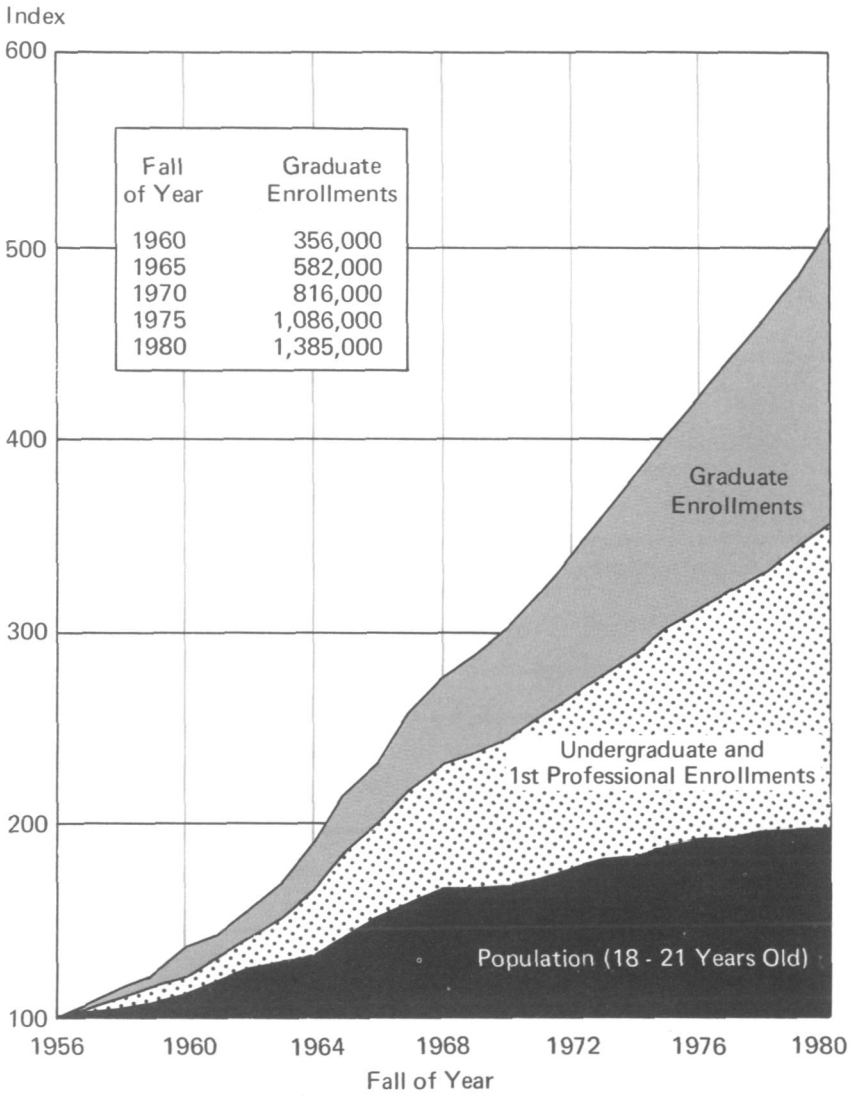
SEQUENCE OF FIRST DOCTORAL AWARDS BY STATES

Year	State	Total States	Year	State	Total States
1861	Connecticut	1	1900	Iowa	28
1866	New York	2	1902	West Virginia	29
1871	Pennsylvania	3	1914	North Dakota	31
1873	Massachusetts	4		Washington	
1875	District of Col.	5	1915	Texas	32
1876	Michigan	6	1922	Arizona	33
1878	Maryland	7	1926	Hawaii	35
1879	New Jersey	10		Oregon	
	Ohio		1929	Oklahoma	36
	Tennessee		1931	Vermont	37
1883	Indiana	13	1934	Florida	38
	Missouri		1940	Georgia	39
	North Carolina		1947	New Mexico	41
1885	California	15		Utah	
	Virginia		1948	Delaware	43
1887	Louisiana	16		Wyoming	
1888	Minnesota	17	1952	Alabama	44
1889	Rhode Island	18	1953	Arkansas	45
1891	South Carolina	19	1955	Alaska	46
1892	Wisconsin	20	1956	Montana	47
1893	Illinois	22	1959	South Dakota	48
	Mississippi		1960	Maine	49
1894	Kentucky	23	1962	Idaho	50
1895	Colorado	24	1964	Nevada	51
1896	Kansas	27			
	Nebraska				
	New Hampshire				

Source: American Council on Education; Office of Education (DHEW).

Figure 1

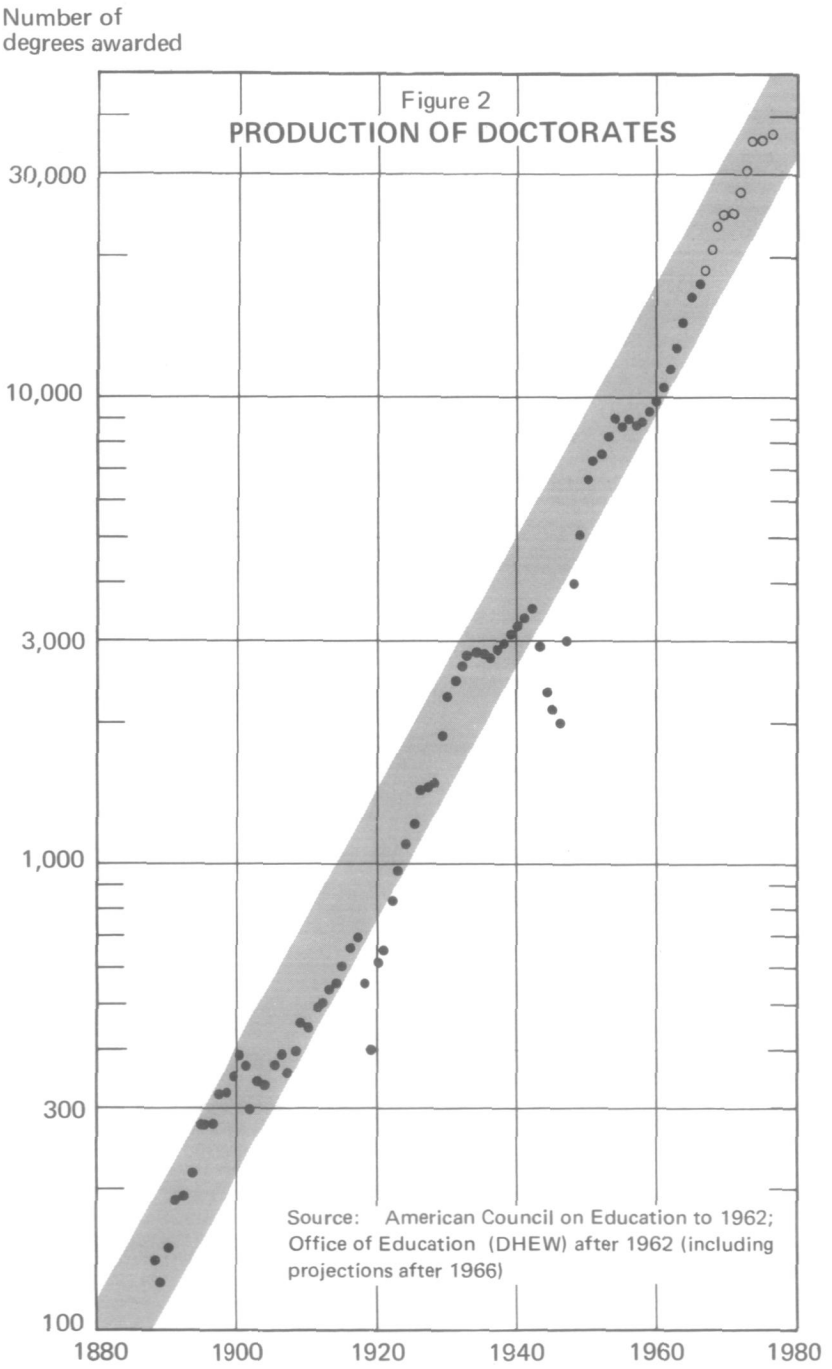
GROWTH OF GRADUATE ENROLLMENTS

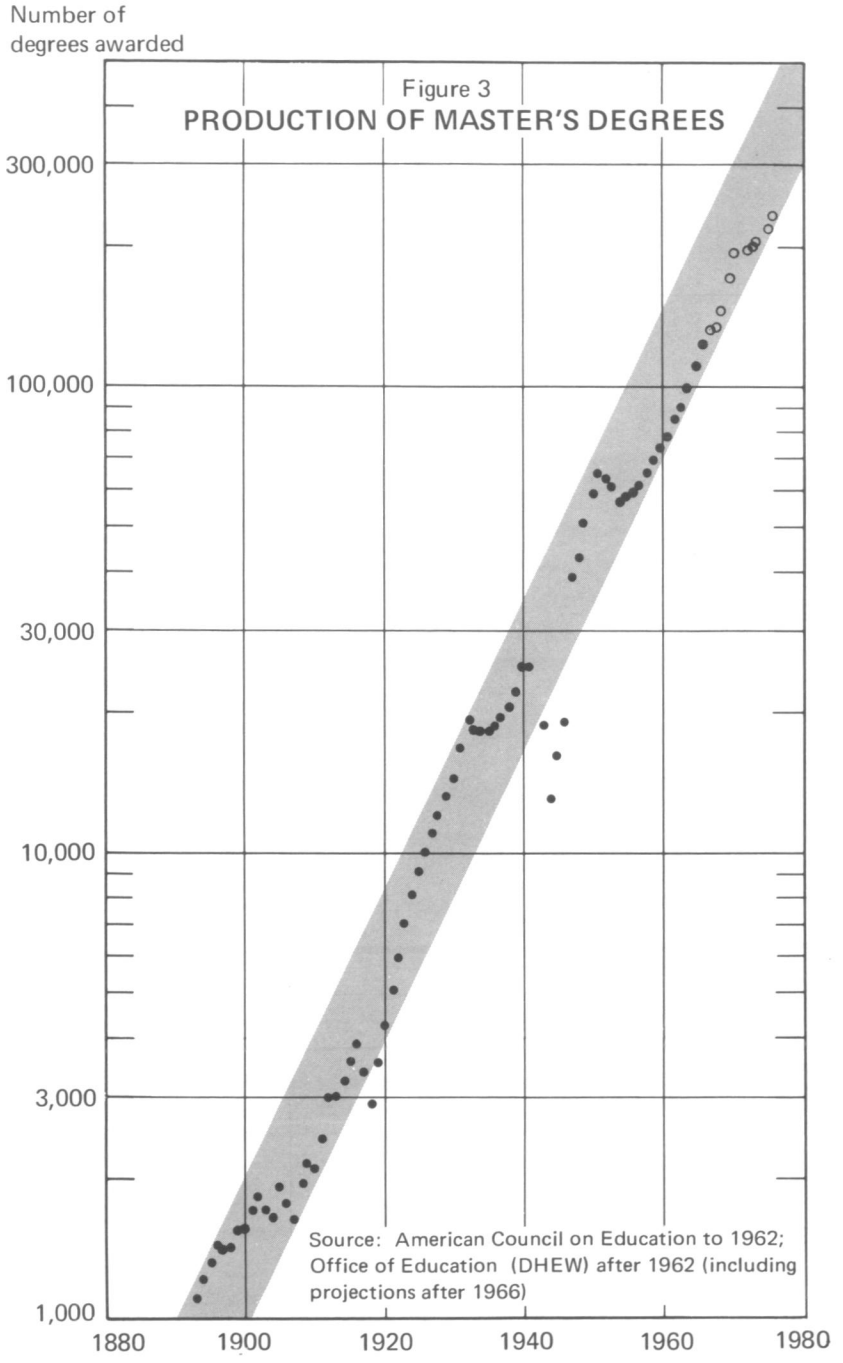


Fall of Year	Graduate Enrollments
1960	356,000
1965	582,000
1970	816,000
1975	1,086,000
1980	1,385,000

The index has been computed by dividing the population (or enrollment) figure for a given year by the value for 1956 and multiplying by 100.

Source: Office of Education (DHEW); projections after 1976 by National Science Foundation.


Number of degrees awarded
Figure 2
PRODUCTION OF DOCTORATES
30,000
10,000
3,000
1,000
300
100
1880
1900
1920
1940
1960
1980
Source: American Council on Education to 1962; Office of Education (DHEW) after 1962 (including projections after 1966)


Number of degrees awarded
Figure 3
PRODUCTION OF MASTER'S DEGREES
300,000
100,000
30,000
10,000
3,000
1,000
1880
1900
1920
1940
1960
1980
Source: American Council on Education to 1962; Office of Education (DHEW) after 1962 (including projections after 1966)

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lation and resources of the Nation than has been the case heretofore. Provision of the institutional capacity to meet this next decade of growth, while maintaining or improving the all-important quality of graduate programs, constitutes a major national challenge and an opportunity that will not recur in this century.

There are those who will demand documentation clearly indicating that American society will require the services of this greatly increased, highly trained population. With seeming logic, they may request a forecast, on rational premises, of the national requirement, in 1980 or 1985, for organic chemists, economists, molecular biologists, anthropologists, electronic engineers, or other specialists. But it is extremely doubtful that there exists an acceptable basis for such forecasts. Indeed, the creative innovations of graduate education and academic research may even render one or more of such categories obsolete by 1980.

Accordingly, this report rests on the premises that: (a) In very large measure, it is the supply and contributions of trained individuals that engender demand. (b) The current success of American science-based industry, in considerable degree, reflects the fact that industrial, Government, and academic laboratories employ not only the gifted few of high creative talent but substantially larger numbers of competent, well-trained investigators and engineers who make it possible to capitalize on the unique contributions of that highly talented few. (c) The Nation has much yet to learn concerning optimal mechanisms for applying the natural and social sciences to the problems of a changing society; as this capability is attained, the demand for knowledgeable and skilled individuals will necessarily increase. (d) It is characteristic of well-trained scientists and engineers that they are flexible and can adapt themselves to changing circumstances, applying their experience and habits of mind to new and different challenges. (e) The larger the number of qualified individuals given the opportunity to undertake graduate education, the greater is the likelihood of identifying and appropriately educating those who will be the future leaders in all areas of human endeavor. (f) There is a continuously expanding and unmet need, in institutions which offer undergraduate education, for large numbers of qualified teachers who have received sound, advanced training in the sciences and engineering; providing these teachers with high quality graduate education is basic to the structure of tomorrow's society. (g) A foreseeable consequence of **apparent** overproduction of graduate school-trained scientists and engineers, in

the sense of national inability to employ some fraction of them in traditionally or newly acceptable types of positions, would be the upgrading of the teaching staffs of the Nation's secondary school system, an event which could only be deemed desirable in itself. In short, the position taken in this report is that it is not possible to produce too many highly educated people in the United States as long as appropriate educational standards are not sacrificed.

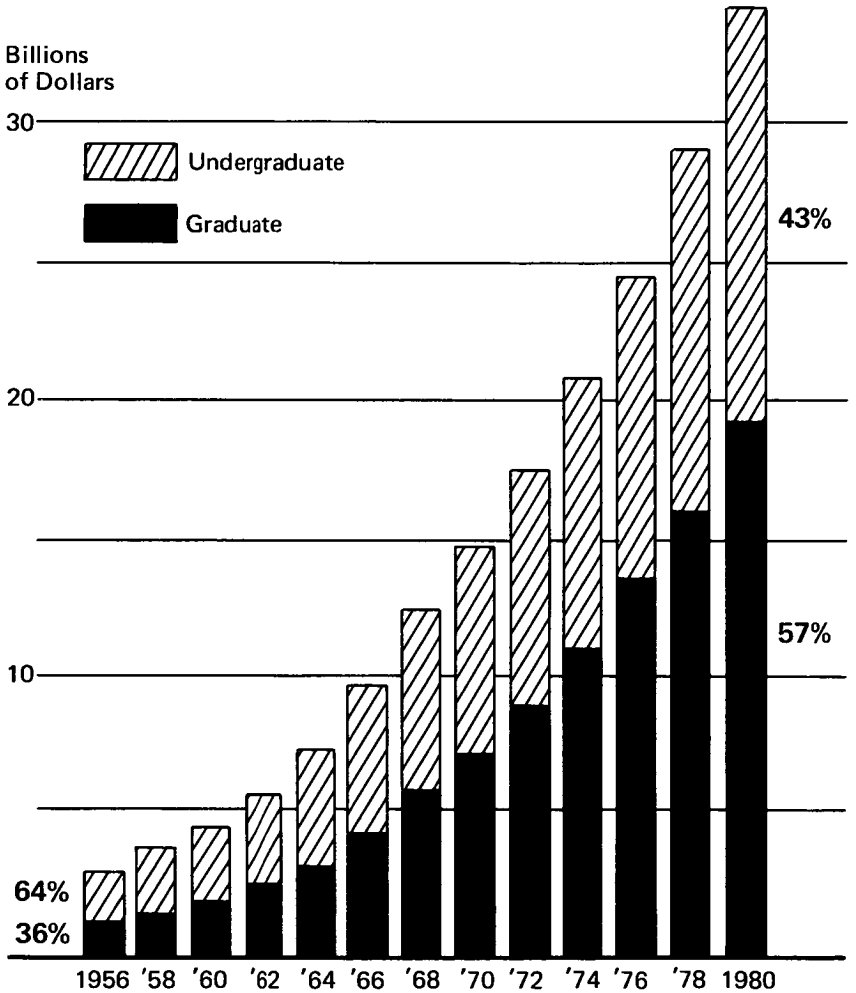
(3) The changing needs of communities and regions throughout the United States extend from problems of economic and social development to the needs of all individuals to accommodate to the intellectual and emotional demands of a scientific and technological age, thereby compelling institutions with graduate programs continually to appraise the adequacy, currency, and relevance of their programs. Conflicts can arise between the accelerating demands of public service and the conservative traditions of established academic disciplines. In addition to the continuing obligation of the graduate institution to ensure the high quality of its advanced degrees in traditional disciplines, it is increasingly important to design advanced programs in which the strengths of many disciplines are brought to bear on current and emerging problems of society, including, those that lead to new professional degrees for individuals who do not plan research careers.

(4) The development of graduate education in the United States has been geographically uneven. Many private graduate institutions were established in centers of population, while the Morrill Act and the early orientation of public higher education to "agricultural and mechanical" colleges resulted in the location of many of the now large State universities in rural settings. Although even public graduate education has more recently become increasingly urban, there remain many metropolitan areas that are inadequately served by graduate institutions, or not so served at all. Yet a maximum contribution of the graduate institution to society can be attained only through interaction with both the problems and the individuals of society. The educational and research programs of the university can stimulate and provide support for the local economy, participate in the solution of local social problems, and provide individuals appropriately trained to function within the community. Moreover, approximately one-half of the Nation's graduate students in science and engineering are part-time students, including an increasing number from industry, who must pursue their educa-

Figure 4

PROJECTED COST OF GRADUATE EDUCATION

Expenditures for Educational and General Purposes (Current Dollars)



Estimate of cost of graduate education and projection to 1979-80 by National Science Foundation.

Source: Office of Education (DHEW) projections for higher education to 1975-76; graphical extrapolation to 1979-80.

Table 2

INCOME RELATIONSHIPS

Distribution of Current-Fund Income for Educational and General Purposes

PUBLIC UNIVERSITIES (1)

Year	Total (millions)	Student Fees	Federal Research	State	Other (2)
1951-1952	746	9.7%	N.A.	50.3%	N.A.
1953-1954	878	10.6	12.3%	51.4	25.7%
1955-1956	1,158	11.7	12.6	50.3	25.4
1957-1958	1,507	11.7	15.0	50.5	22.8
1959-1960	1,862	11.3	18.8	48.1	21.8
1961-1962	2,389	11.2	21.9	45.9	21.0
1963-1964	3,080	12.0	23.4	44.0	20.6

PRIVATE UNIVERSITIES (1)

Year	Total (millions)	Student Fees	Federal Research	State	Other (2)
1951-1952	478	30.3%	N.A.	7.0%	N.A.
1953-1954	520	34.2	20.9%	3.7	41.2%
1955-1956	625	35.1	20.9	3.6	40.4
1957-1958	789	35.1	23.3	2.9	38.7
1959-1960	1,030	32.9	29.6	2.9	34.6
1961-1962	1,336	32.1	32.5	3.0	32.4
1963-1964	1,669	29.7	35.2	2.7	32.4

(1) Includes 88 publicly and 58 privately controlled institutions
(2) Includes endowment earnings and gifts and grants from individuals, philanthropic organizations, business corporations, and other private sources, etc.

Source: Derived from data made available by the Office of Education (DHEW).

tions not far distant from their dwelling and working places.

In addition, the graduate institution has become an important focus of American culture, from the pursuit of natural science and social understanding to the expansion and intensification of efforts in the arts and humanities. In this sense, such an institution generates much of the tone and quality of life for the immediately surrounding community. Accordingly, as many communities as possible should be enabled to share in these diverse benefits.

(5) Although graduate education will remain, numerically, the smallest element of the educational system, of necessity it will also remain, inherently, by far the most expensive element on a per student basis. Hence, if graduate enrollments do indeed double by about 1980, as now projected, and if the cost per student also doubles, as seems likely, the total cost of graduate education in the United States may be expected to increase to an annual figure of about $20 billion. A projection of this growth is illustrated in Figure 4. If advanced educational opportunity of high quality is to be made available to all qualified students, significant funding will be needed to supplement such sources as endowment income, tuition charges, philanthropic gifts, and State appropriations, which are, of necessity, heavily committed to primary, secondary, and undergraduate education. Trends during recent years in the relative behavior of selected, major elements of university income, shown in Table 2, clearly support this conclusion.

In the last two decades the traditional means of financial support, particularly for the private institutions, have not grown at a rate commensurate with the rising aspirations of the American people and the increasing demands of all elements of American society for highly educated and skilled individuals. From all available indications, this disparity between institutional resources and societal needs is fast increasing. The situation will become worse unless Federal funds, on a substantial scale, can be made available. Historically, the financial support of educational institutions has been provided by the areas and populations that they have primarily served. In this sense, since virtually all graduate schools draw a large fraction of their students from a national base and since their graduates, in turn, are then redistributed nationally, there is a special logic in the argument that graduate schools should be that element of the educational system which, initially, should receive

support from the Federal Government on such scale as to constitute a major fraction of its total financing.

Taken together, these circumstances suggest that the support and development of graduate education, despite its long history of successful growth and its evident contributions to the Nation, are among the most serious and important problem areas facing American society today. It is the purpose of this report to examine in some detail the measures believed to be necessary if graduate education is to serve the United States as well in the future as it has in the past.

Characteristics of Quality in Graduate Education

The quality of an educational institution is a property of the total institution and thus reflects the concepts and the creative genius of those who establish or function within the enterprise. As such, quality is not amenable to precise or quantitative determination, nor can well-defined preconditions ensure the achievement of high quality. Nevertheless, several indicators or operational characteristics of educational institutions or graduate programs appear to correlate well with measures of perceived quality. These indicators may assist in the appraisal of existing graduate programs or in the formulation of new programs. The following principles and **minimal** conditions are offered for the consideration of those responsible for planning or appraising institutional quality.

THE INSTITUTION

An educational institution can be effective in its service to society only through the achievement and preservation of high quality. The quality of an institution, however, is an attribute of the institution as a whole, viz., administrative policies, the faculty, the instructional process, research performance, and the student body. While institutions of inferior quality may contain individual students or professors of exceptional merit, **it can hardly be expected that, in general, first quality products — graduates, research results, or services to the community — will be produced by inferior institutions.** It is in the public interest that the quality of existing institutions be strengthened wherever possible.

Some measure of institutional specialization may be necessary in order to achieve peaks of excellence in all fields throughout the Nation. Whereas some disciplines are sufficiently fundamental to the general structure of the sciences and engineering that any institution aspiring to excellence must excel in them, strength in other disciplines may be justified only in relatively few major centers.

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In order fully to meet their responsibilities for service to society, colleges and universities with graduate programs must retain the independence of decision necessary to maintain the integrity of the educational process. Whereas each institution needs to be perpetually alert to the advisability of adapting its programs to the changing needs of society, its essential autonomy should not be compromised by unrelated, external pressures generated by the **administrative** requirements of private, State, or Federal financial support.

THE FACULTY

Central to the quality of graduate education is the quality of the graduate faculty. As a general principle, the members of the graduate faculty should themselves hold the doctorate.

In general, a faculty of appropriate quality is possible only when institutional policies concerning compensation are such as to attract and retain professors of high quality. **Members of the continuing faculty should not be expected to obtain part or all of their salaries from external sources.**

The time required for an effective tutorial relationship with graduate students is properly part of the instructional duties of a professor and should be taken fully into account in establishing faculty teaching assignments. The student-faculty ratio provides an approximate measure of this relationship, but it must be supplemented by consideration of the total pattern of obligations of individual faculty members.

To be consistent with its mission, the educational institution should ensure that all faculty members contribute directly to the intellectual environment of the graduate and postdoctoral students. **A personal commitment to research and scholarship by each member of the graduate faculty is essential to competent graduate teaching.** However, the establishment of numbers of research professorships, without formal teaching responsibilities, should be discouraged.

THE GRADUATE STUDENT

The establishment and control of appropriate admission standards is of primary importance, for the quality of the

graduate student is a central determinant of institutional quality. The maintenance of such standards serves, furthermore, to strengthen and raise the standards of the undergraduate institution. Graduate and undergraduate institutions thus share a common interest in the attainment of high quality.

Provision for the financial support of graduate students should ensure the continuity of education of those who are qualified to continue their progress towards advanced degrees. It is not in the interest of the student, the quality of the graduate program, the institution, or society to prolong unduly or to vitiate the student's educational opportunity for financial reasons. Graduate student stipends should be adequate to meet normal, modest living standards; funds should also be available for student loans to meet unusual needs. **In any event, the student's stipend should be regarded as a means for his personal support, not as a fee for service.**

The doctoral student's educational experience necessarily involves a balanced program of formal study, seminars, tutorial instruction, and research participation. It is entirely appropriate, and in his own interest, that the graduate student be, during the course of his graduate work, student, research assistant, and teacher of undergraduates. Only the more able students, however, should be privileged to serve as instructors, under faculty supervision, and this only when the opportunity is consistent with their own development and career plans.

In the process of graduate education at the doctoral level, research and instruction are generally inseparable. The participation of graduate and postdoctoral students in research projects, in association with the faculty, is an integral part of their education.

Central to graduate education in the sciences and engineering, particularly at the doctoral level, is the tutorial relationship between teacher and student. The support and conduct of research in graduate institutions should strengthen, not compete with, this important relationship.

Similar principles apply to the successful administration of programs leading to the master's degree. Although the large numbers of students involved in these programs often preclude

a full tutorial relationship with each student, a close collaboration between one or more faculty members and the student and a continuing appraisal of his progress, as well as careful planning of his program to ensure balance between instruction and independent investigation, are essential to high quality.

The requirement of high quality for successful education applies equally to master's and doctoral programs. It is particularly important that academic departments that offer both degrees make every effort to ensure the quality of the master's degree.

GRADUATE PROGRAMS

In general, an academic department of high quality that offers the doctoral degree will exceed a minimal critical size, in terms of the numbers of faculty members and graduate students. The existence of such a minimum is due to the essential contribution to a creative environment that results from full opportunity for inter-personal communication among peers. Above such a minimum the actual size of departments may vary with their disciplinary scope. Thus, a relatively small group of faculty and graduate students may suffice for disciplines such as geophysics, anthropology, biochemistry, or astronomy, while substantially larger minimal groups are necessary for comprehensive, structured departments of physics, chemistry, biology, economics, or mathematics.

For similar reasons, a doctoral program of high quality in a particular discipline is possible only when the institution also provides adequate coverage of closely related disciplines in allied departments of high quality. This is notably true in the sciences and engineering where individual disciplines are strongly dependent upon the information, techniques, and progress of related fields. Such a group of related departments, either in the natural or social sciences, should generally involve at least 50 faculty members and about 300 graduate students. Such a minimal graduate institution, however, is necessarily of a specialized character; while it should offer advanced programs in appropriate, central, basic disciplines, it cannot provide full coverage of less closely related fields.

While retaining and building upon the wisdom of the past,

the institution should ensure, through experimentation and continual appraisal, that its graduate programs, its degree structure, its exploitation of research opportunity and interdisciplinary cooperation, and its interaction with the community not only serve the contemporary needs of both the students and the public, but are being adapted to problems and purposes anticipated for the future.

RESEARCH

A doctoral program of high quality will produce research results of high quality. Evidence of such research quality is most readily found in the quality of an investigator's publications and in the judgments of his peers, in institutions across the Nation; in general, the quality of an investigator's research is evident in his success in national competition for research project funds.

FACILITIES

It is essential to the achievement of high quality that the institution be committed to the provision of adequate facilities for graduate education. Of special importance are the libraries, computers, and other facilities needed for research. Although standards for such facilities have not generally been established, institutions should not minimize these basic requirements or adopt inadequate standards for reasons of expediency.

FUNDS

A graduate program can maintain high quality only if it can be assured of continuity of essential financial support. Significant short-term variations in funding are especially serious, for they are destructive of morale. It is more difficult and requires a longer time to build high quality than to destroy it.

UNDERGRADUATE EDUCATION

In most institutions the graduate and undergraduate faculty are largely identical; graduate students and some postdoc-

toral fellows frequently serve as teaching assistants. In consequence, the quality, the general liveliness of the graduate research program, and the extent to which it is engaged in frontier research and major societal problems necessarily have great impact upon undergraduate education in the same institution. The enthusiasm, the profundity of thought, the clarity of insight, the breadth of vision, the problem-solving habits of mind can all be communicated to the undergraduate student in the same environment, albeit perhaps in lesser degree.

Moreover, this process extends beyond the campus of the graduate institution. It is the products of the graduate school who must become the faculty of the four-year college and of the junior college. And the quality of their graduate education will determine the nature and quality of the undergraduate education of their students in these institutions. And thus is a cycle completed, since these colleges constitute a major source of future graduate students whose capacities to profit by the opportunities available in graduate school are markedly affected by the quality of their undergraduate experience.

Accordingly, measures which strengthen graduate education also upgrade undergraduate education both in graduate and undergraduate institutions.

Several of the principles listed above relate uniquely to graduate education, several to the educational institution as a whole. As a distinct educational process, graduate education can properly be guided, planned, appraised, and supported as a separate activity. It remains, however, part of the total institution, coordinate with undergraduate education, and must share the policies, standards, and purposes of the whole.

A National Policy for Graduate Education

The nature, magnitude, and support of graduate education in the United States today are, in large measure, the by-products of three national efforts that are historically unrelated, and that characterize in varying degree the activities of different types of both educational and noneducational institutions. These efforts have been the national responses to public policies concerned with:

(1) The provision of full educational opportunity for an expanding proportion of all citizens, a policy that, historically, has witnessed its nearest fulfillment successively in primary, secondary, and undergraduate education.

(2) The full use of scientific and engineering resources in the public service, especially in support of the complex requirements of national security, agriculture, public health, and social welfare. This policy, which has been operative over the entire history of the Nation, has been most strikingly implemented during the past 25 years, and now requires a continuing relationship between educational institutions and national programs.

(3) The contribution of American science and engineering to human welfare throughout the world and to the support by the United States of the aspirations of new and developing nations, a more recent policy that has seen the participation of the United States in many international undertakings.

While graduate education grew sturdily in the years before World War II, under the initiative of the States and of diverse private bodies, there existed no coherent, explicit national policy in this regard. And while Federal funds, quite deliberately, gave impetus to the postwar growth of graduate education, particularly in the sciences and engineering, there has been no overall plan for this endeavor. Each year these funds have increased, but only a small fraction of the total has represented funds deliberately appropriated in support of graduate education *per se*. Instead, support

has derived largely from funds appropriated to sustain the national efforts, for example, in defense, health, atomic energy, space, or even in fundamental research. Important beneficial, as well as potentially injurious, consequences to graduate education in the United States have resulted from this form of implementation of these three policies, in the absence of a directly implemented Federal policy to support graduate education.

Academic research in the sciences and engineering has experienced a vigorous, dynamic growth in the United States. In direct consequence, American science is at the forefront of most major lines of scientific endeavor, while the national scientific "labor force" is at an all time high. All Americans may well be proud of the scientific and technological accomplishments of the last two decades.

Because the financial support of this research has been largely unrelated in concept to graduate education, much of the planning which has shaped academic science has occurred in a different context, viz., the procurement of research results which might find specific application to agency missions in the near or long-term future. The university has thus been forced to compete, in some part, with other types of organizations (e.g., industry, research institutes, non-profit organizations, and even Government laboratories) designed specifically to engage in research.

Potentially, the support of academic science and engineering principally by Federal agencies whose primary missions do not directly involve education could have been divisive and distorting in its effect on the balance of graduate programs and their relationship to the educational process, progress in scientific disciplines, and the character of the relationship of universities to the problems of Federal agencies. Indeed, there are examples of universities in which certain graduate programs have been patterned rather closely on the mission requirements of individual Federal agencies. The extent to which these problems have been generally avoided is a testimonial to those, both in Government and in the universities, who have administered these programs. Nevertheless, because of the necessary relevance of research funding to the missions of Federal agencies, and because an increasing proportion of the resources for graduate education depends upon such funding,

there is a growing danger that, overall, graduate education might be distorted by responding to criteria and priorities that could be invoked without regard for educational objectives.

Indeed, because of the existing indirect mechanism for funding graduate education, and because of the increasing dependence of graduate education upon these funds, a period of budgetary uncertainty or retrenchment in the magnitude of the national research and development enterprise, such as the present, imposes inappropriate pressures on educational planning, rather than decisions consciously reached concerning the educational programs of American society.

The benefits to graduate education that have derived from this form of support, however wisely administered, have necessarily accrued to the limited number of institutions with comprehensive graduate programs. A large number of graduate institutions with master's or minimal doctoral programs, have received decidedly less benefit from current Federal funding of academic research.

The growth of graduate and undergraduate education in the years since World War II has necessarily been accompanied by concurrent growth of the physical plant and of the faculty. This growth has continued to strain the resources of both public and private institutions. For this reason, the colleges and universities, since shortly after World War II, have accepted the device of partially financing faculty salaries from the research grants and contracts that simultaneously fund other aspects of academic research. In varying degree this practice has had the effect of eroding faculty loyalties to the institution, and contributing to such validity as there may be in the allegation of a "flight from teaching," while hindering the colleges and universities in their attempts at rational long-range planning of their research and educational objectives.

A large number of graduate student stipends is also provided through the research grant or contract mechanism. Statistically, this assures that the research experience of many graduate students is relevant to problems and research projects that have been judged to be significant and of suitable quality by Federal agencies and their scientific advisory groups. Concomitantly, however, this mechanism can deprive an individual

student of his options in selecting a mentor or a research problem and, in extreme instances, can derogate the research experience of the student to the role of technician rather than that of junior colleague.

The resulting trends in the financial support of graduate education thus introduce serious risks. Although support of academic research has benefited from a diversity of sources, it can require excessive or inappropriate response by the universities; although it has resulted in major centers of national scientific and engineering strength, it has been incomplete in its coverage of the graduate educational process, both by discipline and by distribution of institutions; although it has led to national strength in specific fields of science and technology, it has not been correlated with long-range national needs for a balanced supply of competent scientists and engineers, that is, for the products of graduate education. Its inadequacies become most evident during periods of budgetary stringency, when graduate education must adjust to circumstances unrelated to the national need for graduate education.

In order to meet its obligations to society, graduate education must be assured of long-term support from funds and appropriations conveyed to the graduate institutions by instruments appropriate to this purpose.

To contribute to this end, the National Science Board urges the formal recognition and adoption of the following as an expression of national policy:

> **It is the policy of the United States that the Federal Government, in cooperation with State governments and all other participating institutions, shall encourage and financially support the conditions essential to graduate education: the fruitful and mutually strengthening associations of student and teacher, of research and instruction, and of the graduate institution and society. It is in the national interest that there shall be colleges and universities in all regions of the Nation that maintain programs of high quality in graduate education, dedicated to creative inquiry in the arts and humanities and in the social and natural sciences and engineering, to the transmission of high standards of research, scholarship, and professional service to succeeding generations, and to the use of such knowledge and understanding for the benefit of mankind.**

IV

Recommendations to Educational Institutions

The integrity of an institution of higher learning, the achievement and maintenance of high quality, and the determination of its public purpose are responsibilities of the governing board, the administration, and the faculty of the institution. Only they can establish the policies and objectives of the institution and its response to the needs and opportunities for public service. As enrollments expand, as all parts of the Nation increasingly demand the social, economic, and cultural advantages to which educational institutions can contribute, especially those that engage in graduate education, these opportunities will multiply. The relationship of the educational institution to its supporting body involves mutual responsibilities for the quality of the educational enterprise, the quality of the research effort, and the prudent use of funds which they hold in public trust. These relationships also impose a severe responsibility on the university administration to ensure the adequacy of its organization, its administrative mechanisms, and its programs, as well as their relevance to the needs of society today and tomorrow. Several recommendations are addressed to this responsibility:

Although the character and progress of American science are ultimately dependent upon the quality of doctoral education, many more students, because of their qualifications, opportunities, or motivation, seek the master's degree. The institution should ensure that this degree, when offered, is well conceived and well planned. The candidate for a master's degree should be welcomed in his own right and made to feel that the resources of the institution have been made available to him as they are to candidates for a doctoral degree. In short, this educational experience should be rich and intensive.

Baccalaureate colleges should undertake graduate programs in science or engineering, leading to the master's degree, only when they already have strong undergraduate

majors, of significant size, in these fields, and can commit adequate resources to the graduate program. A similar admonition is appropriate for institutions, currently offering the master's degree, that contemplate the transition to a doctoral program. The need to provide a more intellectually stimulating environment for the faculty, requiring the acquisition of adequate research facilities, should never be the primary reason for undertaking graduate work. Better solutions to this admittedly important problem may be found in advanced undergraduate honors and research participation programs and in cooperative research relationships with neighboring colleges and universities.

THE PARAMOUNT RESPONSIBILITY OF THE UNIVERSITY IS THE DEVELOPMENT AND MAINTENANCE OF SOUND PROGRAMS OF EDUCATION AND ASSOCIATED RESEARCH IN BOTH THE TRADITIONAL AND THE DEVELOPING SCHOLARLY DISCIPLINES.

In addition, however, the institution should avoid rigidities which inhibit cooperative behavior among departments so engaged. Characteristic of research and of operational programs directed to many of the problems of modern society is the need for the simultaneous contributions of many disciplines. Opportunities for public service may often require the development of graduate programs of a multidisciplinary character, variously involving the natural sciences, the social sciences including law, medicine, and engineering, as well as the arts and humanities. Here again, the quality of these contributions will determine the ultimate value of the product. A first rate multidisciplinary program cannot be compounded from second-rate disciplinary efforts.

The progress of American science and the continuity of the educational process require growing numbers of highly trained scientists and teachers who have earned a research doctorate. But there is also a need for large numbers of individuals with advanced training in several disciplines, a preparation for contributions of a professional character in public service, in industry, and in other walks of life. Thus, the doctorate degree in medicine carries with it dignity and prestige; it represents preparation for the assumption of responsibility for applying existing knowledge to problems

of human health. The baccalaureate in engineering or architecture, traditionally, has also been of this quality. Both degrees represent multidisciplinary preparation for professional practice, but neither denotes, today, sufficient preparation for a career in research. Few other scientifically based professions have been developed. It seems advisable that some institutions develop advanced multidisciplinary programs, at the master's or doctoral level, specifically designed to prepare students for professional careers in areas of defined social need. Such programs, characteristically involving a challenging internship of supervised professional practice, but only minimal independent research experience, are being developed in a number of fields. New interdisciplinary programs could successfully be based on such fields as business and public administration, appropriately combined with the natural sciences, the social sciences including law, or engineering.

V

Recommendations for State and Regional Planning

The immediate task facing responsible planners is the formulation of decisions concerning the number, location, quality, and appropriate development of institutions offering graduate programs. The following observations are relevant to these decisions:

Although projections of national graduate student enrollments and of the production of advanced degrees indicate that student demand for advanced education in the United States will approximately double during the next decade, **no increase in the number of institutions is needed simply to provide for the numerical requirements of nationally increased graduate capacity.** This prospective growth in the graduate student population can successfully be managed by a combination of reasonable growth of the programs of currently major institutions and of well planned, soundly financed, and significant expansion of the graduate programs of institutions that are presently at minimal or subminimal levels. The distribution of existing institutions, in terms of the numbers of graduate students in science and engineering, is shown in Figure 5 for a recent academic year.

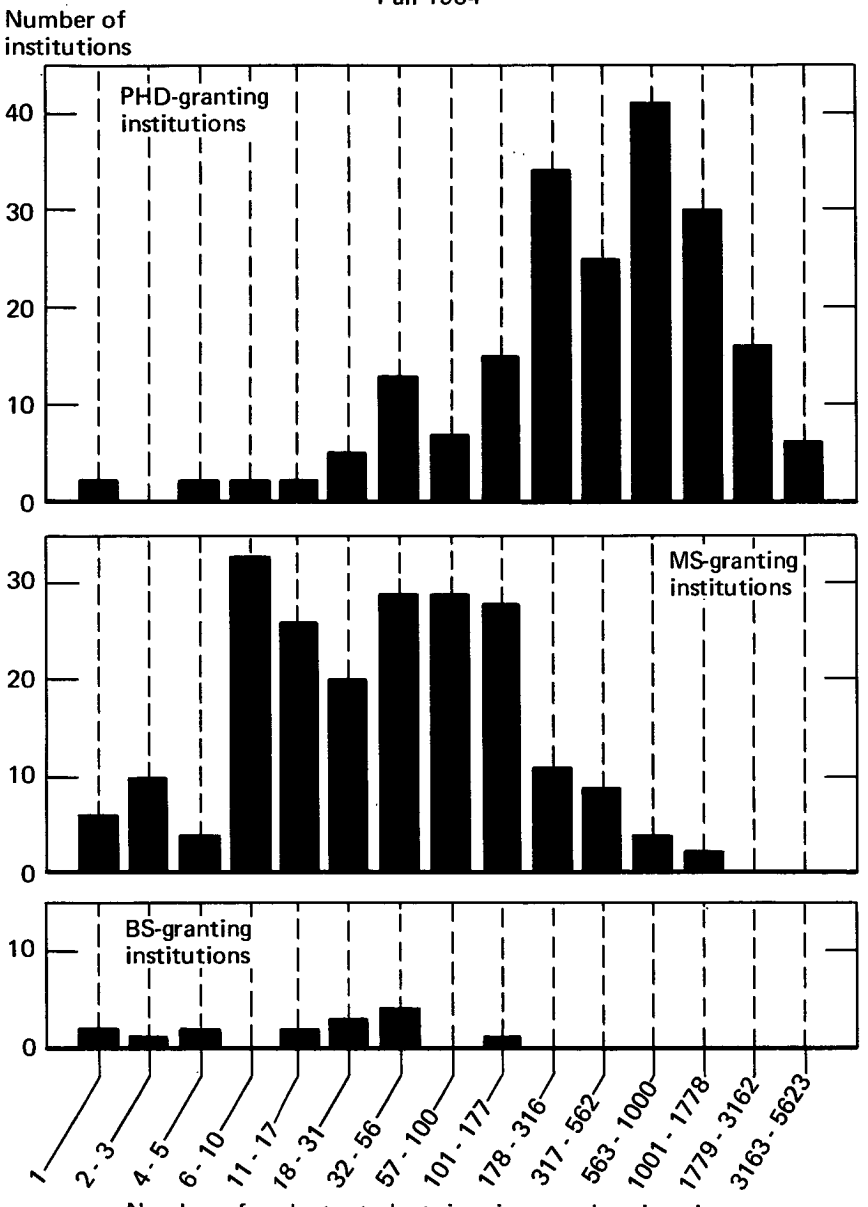
There are, however, many States and metropolitan areas that are not adequately served by institutions with graduate programs, as illustrated in Figures 6 and 7. There is an urgent need for either existing or new institutions in such areas to undertake substantial, sound programs of graduate education. Moreover, these institutions will have unusual opportunities to develop new types of graduate programs emphasizing the productive interaction of the institution and the community.

Since the time required for the development of a graduate institution of high quality is in general measured in decades, early planning of graduate institutional development is essential if this challenge is to be met successfully.

Figure 5

DISTRIBUTION OF GRADUATE ENROLLMENTS IN SCIENCE AND ENGINEERING BY TYPE AND SIZE OF INSTITUTIONS

Fall 1964



Source: Computed from statistics of Office of Education (DHEW). The size classes have been chosen to have approximately equal percentage widths.

Limited national resources, especially of qualified faculty, preclude the indiscriminate undertaking of new graduate programs, particularly at the doctoral level, by the majority of institutions of higher education, if high quality is to prevail as a goal.

Some institutions may be tempted to undertake new graduate programs for the wrong reasons. In the process, they may thereby be transformed from first-rate liberal arts colleges into second-rate universities. In other instances, where a community may be served only by an inferior undergraduate college, regardless of its size, it may be important to weigh the advantages of establishing a new institution, rather than to attempt the transformation of the existing one.

Several conclusions are offered for the consideration of those who are responsible for planning the development of higher education in States and regions of the Nation.

Because of the distinctive requirements of graduate education for human, financial, and physical resources, as well as its distinctive purposes, methods, and activities, planning for graduate education should be conducted as a separate exercise, although coordinated with planning for higher education as a whole.

In establishing new graduate institutions, or in expanding present graduate programs, consideration should be given to:

(a) The availability and commitment of the resources necessary to achieve a program of high quality and of significant scale and scope.

(b) The capacity of the population and the economic strength of the community, State, or region to support the proposed program. In this connection it should be noted that the number of graduate students in science and engineering in the United States is now of the order of 0.1 percent of the population. Considerations of minimal size of graduate programs of high quality thus imply that, in general, a graduate institution in science and engineering must draw most of its students and much of its financial support from a total population of not fewer than about

Figure 6

GRADUATE ENROLLMENTS AND DOCTORATE AWARDS IN SCIENCE AND ENGINEERING

Distribution of States (Academic Year 1964-1965)

Graduate Enrollments per 100,000 Population (U.S. Average = 96)	PhD Awards per 1,000,000 Population (U.S. Average = 57)				
	1 - 18	19 - 56	57 - 89	90 - 134	135 or Greater
158 or Greater			Arizona	Colorado Delaware Utah	Massachusetts
125 - 157		New Mexico	California Kansas New York Oklahoma	Rhode Island	
97 - 124		Wyoming	Connecticut Maryland Oregon Washington Wisconsin	Indiana Iowa	
74 - 96		Hawaii Louisiana Missouri New Hampshire New Jersey North Dakota Ohio Pennsylvania Texas	Illinois Michigan Minnesota		
41 - 73	Alabama Idaho Nevada South Dakota Vermont West Virginia	Florida Georgia Montana Nebraska Tennessee Virginia	North Carolina		
1 - 40	Arkansas Kentucky Maine Mississippi South Carolina	Alaska			

Source: Derived from data from the 1960 Census and Office of Education (DHEW).

Figure 7

GRADUATE ENROLLMENTS AND DOCTORATE AWARDS IN SCIENCE AND ENGINEERING

Distribution of 55 Metropolitan Areas (Population 500,000 or Greater) (Academic Year 1964-1965)

PhD Awards per 1,000,000 Population (U.S. Average = 57)

Graduate Enrollments per 100,000 Population (U.S. Average = 96)

	0	1 - 29	30 - 56	57 - 113	114 or Greater
195 or Greater					Albany * Boston * Columbus Denver Minneapolis * Oklahoma City Sacramento San Francisco * San Jose Seattle Syracuse Washington
96 - 194		Akron Dallas	Atlanta Honolulu Jersey City New York Philadelphia Phoenix	Los Angeles * Pittsburgh Providence * Rochester	San Diego
47 - 95	Dayton San Antonio Toledo	Detroit Fort Worth Hartford Milwaukee Newark San Bernardino*	Buffalo Cincinnati Houston New Orleans St. Louis	Baltimore Chicago Cleveland	
1 - 46	Anaheim * Birmingham Indianapolis Memphis Paterson * Portland, Ore. San Juan	Louisville Miami			
0	Gary * Norfolk * Tampa * Youngstown*				

*Standard Metropolitan Statistical Area includes other cities.
Kansas City omitted because of insufficient information.

Source: Derived from data from the 1960 Census, the Bureau of the Budget, and the Office of Education (DHEW).

350,000 persons, and that a substantially larger base is much to be preferred.

(c) The potential contribution of the proposed program to meeting the economic, social, and cultural needs of the community, State, and region within which it would be located.

There is a PhD-granting institution in every State of the Nation. Some of these institutions are of subminimal quality and are seriously in need of strengthening. In addition to the further development of these institutions, and as a norm, strong graduate programs should be established in all metropolitan areas anticipated to have a population in excess of 500,000 in 1980.

In planning the establishment and development of graduate programs, the existence of other educational resources (colleges or universities, museums, research institutes, hospitals, etc.) in the environment of the institution should be considered and full cooperation among such institutions should be encouraged.

Many of the Nation's large graduate institutions have attained or are approaching a size beyond which they are likely to grow relatively slowly. Accordingly, the expected growth of the national graduate student body must occur largely in the smaller graduate institutions that exist today and in the new institutions to be created during the decade ahead. IT IS PRECISELY THIS PATTERN OF GROWTH, OUTSIDE OF PRESENT MAJOR INSTITUTIONS, WHICH WILL CONSTITUTE THE PRINCIPAL MEANS AND THE OPPORTUNITY FOR ACHIEVING A "MORE EQUITABLE DISTRIBUTION OF FEDERAL FUNDS."

VI

Recommendations to the Federal Government

The firm commitment of the Federal Government to the continuing, albeit partial, support of primary and secondary education, and of higher education generally, has been expressed in relatively recent Congressional actions, although the interest of the Federal Government was manifest more than a century ago in the special legislation which made possible the Land Grant Colleges. Public primary and secondary education have, until recently, been considered the exclusive sphere of the States. Graduate education, although technically eligible under the terms of some of the principal legislation addressed to higher education, has been a relatively minor beneficiary of **direct** Federal educational support. However, through the multi-agency support of academic research, the Federal Government has **in fact** provided a proportionately larger measure of support for graduate education than for educational programs at other levels.

It is recommended that the Federal Government accept a continuing responsibility for a significant share of the total support of graduate education, to assist in the implementation of the national policy previously proposed. Such support should supplement and should encourage the support furnished by non-Federal sources, public or private.

This role of the Federal Government is appropriate for several reasons:

Graduate institutions are national resources. The graduate student body, especially at larger institutions and at the doctoral level, is drawn from a wide geographic area, frequently from the entire Nation, while the trained scientists and engineers provided by graduate education are also highly mobile and distribute themselves nationally as career opportunities warrant.

The increased understanding of man, of society, and of the universe, resulting from academic research that is principally

supported by Federal funds in response to national objectives, has wide applicability and is the property of all.

By virtue of its broad programs of research and development, the Federal Government, directly and indirectly, is one of the largest single users of the services of graduate scientists and engineers.

The maintenance of an adequate supply of well-prepared teachers of science and engineering for service at all educational levels is a matter of national concern. Characteristically, such teachers require a graduate experience leading to the master's degree or the doctorate.

The Federal Government is in a special position to redress geographic imbalances and to provide assistance for the development of graduate programs to benefit communities and regions that could not, initially, support such efforts through local funding.

There is a rapidly increasing disparity between the financial resources of most institutions of higher learning and the expectations of American society. While these expectations will make graduate education the most rapidly growing segment of American education during the next decade, neither the voluntary contributions of private philanthropy or industry, nor local and State appropriations, nor other conventional sources of institutional income, will suffice to support the growth and rising costs of this endeavor at a level commensurate with the national need. Indeed, non-Federal resources will be hard pressed to finance education at lower levels and, increasingly, will find it difficult to support graduate education which, while embracing fewer students than any lower educational level, is necessarily **per student** the most expensive form of education. Accordingly, the needs of the future can be met only if the Federal Government accepts the role here proposed.

There is, however, a patent need for the development of a new and different approach to the Federal funding of graduate education than has prevailed in the recent past. Existing patterns have certainly served an important function in the development of American science since World War II. But, quite apart from the present budgetary uncertainties in the many Federal agencies involved, these patterns will not assure healthy and balanced development

of graduate education during the years of expansion ahead. These patterns had their origin in the nominal support of academic science during the early postwar period. Today, while Federal agencies, quite appropriately, must defend their budgets in terms of relevance to their primary missions, graduate education, now heavily dependent upon support from these agencies, must respond to forces unrelated to decisions concerning national educational needs.

It is important, to be sure, that sufficient total funds be available for the institution to improve its quality, to develop its programs, and to provide for the growing needs of graduate education. Equally important, however, is the manner in which these funds are made available. It is not enough for these funds to appear as "income" in financial statements. There must also be assurance that such funds will contribute to the institution's ability to exercise full responsibility for its organization and operations, including the salaries of the faculty, financial support for its graduate students, and the general administration of both the research and instructional elements of the graduate enterprise. The manner in which these funds are provided should encourage the autonomy of the institution to plan its programs, establish its priorities, and determine its response to opportunities for public service, national or local. Yet the present highly fragmented support system permits neither the full assumption of these responsibilities nor a sound basis for reasonable planning.

Accordingly, in order to provide a better basis for the future of graduate education in the sciences and engineering, the following recommendations are offered:

FEDERAL SUPPORT OF GRADUATE EDUCATION

The Federal Government should recognize and support graduate education in the sciences and engineering in American colleges and universities as a distinctive educational process. Such Federal support should be administered separately from those programs which support primary, secondary, vocational, and other forms of education.

Federal support should supplement, not replace, non-Federal sources of funding.

Support of graduate education should receive, in its own name, specific appropriations from the Congress.

Graduate programs of high present or potential quality should be supported in educational institutions, public and private, that offer either the master's degree or the doctorate as the highest degree.

General recognition should clearly be given to the important role played by institutions of various types within the total structure of graduate education in the United States. The spectrum extends from major universities offering both master's and doctoral level training in almost all disciplines to the large number of colleges with master's degree programs in relatively few disciplines, all of which contribute to the Nation's supply of research and professional personnel, teachers, and others who increasingly require a sound preparation in the sciences and engineering. All of these institutions should be eligible for support from the programs to be described below.

In addition, a vital service is also performed by the many 4-year colleges across the United States which, collectively, provide a significant fraction of the Nation's future graduate students. Although the recommendations below are not strictly applicable to these colleges, since they do not offer graduate programs and most of them do not engage in extensive research activities, nor to the undergraduate divisions of universities, it is nevertheless clearly in the national interest that these colleges and undergraduate divisions be supported and encouraged to continue to make their important contribution. While outside the scope of this report, appropriate programs of Federal support should be developed to assist colleges and universities in maintaining and improving the quality of their undergraduate educational endeavors.

ADMINISTRATION OF FEDERAL SUPPORT

Federal administrative procedures should protect the autonomy and integrity of educational institutions by supporting graduate education and academic research in the sciences and engineering as closely related processes.

Recognition of the complementary and inseparable character of most research and instruction at the graduate level

should be incorporated in administrative procedures. The financial support of a research project should be treated as a restricted fund made available to the institution in connection with its on-going activities, not as the negotiated price for a contract service.

Federal procedures for the support of graduate education should not dictate the accounting practices or procedures of colleges or universities. Since fund accounting, as distinct from the determination of the cost of a product or service, is characteristic of an educational institution, audit should be limited to a determination of responsible handling of available funds.

MECHANISMS OF FEDERAL SUPPORT

A pattern of support by the Federal Government that would be appropriate to national needs for graduate education in the sciences and engineering would be assured by the establishment and adequate funding of the six grant programs to be described below. In each program, the decision to make an award and the establishment of the amount thereof should rest on considerations of current or potential quality, the magnitude of the activity in question, and the opportunity it affords. As a general principle, such decisions should be made with respect to the largest organizational unit concerning which a qualified group of external examiners can make an assessment of quality appropriate to the purposes of the scientific program. This unit, then, may be the college or university, a division or school, a department, or an individual professor or student.

Prototypes of all of the six grant programs, proposed below, do, in fact, exist at the present. The recommendations, therefore, should be interpreted as being addressed to the purposes, concept, composition, relative magnitude, and administration of these programs.

1. INSTITUTIONAL SUSTAINING GRANTS

To provide a financial platform for programs of graduate education, and to assure that institutions so engaged can meet their faculty salary commitments and provide the diverse services essential to the complexities of modern academic research and graduate education, IT IS RECOMMENDED THAT THERE BE INAUGURATED A SUB-

STANTIAL PROGRAM OF INSTITUTIONAL SUSTAINING GRANTS.

This program would provide an annual award, **on a formula basis,** for the support of graduate education in the sciences and engineering. Although some funds are provided through institutional grants, no entirely comparable program is presently administered by a Federal agency, whereas funds which are in fact utilized for these purposes are today made available to graduate institutions largely by way of the payments for faculty salaries and indirect costs included in tens of thousands of research grants. Indeed, the aggregate of such payments in fiscal year 1966 exceeded $400 million, but the institutions involved cannot organize or plan for an enterprise of this magnitude under present funding arrangements.

The grant should supplement other forms of institutional income and, to the extent feasible, should provide an incentive to the institution to increase its income from non-Federal sources.

The amount of each grant should be determined by the application of uniform principles, applicable to all educational institutions. The formula used in making this determination should explicitly include factors that correlate with quality, as well as factors that recognize the type and magnitude of the graduate education endeavor in each institution.

Because the graduate educational endeavor usually is not organizationally separate and distinct within the educational institution, and because of complexities in the nature of funds available to the institution, a specific formula is not proposed within this report. Instead, it is recommended that a commission be established at an early date, consisting of representatives of the Federal Government and of the universities and colleges, to determine the formula most appropriate to this type of grant. If this program is to be maximally effective, provision should be made to permit adjustment of the formula as experience warrants.

The funds provided by this grant should suffice for the payment of appropriate faculty salaries, for those general institutional expenditures related to graduate education, particularly expenditures that are currently included in "in-

direct cost" payments in research grants and contracts, for perhaps 10-15 percent of all graduate student stipends to be made available to the university from Federal funds, and for assistance in the inauguration of new graduate educational endeavors.

In the simplest form of transition to the grant system here considered, the institutional grant would substitute for ALL payments of academic year and summer salaries of members of the continuing faculty, presently included in research grants and contracts, since, as a basic principle, SUCH COMPENSATION SHOULD DERIVE ENTIRELY FROM FUNDS AT THE DISPOSAL OF THE COLLEGE OR UNIVERSITY. However, the salaries of senior scientists who are appointed to the staffs of large scientific projects, including those in contract research centers, should continue to be funded through the grants and contracts that support such projects, even though these scientists also hold, albeit secondarily, appointments on the academic staff.

Although the AMOUNT of the grant, determined by formula, would be intended to be adequate to cover the types of expenditures, related to graduate education, indicated above, the grant itself should constitute an UNRESTRICTED FUND. The institution should retain full freedom to determine the detailed disposition of this fund. It would thus be available, as unrestricted current-fund income, for the financing of all of the educational and research endeavors of the institution.

This report is addressed to the distinctive problems, needs, and importance of graduate education. At the same time, the significance of the baccalaureate colleges and of the undergraduate divisions of universities cannot be overstressed. The financial support of graduate education and of undergraduate education must be mutually strengthening. The Institutional Sustaining Grant, as here proposed, avoids the erection of artificial barriers between the two. It would be wholly appropriate for a corresponding institutional grant program to be developed, responsive to the distinctive needs of undergraduate education. In this event, an augmented institutional sustaining grant, combining the two, should properly be considered.

2. DEPARTMENTAL SUSTAINING GRANTS

The functional unit of graduate education is the disciplinary department, or in some cases, the organized, cohesive, multidisciplinary program. Although the graduate student usually undertakes significant study in specialized areas of other departments, his intellectual life occurs principally in the environment of the department of his major interest. As noted earlier, it is the department which is the unit that must exceed a certain critical size if it is to be genuinely effective, it is also the organizational unit that retains the primary initiative and the flexibility to alter its structure and curriculum. At the same time the department is the largest educational unit of the institution concerning which an external peer group can render a meaningful qualitative judgment. Such a judgment, while influenced by considerations of administrative effectiveness, the organization of supporting services, availability of facilities, etc., is heavily dependent upon the sum of judgments concerning the individual members of the faculty, just as any attempt to judge a university depends upon the sum of judgments concerning individual departments. It is the department which is the graduate training unit.

Each type of department has evolved its own style of life. In a general way, this style is similar among corresponding departments in almost all institutions, while great differences may arise among departments in the natural sciences, the social sciences, mathematics, the arts, the humanities, or engineering. In turn, these differences reflect the great diversity of requirements among different disciplines for effective graduate education. Moreover, within a given institution there are frequently great differences among departments in both their intrinsic quality and their graduate training capacity.

> Accordingly, IT IS RECOMMENDED THAT THERE BE ESTABLISHED A SUBSTANTIAL PROGRAM OF DEPARTMENTAL SUSTAINING GRANTS, which would be responsive to the specific needs and requirements of individual graduate departments or organized multidisciplinary programs, so as to maximize their potential for graduate education and its associated research.

Such grants should be awarded in national competition with due regard for the size and quality of the faculty, the organized pro-

grams of graduate study, the previous training record, applications for graduate study, appropriate physical resources, and the amount and nature of project grant research support of the department. Awards should be made as reasonably long-term commitments, recognizing the university's plans for future growth of the department or interdisciplinary program. Included within such awards would be the Federal contribution to most graduate student stipends, special equipment required by the department, the research needs of young investigators during the first few years following their appointment to a faculty, and those general expenditures associated with on-going educational and research programs that maintain and improve the intellectual position of the department. The need for and utility of such a program is evident in the fact that almost $400 million was transferred, via the research project grant system, from the Federal Government to the universities in fiscal year 1966 to be used for the purposes to which Departmental Sustaining Grants are intended. However, it was conveyed in tens of thousands of individual transactions.

The Departmental Sustaining Grant might well serve as the principal research support instrument for those disciplines which have little requirement for experimental laboratories, e.g., mathematics, political science, or theoretical physics, since virtually all other requirements would be provided through the Institutional Sustaining Grant. Moreover, support in this form may be more appropriate to many aspects of the social sciences and of the humanities than is the project grant. Members of the university faculty and their students should have the opportunity to address themselves to those relevant questions which are readily amenable neither to quantification nor to verification, viz., matters of standards, morals, and ethics, as they should also concern themselves with prickly social questions the answers to which may make those who support these efforts temporarily uncomfortable. In the long term society must understand itself if it is to succeed. Inquiry of this sort should not be prejudged except for the professional qualifications of those so engaged. In considerable degree, such investigation can be supported through the Departmental Sustaining Grant, which permits maximum freedom of inquiry.

Appropriate forms of such grants should be used to support multidisciplinary programs of research and education

(e.g., neurobiology, materials sciences, or atmospheric sciences), to stimulate combinational curricula of an applied and professional character (e.g., sociology and transportation engineering, or electronics and business administration); and the special operating costs of departmental libraries and computer installations.

When fully funded, the Departmental Sustaining Grants would provide for the largest single fraction of all graduate student stipends. Additional contributions to graduate student support should continue to come from institutional funds appropriated for undergraduate education (e.g., teaching assistantships), special fellowships, and, when particularly appropriate, from research project grants.

3. DEVELOPMENTAL GRANTS

To assist with relatively non-repetitive, large scale expenditures required for (a) establishment of new institutions planning programs of graduate education, (b) inauguration of new graduate programs in existing institutions, (c) significant strengthening or expansion of on-going programs, or (d) the development of cooperative programs involving groups of graduate institutions, IT IS RECOMMENDED THAT THERE BE ESTABLISHED A SUBSTANTIAL PROGRAM OF DEVELOPMENTAL GRANTS.

Such grants may thus be directed toward increasing the number of truly outstanding graduate institutions, toward sustaining the quality of large middle-grade institutions, or toward capitalizing on special opportunities for improving newly emerging institutions, or toward achieving economies of scale in the utilization of scarce resources. These grants should be awarded on the basis of national competition with due regard for existing quality and the potential for significant improvement.

Consideration of an institution for a developmental grant should include several factors:

(a) Evidence of need for the graduate program proposed, a realistic plan for the provision of needed resources on a continuing basis, and commitment to develop a program of significant size, scope, and quality.

(b) In the case of a new institution, consideration should be given to the location proposed. If there already exist similar graduate programs in the community, State, or region, consideration should be given to existing capacity, measured in terms of population and resources, as well as the need to support another.

(c) Evidence of support of the developmental plan by relevant State, local, or private organizations.

(d) Evidence that the developmental plan is consistent with the normal characteristics of healthy growth of programs of high quality, that is, growth as opportunity, recruiting, and circumstances permit.

4. GRADUATE FACILITIES GRANTS

To help provide the facilities necessary for a graduate program of high quality, including libraries, research and teaching laboratories, and other special facilities, or, occasionally, large-scale facilities, such as specialized libraries or computer centers, to be held in common by groups of institutions, IT IS RECOMMENDED THAT THERE BE ESTABLISHED A SUBSTANTIAL PROGRAM OF GRADUATE FACILITIES GRANTS. The physical plant of institutions currently engaged in graduate education is almost saturated. If the national need and expectation is to be fulfilled, this plant should be almost doubled by 1980.

Space and occupancy standards should be established that will permit the determination and appraisal of institutional needs for facilities on a uniform and common basis.

Requirements for matching funds should be established, in accordance with uniform criteria, through the coordinated procedures of Federal agencies specifically authorized to support graduate education in the sciences and engineering.

The special importance of libraries for graduate education implies that the acquisition of books and periodical collections, as an initial capital item, should appropriately be included as part of the total cost associated with a Graduate Facilities Grant for a new library.

Assistance with residential or other auxiliary and self-liquidating facilities should continue to be provided by Federal loans through existing programs.

Major research installations, involving complex and expensive equipment that is unique or nearly unique, installations that are generally interpreted as being those of "big science," should be undertaken primarily for scientific reasons, rather than for education, and should be funded from appropriations specifically designated for research. Such facilities, regardless of their location, should be regarded as national assets. When located on a university campus, the faculty and students of the institution responsible for the continuing operation and maintenance of the facility, quite appropriately are entitled to a substantial fraction of the total opportunity for its use. In addition, however, the facility should be available for the use of graduate students and faculty of colleges and universities generally for a large fraction of total time.

5. GRADUATE FELLOWSHIPS

The national competitive fellowship is among the oldest and best established forms of support of graduate education. Historically, such programs have set standards for graduate education and for graduate student performance. Receipt of such a fellowship by an undergraduate at a liberal arts college that does not engage in graduate education has frequently served to enhance the morale of students and faculty, and it serves to provide recognition of their accomplishments and the quality of their endeavors.

ACCORDINGLY, IT IS RECOMMENDED THAT THERE CONTINUE TO BE FUNDED A RESTRICTED PROGRAM OF GRADUATE FELLOWSHIPS, OF THE ORDER OF 1 TO 2 PERCENT OF THE FULL-TIME NATIONAL ENROLLMENT IN GRADUATE SCHOOLS.

Such a prestige fellowship should provide a stipend significantly greater than those that would be normally made available through Departmental Sustaining Grants.

Additional awards, also based on national competition, should be made in the form of both junior and senior post-

doctoral fellowships in recognition of the important place of the postdoctoral experience in preparation for research and advanced teaching careers.

6. RESEARCH PROJECT GRANTS

The research project grant has been the principal mode of support of graduate education. Each award is based upon a quality competition and determination of scientific merit, and is made to an institution to assist a member or a group of members of the faculty in conducting a specific research project.

IT IS STRONGLY RECOMMENDED THAT FEDERAL AGENCIES CONTINUE TO MANAGE PROGRAMS OF RESEARCH PROJECT GRANTS. It is in the national interest that colleges and universities with graduate programs should be engaged in fundamental research as well as research that is relevant to the solution of national problems. The corollary is equally valid: The support of academic research by Federal agencies, which engenders numerous contacts between Federal and academic science, serves to strengthen the intrinsic capability of these agencies in the conduct of their own missions. Hence, all appropriate Federal agencies should continue to seek the assistance of educational institutions in the conduct of research that is related to their missions.

Support of academic research by Federal agencies, however, should be consistent with and should contribute to the character of the graduate educational process. In particular, such support should not require an orientation of the institution away from its central function.

Were the other programs, described above, in force and adequately funded, there would remain unsatisfied needs for special equipment, salaries of persons employed specifically for the research proposed, travel, publication costs, computer time, consumable supplies, and minor equipment specifically required for the work. All would be eligible for inclusion in the revised Research Project Grant program.

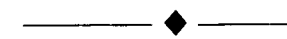
Only the direct expenditures involved would be included in this type of grant. Indirect expenses, the salaries and stipends of faculty and students, some major items of equip-

ment used communally by the department, and the normal expenditures of the department would be provided by the other types of grants recommended above.

Although the fraction of all funds in support of graduate education to be provided as Research Project Grants would be markedly diminished, they would not diminish in significance. There is no intention in these proposals to remove from the individual investigator his authority to determine the specific uses of his research funds or to reduce his freedom to seek the funds needed for his creative work. But he should not be obliged to secure funds for his own salary, or for the support of his students, storeroom keeper, or dean, in order to assure the continuity of the institution itself. Moreover, in some disciplines and especially in the experimental sciences, as a major indicator of the quality of its endeavors, the success of a department or faculty group in securing such funds in open competition would be among the most significant criteria to be employed in reaching decisions concerning the first four categories of awards.

These six grant programs are addressed to the graduate education of the individual and his preparation, as a highly trained scientist or engineer, to serve society. If these goals are to be achieved, the instruction of the student must occur within the *milieu* provided by the engagement of the institution in significant research of high quality. In many disciplines, the specific support of individual research projects provides perhaps the best available means for continuously monitoring the quality of the research endeavor, viz., limiting support to that research deemed worthy by a jury of competent peers.

At the same time, the Research Project Grant program provides a device for funding first quality research in its own right, even in those instances where the educational involvement is relatively slight. **A major objective of the university, essential to the maintenance of the dynamic research environment of graduate education, is the pursuit of knowledge and understanding.** The Research Project Grant, as in the past, should be an important means to this end.



As noted above, important contributions to graduate education are also made by many baccalaureate institutions as significant sources of graduate students. In many instances, research of merit

is conducted within these institutions, although they do not offer graduate programs. Although outside the scope of this report, it is appropriate that a specific program be developed for the Federal support of such research.

COMPARISON OF CURRENT AND PROPOSED PATTERN OF FEDERAL FUNDING

If appropriately funded and utilized, these six grant programs would fulfill the proposed Federal role in the support of graduate education. They would further assure that funds would be made available through grant instruments designed to match the characteristic operations and needs of colleges and universities, providing stability and flexible opportunity where most appropriate.

The disparity between the proposed pattern of support mechanisms and that prevailing today, in which the bulk of support is provided through a single instrument, the research grant or contract, is illustrated in Figure 8. In this chart the amounts provided to the universities in fiscal year 1966 are shown, in programs equivalent to those **designated,** as well as the manner in which the same total amount would have been distributed were the six programs here proposed in force, and the funds utilized for the purposes for which they were actually used, in fiscal year 1966, but now allocated among the six proposed programs according to their actual manner of use. In constructing this chart, it was assumed that the use pattern of research funds from all agencies was similar to the experience of the National Science Foundation; faculty salaries and indirect expenses were then assigned to institutional grants, most student stipends to departmental grants, etc. Although this analysis is subject to substantial errors, nevertheless it strikingly reinforces the arguments, advanced earlier, in favor of restructuring Federal programs in support of graduate education and academic research.

The rationale of current operational support justifies payments for faculty salaries, student stipends, and indirect costs on the grounds that all are required for the performance of essential research. As indeed they are. The plan advocated in this report does not challenge this view but, rather, proposes also to provide for a substantial measure of stability, for opportunity for long term planning, for deliberate creation of strong graduate centers in previously deprived regions, and for strengthening of existing graduate pro-

NOTES TO FIGURE 8

(1) Includes estimates of the amounts of Institutional Grants (National Science Foundation) and General Research Support Grants (National Institutes of Health) that are applicable to graduate education, as defined in this report. Also includes the NIH Biomedical Science Support Program, as well as an estimated "cost of education" allowance of $2500 for each of approximately 30,000 recipients of Federal graduate student stipends.

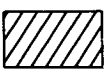
(2) Includes the NIH Training Grants, Institute of General Medical Sciences, and all Federal graduate student stipends other than competitive fellowships.

(3) Includes the NSF University and Departmental Science Development Program, and the NIH Health Sciences Advancement Awards.

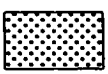
(4) Includes NSF and NIH competitive fellowship stipends, exclusive of the "cost of education" allowance.

(5) An approximate total based upon figures contained in "Federal Funds for Research, Development, and Other Scientific Activities," Volume XVI, NSF, 1967, adjusted for reconciliation with analyses of the Committee on Academic Science and Engineering (Federal Council for Science and Technology). Academic research support by NIH is included: (a) such support is not specifically applicable to medical education; (b) such support contributes to the graduate educational research environment of medical schools; and (c) the participation of both medical school faculty and postdoctoral students in graduate education precludes a realistic allocation of these funds to medical and graduate education respectively.

(6) This redistribution is based upon a detailed analysis of NSF basic research project grants for FY 1964. It is thus assumed that this analysis is characteristic of academic research grants generally.



Faculty salaries, indirect costs, employee benefits, and estimated direct costs applicable to the institution.



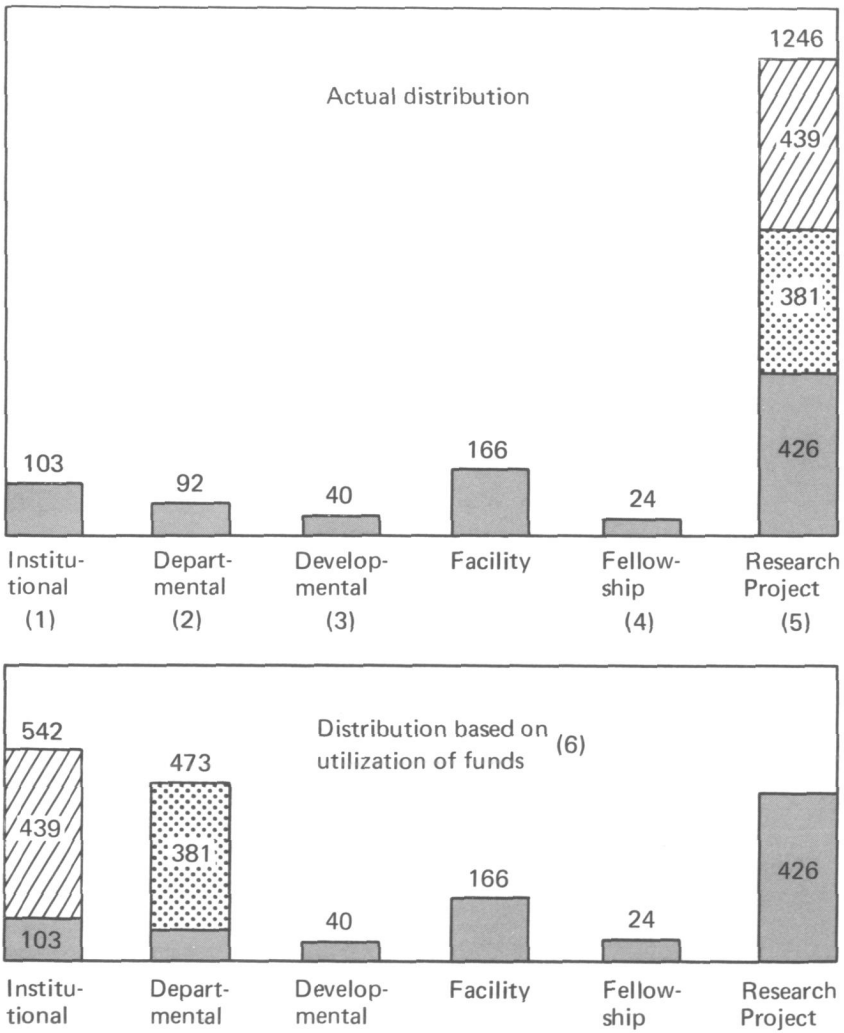
Research assistant compensation, and other estimated salary, equipment, and direct costs applicable to the department

Figure 8

FEDERAL SUPPORT OF GRADUATE EDUCATION FOR FY 1966

Comparison of (a) the distribution of funds among programs actually employed in FY 1966 with (b) the approximate distribution that would have resulted from the employment of programs suggested in this report and based upon the purposes for which these funds were utilized.

(Figures in Millions of Dollars)



grams and generation of new programs while removing from the present system its most serious disadvantages, particularly the payment of faculty salaries and student stipends from individual research grants. Moreover, the plan here described appears to be decidedly more suitable for those disciplines which do not require heavy expenditures for experimental laboratories than is the current research project grant system.

FEDERAL AGENCY AUTHORIZATIONS

The implementation of these recommendations necessarily raises questions as to the manner in which the Federal Government can best be organized to discharge its responsibilities in the areas of research and education. In any case, specific Federal agencies should be authorized to administer Federal support for graduate education in the sciences and engineering under the six grant programs proposed.

The following general pattern of authorizations is recommended:

(a) A single Federal agency should be authorized to administer the program of Institutional Sustaining Grants.

In the event of Federal support of professional education (e.g., medical), arbitrarily omitted from the discussion of graduate education in this report, it may be appropriate to consider the adoption of an institutional grant instrument, designed to include both the professional and graduate aspects of a single subdivision of the educational institution (e.g., a medical school), as well as other grants analogous to those proposed here. In this event, additional agency authorizations would also be appropriate. In the absence of the latter arrangement, programs of graduate education within appropriate departments of such professional schools should be eligible for support from the general Institutional Sustaining Grant.

(b) Several Federal agencies should be authorized to administer the Departmental Sustaining and Graduate Facilities Grant programs, as appropriate, depending upon subject matter involvement. The determination of

these agencies should be based upon their principal mission responsibilities and the role played by relevant research in their programs. Only a single agency, however, should be authorized to administer Departmental Sustaining and Graduate Facilities Grants for a specific academic discipline.

(c) The agencies identified under (a) and (b) above should be authorized to administer Developmental Grants. For broad programs of institutional scope (e.g., the establishment of a new graduate institution, or a broad program of institutional development), the appropriate agency would be that authorized to administer Institutional Sustaining Grants. For developmental programs of departmental or limited scope, authority should follow subject matter involvement, as provided above.

(d) The agency identified under (a) above should be authorized to administer the Graduate Fellowships program, including the graduate and the junior and senior postdoctoral awards.

(e) No special additional authorizations are recommended for the administration of Research Project Grants. The pattern of Federal agencies currently involved in the support of academic research should be continued. The nature of the proposed grant, however, requiring relatively smaller obligations per award, and with the basic institutional expenditures funded through institutional and departmental grants, would be anticipated to lead to increased diversity of Federal agency participation, as well as that of industry and local and State governments, in the support of academic research.

Provision should be made for effective program coordination among the agencies so authorized to ensure a reasonable degree of uniformity of practices and procedures and the avoidance of duplication.

In view of the urgency attending the development of graduate education in the United States and the rapidity of change that can be anticipated during the years ahead,

Congressional appropriation authorizations for all grant programs, other than Research Project Grants, should be made annually, in order to assure adequacy and currency of provisions for Federal support of graduate education.

THE TRANSITION

Had the Federal commitment to graduate education been recognized and acknowledged two decades ago, before the growth and multiplication of the Federal programs that now provide its principal support, inauguration of the six-grant plan here proposed could have been readily accomplished. Today, conversion from the great number and diversity of current programs to those proposed is, patently, complex and difficult. Accordingly, this plan should be regarded as a goal toward which the Government should move over a period of several years. In so doing, however, full recognition should be given to the importance of the sequence of steps through which complete implementation is achieved.

There are two prime considerations to be taken into account in planning the transition. (1) The magnitude and rapid growth of graduate education, foreseen over the next ten years, will require large increases of funding from all sources. **It is especially important that the Federal contribution to this major incremental funding be made within the framework of the proposed grant programs, rather than through the present system of research grants and contracts, thereby avoiding further magnification of the unfavorable aspects of the latter. It is thus urgent that the transition be made as quickly as possible.** (2) At the same time, care must be exercised to ensure that no institution is impeded in planning its future or maintaining the stability of its graduate programs by virtue of the transition itself. **As a first step, therefore, the Institutional Sustaining Grant program should be established, followed by the Developmental and Departmental Sustaining Grant programs. Each of these programs should be initiated, funded, and gradually expanded before attempting the formal restructuring of agency programs and appropriations implicit in the full operation of the plan.** In particular, this procedure would afford an opportunity to gain experience with the formula for institutional support and to modify it as necessary in order to meet the needs of both established and developing institutions.

IN ORDER TO MEET THESE OBJECTIVES IT IS STRONGLY URGED, AS AN ESSENTIAL FIRST STEP, THAT THE INSTITUTIONAL AND DEPARTMENTAL SUSTAINING GRANT PROGRAMS RECEIVE LEGISLATIVE AUTHORIZATION AT AN EARLY DATE AND THAT THE INITIAL APPROPRIATIONS FOR THESE PROGRAMS BE MADE NOT LATER THAN FISCAL YEAR 1972.

When full transition has been accomplished, both the institutions and the Federal Government will have acquired greater awareness of the problems discussed above, a fuller sense of their mutual obligations and responsibilities, and the necessary sophistication in managing these programs to achieve their desired goals.

VII

The Opportunity

The next ten years could prove to be the most difficult that graduate education has experienced during its history in the United States. In the number of citizens affected and in its importance to the goals of the Nation, graduate education must assume a role in education for tomorrow comparable to that of undergraduate education yesterday. The development of graduate education represents the maturity of the entire educational process. No arbitrary limits can be set for the American people in seeking education to their fullest capability. At the same time, the demands of society for the services of persons highly trained and proficient in the disciplines of modern science and technology will continue to increase.

If the task ahead is great, so too are the opportunities, provided that early planning, forthright action, and cooperative efforts are pursued by all individuals, groups, and organizations involved in this challenge. In undertaking this task America is fortunate in the strength that has already been brought to graduate education by the actions of the Congress and of the Executive Branch through the programs of Federal agencies. It is also fortunate in the outlook provided by the constructive work of State and regional planning groups, State governments, philanthropic foundations, and organizations of many types across the Nation. It is to assist in this common effort that this report has been prepared.

It is the firm conviction of the National Science Board that early policy decisions and definitive legislation are needed to implement the recommendations of this report and to ensure the strength of graduate education in the sciences and engineering in 1980.

Comments and Dissenting Views

Several members of the Board have expressed reservations on the desirability of the Departmental Sustaining Grants, particularly as a means of supporting a large segment of the graduate student population in a department. There is concern that the judgment of peers in evaluating the quality of a body as large as a department, particularly from the point of view of the department as an **educational** unit, may exercise an undesirable degree of control of the student body.

The strength of the grant system for the support of research is largely due to quality selection of individuals by their peers, irrespective of the strength or lack of strength of their colleagues. It is much more difficult and perhaps less meaningful to rate an entire department, and such "evaluations" may tend to be based on non-objective judgments influenced by out-of-date information. A collective rating of individuals in determining the degree of support a department is to receive would probably be better than an overall evaluation, although such a method of rating also has the weakness of not considering the department as an educational unit. If, on the other hand, an attempt is made to consider the educational function of the unit, what will happen to the unusual, the revolutionary, the new and the "non-conforming" departments? One might argue that there is a greater need for non-conformity in the make-up of departments than now exists, yet prejudice against non-conformity does exist, and many departments may attempt to conform to a successful norm, or a series of norms, bad as they may ultimately prove to be. A "well-balanced" but somewhat dull department may receive a higher rating and more student support money than a more brilliant group with an unusual but perhaps less popular bent.

It is also felt that a reasonably sensitive and quickly reactive mechanism is needed for the funding for student support. The faculty make-up or quality of a department can change rather rapidly, for better or for worse, yet its reputation may change rather slowly. This is particularly true if young and relatively unknown faculty members are taken on, yet it may well be that some of the "unknowns" figure most strongly in the educational functions of the department. We are concerned that the number of students that any

department may be able to support could be strongly influenced or controlled by an evaluation mechanism that tends to be out of phase with the current status of the department. Furthermore, the size of the student body in any university would in a real sense be affected by outsiders, removing a certain degree of freedom from the university. It seems to be an intrusion on the individuality and into the internal policy of universities if the Departmental Sustaining Grant mechanism as proposed is implemented.

Julian R. Goldsmith
Katharine E. McBride
Edward L. Tatum
F. P. Thieme

The Research Project Grant system has been very successful in promoting quality in Research and the accompanying Graduate Education. The progress of Science in the United States during the past two decades has been truly phenomenal and this progress has been due in large measure to the form of support it has received.

Perhaps one of the reasons the system has worked so well in promoting quality is that it has used the principle of peer judgment in determining who will receive support. This has insulated the decision from the sphere of local politics. In the case of support of very junior staff, the Department may be better able to make a judgment than a reviewer. In such cases, Departmental Sustaining Grants may be the best vehicle for giving support with the Department determining which of the young Ph.D.'s will get research support. However, in other cases, the quality evaluation of researchers by their peers, irrespective of the strength or lack of strength of their colleagues, may lead to a better selection on the basis of quality.

In some disciplines (Mathematics, Theoretical Physics) the salary component is the significant part of the Research Project Grant. If this portion were removed, the system would atrophy.

It is felt that the Research Project Grant system should remain a primary mechanism for supporting basic research in theoretical science in institutions of higher learning. I concur in the position taken in the report that regular continuing faculty even of schools with Institutional Sustaining Grants and Departmental Sustaining

Grants should be permitted and encouraged to participate in the new Research Project Grant system. If they are to participate in a meaningful way in situations where the salary component is a major portion of the grant, it should be permitted to charge the salary of even the regular faculty member to the grant for the period of time that he is working full time on the specific research project.

R. H. Bing

U.S. GOVERNMENT PRINTING OFFICE : 1969 O—328-298

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