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ABSTRACT

Long-range biomedical manpower needs up to 1985 have been projected and the best estimate indicates that there will be an increase from 64,000 workers in 1965 to 150,000 in 1985. The related expenditure is expected to increase from 1.9 billion dollars to 15.7 billion dollars in the same period. Alternate predictions, based on other possible economic policies, lead to different results. The methods used, and the assumption made, for each projection are discussed. The period from 1947 to 1967 is used for a base, and a comparison of similar projections made in 1961 with the actual figures up to 1967 demonstrates the utility of the model. The projections imply that there will be (a) a need to fully utilize Ph.D.'s research skills; (b) a decrease in the proportion of M.D.'s trained as clinical investigators; (c) continued need for expansion of National Institute of Health training facilities; and (d) a need to continue accelerating expansion of facilities and equipment for health research. Appendices tabulate the projections, define biomedical research, and list localities where graduate education is expected to significantly expand. (AL)

for MEDICAL RESEARCH

REPORT NO. 11 DECEMBER 1968

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

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Report No. 11
December 1968

RESOURCES
for MEDICAL RESEARCH

BIOMEDICAL RESEARCH MANPOWER – FOR THE EIGHTIES

Office of Resources Analysis, National Institutes of Health,
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

FOREWORD

The period immediately ahead presents challenges and opportunities unparalleled in American history. Advances in the character and quality of health care and the improvement of the health of American people through research will require accelerated expansion in the supply of health manpower for service, research, and education. This acceleration fortuitously coincides with the surge of 22-year olds seeking graduate and professional education and, subsequently, postdoctoral training and careers in medicine and related health professions. Meeting the challenge will demand: (1) Substantial expansion of existing institutions; (2) upgrading of weaker institutions with the potential of reaching excellence; and (3) the creation of 25 new medical schools and nearly 150 new graduate schools, about one-half of whom plan doctoral programs in the health sciences.

The future growth of health research is the cardinal determinant of the need for trained biomedical manpower. An effort to look ahead for two decades is speculative and necessarily tinged with uncertainty. Many as yet unforeseen forces are bound to influence the growth of biomedical research during this 20-year span. Some of these forces, like the 1965–1968 escalation in Vietnam, have depressed growth. As the outlook brightens, however, it is anticipated that the rate of advance of biomedical research will be accelerated, responsive to the health needs of the American people and taking full advantage of scientific opportunities. Recognizing the inevitability of peaks and valleys that will reflect the impact of such unique and specific circumstances, long-range projections of national biomedical manpower needs for research, teaching, and related service activities provide the most useful frame of reference for the development of plans for NIH training activities.

Four different methodological approaches have been utilized in developing alternate projections of long-range biomedical research manpower needs. First, because of the direct connection between dollar support for biomedical research and the utilization of scientific capability, alternative levels of the Nation's investment for biomedical research (1965–85) have been estimated, in terms of—

(1) continuation—at a diminished rate—of long-term secular growth in expenditures for biomedical research, in relation to the Nation's economic capability (GNP) and
(2) prolongation of the current (1967–69) constraints on the nondefense aspects of Federal programs.

To derive the estimated manpower for research, teaching, and related service activities, alternative dollar levels of support for biomedical research have been related to a projected expenditure per professional worker for each of the 5-year periods, 1965–70, 1970–75, 1975–80, and 1980–85, to derive estimated biomedical manpower needs.

An opposite approach has been taken by projecting the probable size of the labor force of highly trained manpower for research, teaching, and related service activities; in effect, this approach sets upper limits upon future manpower requirements.

In contrast to these two macro approaches, two appraisals have been made of biomedical research manpower needs at the micro level. Quantitatively, we have assessed the high priority functional staffing requirements to pinpoint specific biomedical manpower needs for—

(1) Staffing medical schools and other health professional schools,
(2) providing faculty for biomedical components of graduate schools and for advanced undergraduate education, and
(3) staffing specialized biomedical research centers in the national interest, e.g., cardiovascular research and training centers, eye research institutes, population research centers, environmental health research and training centers, and institutes for the study of aging.

Qualitatively, we have taken into account critical shortage categories such as bioengineering, behavioral sciences, environmental health sciences, clinical investigation, and the neurosciences.

The "best judgment" projection of manpower needs for the future is based upon continuation—at a diminished rate—of the long-term secular growth in support for biomedical research, in relation to the growth in GNP. The critical assumptions in making this projection are that:

1. The key factors influencing the growth of biomedical research are (1) the thrust and promise of science, (2) human needs and expectations, (3) population dynamics and the institutional base of biomedical science, and (4) economic capability.
2. The future cost per professional worker will continue to rise but at a slower rate than the experience of the past decade.

The implications of the projections are clear and call for action now to assure an adequate supply of highly trained biomedical manpower for the future:

1. By 1985, 150,000 professional workers will be needed for biomedical research, education, and related service activities.
2. Ph. D.'s will comprise a steadily increasing share of biomedical research manpower, with major increments from the behavioral sciences, engineering, mathematics, and the physical sciences.
3. The proportion of biomedical research conducted by industry will rise in consonance with the extensive utilization of systems analysis techniques and growing opportunities for development of end products which will improve diagnosis, therapy, and rehabilitation.
4. Staffing new medical schools and graduate schools and facilitating the sorely needed expansion of existing institutions constitutes a major foreseeable manpower need.

The conclusions presented in this report pose a host of broad policy issues:

1. What proportion of GNP should be devoted to biomedical research?
2. What measures will be most effective in changing the M.D.-Ph. D. biomedical research manpower mix?
3. What is the desirable level of Federal support of graduate and medical education to increase and to enrich supply during the next two decades?
4. Can we depend upon the market to attract nontraditional Ph. D.'s (behavioral sciences, mathematics, and engineering) into biomedical research or should we intervene with training programs tailored to induce participation during the formative period of graduate study?
5. What kinds of facilities will be needed, where, when, and what will they cost for:

    a. Teaching
    b. Research

All reports in the *Resources for Medical Research* series are prepared under the direction of Dr. Herbert H. Rosenberg, Director, Office of Resources Analysis, Office of the Associate Director, Program Planning and Evaluation.

Robert Q. Marston, M.D.
Director
National Institutes of Health

TABLE OF CONTENTS

TABLE OF CONTENTS—Continued

LIST OF TEXT TABLES

LIST OF TEXT TABLES—Continued

LIST OF CHARTS

SUMMARY

The future growth of health research is the cardinal determinant of the need for trained biomedical manpower. An effort to look ahead for two decades is speculative and necessarily tinged with uncertainty. Many as yet unforeseen forces are bound to influence the growth of biomedical research during this 20-year span. Some of these forces, like the 1965–68 escalation in Vietnam, have depressed growth. Recent changes in the Selective Service law and regulations may depress graduate enrollment and subsequent Ph. D. output over the short run. As the outlook brightens, however, it is anticipated that the rate of advance of biomedical research will be accelerated, responsive to the health needs of the American people and taking full advantage of scientific opportunities. Recognizing the inevitability of peaks and valleys that will reflect the impact of such unique and specific circumstances, long-range projections of national biomedical manpower needs for research, teaching, and related service activities provide the most useful frame of reference for the development of plans for NIH training activities.

Approaches to Estimating Biomedical Manpower Needs for the Future

Long-range biomedical manpower needs have been projected in this report following four different methodological approaches in relation to: (1) the probable course of fiscal capability, (2) high priority functional staffing requirements for the nonprofit sector, (3) probable size of the available labor force for biomedical research, and (4) critical manpower shortage areas.

First, because of the direct connection between dollar support for biomedical research and the utilization of scientific capability, alternative levels of the Nation's investment for biomedical research (1965–85) have been estimated, in terms of—

(a) continuation—at a diminished rate—of long-term secular growth in expenditures for biomedical research, in relation to the Nation's economic capability (GNP) and

(b) prolongation of the current (1967–69) constraints on the nondefense aspects of Federal programs.[1]

To derive the estimated manpower for research, teaching, and related service activities in 1970, 1975, 1980, and 1985, the alternative dollar levels of support for biomedical research have been related to a projected expenditure per professional worker for each of the 5-year periods, 1965–70, 1970–75, 1975–80, and 1980–85, to derive estimated biomedical manpower needs (See ch. III, pp. 35 ff).

Second, an assessment of the high priority functional staffing requirements for the nonprofit sector, 1967–75, has been developed to pinpoint specific biomedical manpower needs. The estimate yielded by this microanalytic approach compares closely with the "best judgment" projection for the nonprofit sector (See ch. III, pp. 50 ff).

Third, the biomedical research manpower for 1985 has been estimated from projections of the probable size of the available labor force of highly trained manpower for research, teaching, and related service activities (See ch. III, pp. 43 ff).

Fourth, another approach, only partially susceptible to quantification, has been the identification of critical shortage categories. Despite the lack of precise estimates, this approach should contribute to the development of NIH training plans and programs aimed at expanding the supply of biomedical manpower in these critical shortage categories (See ch. III, pp. 55 ff).

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[1] There is no inherent certainty about either of these divergent assumptions. Secular trends can be modified by future developments. While it seems unlikely that the current situation will be prolonged much longer, this assumption cannot be dismissed without appraising its probable implications.

Alternative Projections

The best judgment projection of manpower needs for the future for biomedical research, teaching, and related service activities is based upon continuation—at a diminished rate—of the long-term secular growth in support for biomedical research. This projection indicates that biomedical research manpower needs would increase from *64,000 in 1965; to 71,000 in 1970; 100,000 in 1975; 130,000 in 1980; and 150,000 in 1985.* The related expenditures for biomedical research (in 1967 constant dollars) would increase from *$1.9 billion in 1965, to $2.9 billion in 1970; $5.5 billion in 1975; $9.7 billion in 1980; and $15.7 billion in 1985.*

In making these projections, it has been assumed that expenditures (in 1967 constant dollars) per professional worker would continue to increase at the rate of 6 percent a year for the Government and nonprofit sectors and 7 percent a year in industry—the same rates experienced during the decade from 1954 to 1965. Rising expenditures per professional worker during the seventies and eighties will reflect the following factors: (1) Greater use of more complex, automated, and precise instrumentation and other costly research equipment; (2) the operation of large-scale population studies requiring use of computerized techniques; (3) greater involvement of technicians and supporting staff for the efficient conduct of research by the principal investigator and his collaborators; and (4) a higher proportion of more costly applied research and development. As a consequence, expenditures per professional worker in biomedical research are projected to increase from $30,000 in 1965; to $41,000 in 1970; $55,500 in 1975; $75,000 in 1980; and $105,000 in 1985 (expressed in 1967 constant dollars).

The austerity projection (alternative C) is based upon the assumption that the current (1968–69) stringent fiscal constraints may be prolonged indefinitely. Using the same methodological procedure, this assumption results in a steady drop in biomedical research manpower requirements from *64,000 in 1965; to 63,400 in 1970; 56,000 in 1975; 50,700 in 1980; and 44,000 in 1985.* This would represent a net reduction of 20,000 workers—almost one-third below the number engaged in biomedical research in 1965. The related expenditures for biomedical research (in 1967 constant dollars) would increase from *$1.9 billion in 1965; to $2.6 billion in 1970; $3.1 billion in 1975; $3.8 billion in 1980; and $4.6 billion in 1985.*

In the decade from 1957 to 1967, medical research expenditures trebled as a proportion of GNP; the best judgment projection is based on a trebling in *two* decades, 1967–1985. Conversely, the austerity projection posits no further increase in the allocation of resources for biomedical research, expenditures for biomedical research remaining constant as a proportion of GNP, 1967–85.

Factors Influencing the Growth of Biomedical Research

The key factors influencing the growth of biomedical research are:

1. *The Thrust and Promise of Science.*—The progress of science has revolutionized the range of diagnostic, therapeutic, and preventive capability available for medical and health services. It is anticipated that the prospect for even more revolutionary findings will compel greater and broader research efforts. This prospect is coupled with the urgent need for transforming both current and new information into diagnostic, therapeutic preventive technology, and the utilization of this advanced technology to improve the delivery of services (See ch. III).

2. *Human Needs and Expectations.*—Despite the enormous progress in medicine and health, the scientific base of knowledge and technology remains critically limited. At the same time, advances in the social, economic, and scientific capability of the nation have greatly accelerated public and private expectations that health problems will be diminished through further public action. These circumstances create a continuing condition of public demand for progress in both the science and practice of medicine.

3. *Dynamics of the Population and the Institutional Base of Biomedical Science.*—The first postwar birth cohort (1946) will reach age 22 in 1968. For that and subsequent years, there is the prospect of substantial increases in potential enrollment in graduate and health professional schools. As indicated in chapter II, (pp. 15 ff) the new Selective Service Act and regulations may channel these increases away from graduate schools into the Armed Forces. This trend will be reflected in pressure for increased graduate and professional educational capacity, through expansion of existing facilities and creation of new ones, with increases in faculty, resource, and support requirements. The Nation also faces critical problems in sustaining the vigor and stability of existing institutions and substantially upgrading the quality of the weaker and less capable components. At the same time, the Nation must meet urgent needs for the expansion of resources to (1) meet critical national objectives in health-related areas and (2) bring about a more equitable geographic distribution of the relevant educational resources and scientific capability. These dynamics represent the third set of forces playing upon the future directions and dimensions of the national biomedical research effort (See ch. III, pp. 28 ff).

4. ***Economic Capability.***—Medical research expenditures have trebled as a proportion of gross national product since 1957. If long-term trends in the relationship between national expenditures for biomedical research and gross national product are sustained, then biomedical research expenditures would probably increase by 11 percent per year for the next two decades appreciably below the 15-percent increase for the past two decades (1947–67) and the 16-percent increase, 1957–67.

Manpower for Biomedical Research, Teaching, and Related Service Activities

The number of professional workers engaged full or part-time in biomedical research rose from 19,000 in 1954 to 42,000 in 1960—more than a 100-percent increase. Between 1960 and 1965, the number increased more than 50 percent to 64,000—an additional 22,000 professional workers in biomedical research and related activities. The dominant characteristics of this growth can be summarized briefly:

1. The largest increase has taken place in universities and research institutes;
2. The number engaged full-time in medical research has been rising, and those working part-time are devoting a larger share of their energies to research;
3. Participation of Ph. D.-trained manpower in the basic medical sciences has been rising rapidly, accompanied by the growing involvement in biomedical research of (1) the other biosciences, (2) the behavioral sciences, (3) the physical sciences, (4) mathematics, and (5) engineering;
4. Research opportunities combined with teaching and/or service responsibilities have become increasingly attractive to M.D.'s;
5. The underlying supportive force in this development has been the substantial enlargement of national programs for public and private support of research, research training, and construction of research facilities.

It should be emphasized that a large pool of trained manpower, cumulated through the depression and the war, was available for independent investigation at the end of World War II. Without this substantial pool of talent as a base, it would have been impossible to man the current national medical research effort. No such pool of underutilized talent is available for the future.

As summarized above, several approaches based upon divergent assumptions have been used to estimate biomedical manpower needs for the future, 1967–75, and the decade beyond. The results produced by these divergent assumptions (with one exception—indefinite prolongation of the current situation) lead to the same general conclusion: The supply of manpower for biomedical research, teaching, and related service activities must be enlarged substantially to meet the needs for:

1. Staffing the expansion of biomedical research;
2. Facilitating the enlargement of biomedical faculties in existing medical schools and health sciences programs of existing graduate schools;
3. Contributing to the upgrading of weaker medical schools and weaker health sciences programs in graduate schools;
4. Aiding in the creation of *25* new medical schools and *150* new graduate schools over the next decade;
5. Meeting high priority functional requirements between now and 1975 (See ch. III, sec. E);
6. Providing research-trained personnel for staffing the national network of regional medical programs;[2]
7. Developing manpower in critical shortage categories such as bioengineering, behavioral sciences, environmental health sciences, neurological sciences, clinical pharmacology, radiation therapy, anesthesiology, and diagnostic radiology.

[2] See *Report on Regional Medical Programs to the President and the Congress*, Public Health Service, Department of Health, Education, and Welfare, June 1967.

Outlook for the Future

In assessing the probable future magnitude of the Nation's biomedical research effort, these and alternative projections have been utilized as general guides. It should be emphasized, however, that the best judgment projections of $5.5 billion for 1975 and possibly $16 billion for biomedical research by 1985 are not set forth as goals or targets of this Administration. Nevertheless, in consonance with the Administration's emphasis upon planning, NIH has utilized the projections as a general guide for assessing the future magnitude of the Nation's biomedical research effort, taking full account of alternate assumptions, including indefinite prolongation of the current situation. The best judgment projection suggests that biomedical manpower requirements will reach 100,000 in 1975 and rise to 150,000 by 1985.

Meeting biomedical manpower needs for the future will require (1) full utilization of the research skills of Ph. D.'s in all fields, (2) a modest increase in the output of trained clinical investigators, with the likelihood that this group will decline as a proportion of all M.D.'s, (3) a substantial and continued expansion of NIH training activities, albeit through mechanisms which provide for the synergistic phasing of support for institutional development and formal training programs in the sciences and clinical specialties, and (4) a greatly accelerated expansion of facilities and equipment for health research.

Divergence Between Opportunity and Capability

The years immediately ahead present unparalleled opportunities for progress in biomedical research ultimately aimed at improving the health of the American people. At the same time, staffing requirements for the biomedical sciences will increase to (1) permit expansion of existing medical schools and biomedical components of graduate schools, (2) enable upgrading of weaker institutions, (3) provide faculty for newly created medical schools and graduate schools, (4) assure staffing essential for the operation of a national network of regional medical programs, and (5) expand the supply of manpower needed for specifically designated critical shortage categories.

Population dynamics, mirroring the coming of age of the post-World War II baby boom, provide the potential for an unprecedented enlargement in the resource base, 1968–1980. Experience demonstrates that Federal support for graduate education and postdoctoral training (1) enhances the quality of training, (2) assures that a higher proportion of graduate students complete training through the doctorate, and (3) significantly shortens the duration of training.

There is, however, a sharp divergence between these unparallel opportunities and the financial capability to provide the support necessary to maximize the output of doctoral trained manpower and the quality of training. The current situation, reflecting the growing involvement of the United States in Vietnam, has necessitated stringent fiscal constraints upon a wide range of domestic programs, including support for biomedical research and training in the health sciences. It is not possible to predict the duration of the current situation, although the outlook is far brighter today than it was 3 months ago. For fiscal year 1968 and probably for fiscal year 1969 there is a sharp divergence between diminished financial capability for support and the anticipation of steeply rising numbers seeking support for graduate and postdoctoral training in the health sciences.

I. SECULAR TRENDS IN GROWTH OF BIOMEDICAL RESEARCH

A. Biomedical Research—Funds and Performers, 1947–67

National support for the conduct of biomedical research in the two decades since the end of World War II has increased 25-fold, from $87 million in 1947, to a total of $2,280 million for 1967 (and $2,490 million for 1968). This support has made possible the investigations of an increasing number of highly trained and dedicated scientists using the research facilities of the Nation's governmental laboratories, institutions of higher education, hospitals, research institutes, and industry; principal investigators (and their chief collaborators) engaged in biomedical research in 1954 approximated 19,200; by 1965 they numbered 64,000.

What are the major factors that underlie this post-World War II commitment to biomedical research—exemplified by growth (1) in funds provided by all sectors of the economy for biomedical research, and (2) in the numbers of scientists turning their attention to the solution of problems in health through research?

It is recognized that a view of biomedical research in terms of dollar outlays provides no measure of the scientific significance of thousands of pioneering investigations aimed ultimately at improving the health of the American people; nor does it provide a true measure of the Nation's resolve to conquer disease and uplift the quality of human life. But this evaluation of past dollar trends provides a frame of reference for the presentation in chapter III on the possible future course of biomedical research expenditures; it also provides a base for one delineation of the Nation's requirements for professional manpower for biomedical research.

The factors providing the major impetus to the evolution and growth of biomedical research in the post-World War II period stemmed first, from the realization of the potentialities of a comprehensive, systematic, and large-scale research effort to conquer disease and disability. Secondly, advances in the medical and biological sciences during the war and postwar years made these fields ripe for intensive exploration. Thirdly, the country's economic capability was adequate to support the conviction that a significant part of the research resources of the Nation could be productively directed toward biomedical research. Fourthly, the Congress and the Executive Branch determined that progress in medical research should not be hampered by lack of funds for research, for training, or for the requisite physical facilities. Finally, and perhaps of greatest significance, the interest of the Nation's scientists, in all fields related to health, was stimulated and challenged by the prospects for careers in biomedical research.

The developments summarized above can best be quantified by a review of the trends in the postwar support of biomedical research, in terms of—

1. The relation to the gross national product—the proportion of the Nation's total resources devoted to the conduct of medical research, as an indication of the Nation's economic capability to support this activity.
2. The sectoral sources of the funds for biomedical research.
3. The sectoral performers of biomedical research.
4. The numbers of professional personnel—principal investigators and their chief collaborators—engaged in biomedical research.

B. Relation to GNP

Medical research is a part of the complex process using energy and human effort in the production of goods and services to meet the needs and wants of society. Over the past 20 years, biomedical research has emerged as a distinctly measurable portion of that process, in common with research and development activity in general. Since 1947, the conduct of biomedical research, measured in current dollar terms, has increased 18 percent a year (compounded); in the same period, gross national product—the market value of all goods and services produced in the Nation—increased 6 percent a year. Thus, biomedical research drew upon the Nation's resources in an increasing degree from an amount equal to four one-hundredths of 1 percent of GNP in 1947 to three-tenths of 1 percent in 1967. These trends are summarized in table 1.

TABLE 1.—Biomedical Research and Relation to Gross National Product, 1947–67

[In current dollars]

Year	GNP (billions)	Biomedical research	
		Amount (millions)	Percent of GNP
1947	$231.3	$87	.04
1948	257.6	124	.05
1949	256.5	147	.06
1950	284.8	161	.06
1951	328.4	175	.05
1952	345.5	197	.06
1953	364.6	214	.06
1954	364.8	237	.07
1955	398.0	261	.07
1956	419.2	312	.07
1957	441.1	440	.10
1958	447.3	543	.12
1959	483.7	648	.13
1960	503.7	845	.17
1961	520.1	1,045	.20
1962	560.3	1,290	.23
1963	590.5	1,486	.25
1964	632.4	1,652	.26
1965	683.9	1,841	.27
1966	743.3	2,050	.28
1967	785.0	2,280	.29

Source: *Gross National Product*, Department of Commerce; 1967 estimate—National Institutes of Health, based on first three quarters of 1967. *Biomedical research*—National Institutes of Health.

C. Sources of Funds for Biomedical Research, 1947–67

The widespread public recognition of the potentialities of medical research has stimulated public and private interests to provide the resources to further our knowledge and understanding of disease and disability. In our pluralistic society, the cooperation of diverse forces—Federal, State, and local governments, industry, private philanthropic foundations, voluntary health agencies and individual citizens—with a single objective has generated national support for science as an instrument in advancing the health of the American people.

In realization of the need for, and the capability of advancing the Nation's medical science and technology, all sectors of the economy steadily increased support for medical research (table 2).

Growth in Federal support.—The growing complexity, difficulty and costliness of research has required agencies of the Federal Government to provide a greater proportion of the Nation's resources for biomedical research, rising from less than one-third of the total support in 1947 ($27 million) to almost two-thirds by 1967 ($1,458 million). Congressional support for medical and health-related research has paced and stimulated the growth of the Nation's total capabilities, resources, and technical skills for research in this area. The American taxpayer, through the Congress, has provided funds not only for the programs of Federal agencies whose sole research mission is the advancement of medical knowledge, and whose programs are budgeted and justified on that basis, but resources are also provided for research which, although directly related to human health, is carried on primarily for the fulfillment of an agency's broader mission. Every Federal agency with a major research program contributed in some way to the advancement of medical knowledge; currently, 12 Federal agencies support research in the health sciences. Examples of mission-related health research are the support of life systems required for further explorations in space, elimination of health hazards in connection with the uses of atomic energy, maintaining safety standards in civil aviation operations, and promoting the health of the American people through improvements in nutritional qualities of agricultural products.

In summary, Federal support of medical research now constitutes a comprehensive and large-scale program designed to (1) combat specific diseases and health hazards, (2) provide the information required for the more effective performance of Federal agency missions, and (3) push back the frontiers of knowledge in the basic sciences related to medicine in the interest of advancing the health and well-being of the American people.

The increased levels of Federal support—and the evolution and growth of the grant mechanism for providing funds for research—has made possible the fruitful participation of the knowledge and research capability of investigators working

TABLE 2.—National Support for Biomedical Research, by Source of Funds, 1947–67

[Current dollars in millions]

Year	Source of funds				Percent of total		
	Total	Federal	Industry	All other [1]	Federal	Industry	All other [1]
Total (1947–67)	$16, 041	$9, 509	$4, 243	$2, 289	59. 3	26. 4	14. 3
1947	87	27	35	25	31. 0	40. 2	28. 7
1948	124	50	43	31	40. 3	34. 7	25. 0
1949	147	65	48	34	44. 2	32. 7	23. 1
1950	161	73	51	37	45. 3	31. 7	23. 0
1951	175	85	52	38	48. 6	29. 7	21. 7
1952	197	103	52	42	52. 3	26. 4	21. 3
1953	214	107	58	49	50. 0	27. 1	22. 9
1954	237	119	61	57	50. 2	25. 7	24. 1
1955	261	139	62	60	53. 3	23. 8	23. 0
1956	312	162	79	71	51. 9	25. 3	22. 8
1957	440	229	126	85	52. 0	28. 6	19. 3
1958	543	279	170	94	51. 4	31. 3	17. 3
1959	648	351	190	107	54. 2	29. 3	16. 5
1960	845	448	253	144	53. 0	29. 9	17. 0
1961	1, 045	574	312	159	54. 9	30. 0	15. 2
1962	1, 290	782	336	172	60. 6	26. 0	13. 3
1963	1, 486	919	375	192	61. 8	25. 2	12. 9
1964	1, 652	1, 049	400	203	63. 5	24. 2	12. 3
1965	1, 841	1, 174	450	217	63. 8	24. 4	11. 8
1966	2, 056	1, 316	510	230	64. 0	24. 8	11. 2
1967	2, 280	1, 458	580	242	63. 9	25. 4	10. 7
	Percent increase [2]						
1947–67	17. 7	22. 0	15. 1	12. 0	----------	----------	----------
1947–52	17. 8	31. 0	8. 2	10. 9	----------	----------	----------
1952–57	17. 4	17. 3	19. 4	15. 1	----------	----------	----------
1957–62	24. 0	28. 0	22. 0	15. 1	----------	----------	----------
1962–67	12. 0	13. 3	11. 5	7. 1	----------	----------	----------

[1] Includes private philanthropic foundations, voluntary health agencies, State and local governments, and contributions from other private sources.

[2] Annual compound rate of increase.

Source: National Institutes of Health.

in the laboratories of universities, medical schools, hospitals, and other nonprofit organizations, as well as a greater number of federally employed scientists. (A detailed description of the major Federal medical research programs, the historical setting, and the postwar evolution of these programs was presented in "Federal Support for Medical and Health-Related Research, 1947–1964", *Resources for Medical Research* Report No. 4, August 1963, PHS Publication No. 1068.)

Diversity of sources of support.—Federal agencies have provided a cumulative total of almost $10 billion for the conduct of medical research in the 1947–67 period, the dollar flow increasing at an average annual rate of 22 percent a year, from $27 million in 1947 to $1,458 million in 1967. Biomedical research activities financed by profit-making organizations have totaled cumulatively more than $4 billion since 1947, a 15 percent annual average growth from $35 million in 1947, to $580 million in 1967.

The manufacturers of ethical pharmaceutical products have been the predominant industrial performers of medical research, but in recent years the Nation's electronics, chemical, medical supply and related industries have also become more active in this field; in the current period, industrial sources provide almost one-fourth of the funds for medical research. An additional $2.3 billion for medical research, primarily from the volun-

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tary contributions of the American people through health organizations,[1] from the endowments of philanthropic foundations,[2] and other private gifts represent about 15 percent of the Nation's investment in medical research during the 1947–67 period. (Included in this total are funds made available by State and local governments, amounting to about $400 million cumulative in the postwar period.) The annual support for medical research from this sector increased from $25 million in 1947 to $242 million in 1967, about one-tenth of national support for medical research in 1967. In summary, funds for the support of biomedical research have increased each year since 1947, but the rate of increase in recent years has not equalled the advances of the fifties and early sixties.

D. Performers of Medical Research, 1947–67

While the Federal Government has been the single largest source of funds for medical research in the national schema of medical and health-related research, laboratories and clinics of the Nation's institutions of higher education are the largest performers of medical research. Together with those of other nonprofit agencies (hospitals, research institutes, State and local governments) they currently account for 53 percent, in dollar terms, of the medical and health-related research performed in the United States. With the growth, from 1947 on, in the grant mechanism for the Federal support of investigations of promise by independent scientists, the facilities of nonprofit institutions have increasingly become the site for the performance of biomedical research. Shortly after World War II, about two-fifths of all medical research was performed at nonprofit institutions; by 1960 this sector accounted for 50 percent (table 3).

Since 1957, federally owned research facilities have been the locus for less than one-fifth of the medical research performed in the United States. Although Federal intramural research has continued to increase, currently at about 12 percent a year, a growing proportion of Federal funds has supported the investigations of scientists in nonprofit institutions.

Industrially owned laboratories account for 30 percent of the medical research performed—a proportion of the total that has declined from the early postwar period, although there has been steady growth in funds allocated to this activity by the Nation's manufacturers of pharmaceutical products, of instruments for diagnosis and therapy, and of new biomedical materials. The medical research performed at industrially owned facilities is financed—80 percent—by the companies' own funds with one-fifth provided through contractual arrangements with Federal agencies for specific research and development tasks.

The distribution of funds for biomedical research among the several performers of that research is in marked contrast with the situation concerning the distribution of funds to meet national needs through R&D in areas other than the biomedical sciences. Industrial organizations claim almost 70 percent of the Nation's funds for all R&D, with the remaining 30 percent about equally divided between the science departments of nonprofit institutions (including institutions of higher education) and the laboratories of Federal agencies.

E. Biomedical Research Manpower, 1954–65

Between 1954, the first year for which consistent and comprehensive data are available, and 1965, the numbers of professional investigators engaged in biomedical research increased more than three times, from 19,200 to 64,000. In the same period, funds to support their work increased about eight times, from $237 million to $1,841 million. These trends are shown in chart 1. Expenditures per professional worker in biomedical research, obviously, have increased substantially over this period, reflecting the increasing costliness of research in terms of the more sophisticated equipment and techniques that are available now for explorations of new areas of scientific inquiry not possible heretofore, as well as the general increases in salary

[1] An analysis of the impact of voluntary health agencies on the evolution and direction of programs in the health sciences is presented in "Voluntary Health Agency Expenditures for Research and Research Training," *Resources for Medical Research*, Report No. 7, December 1965, PHS Pub. No. 1417.

[2] A review of the role of philanthropic organizations in medical research and education is presented in "Foundation Expenditures for Medical and Health-Related Research and Education, 1960," *Resources for Medical Research*, Report No. 2, November 1962, PHS Pub. No. 983, and "The Medical Research and Education Activities of Foundations and Nonprofit Research Institutes," *Resources for Medical Research*, Report No. 15, September 1968.

TABLE 3.—National Support for Performance of Biomedical Research, by Performer, 1947–67 [1]

[Current dollars in millions]

Year	Performer: Total	Performer: Federal	Performer: Industry	Performer: Nonprofit institutions [2]	Percent of total: Federal	Percent of total: Industry	Percent of total: Nonprofit institutions [2]
Total (1947–67)	$16, 041	$2, 807	$4, 898	$8, 336	17. 5	30. 5	52. 0
1947	87	17	36	34	19. 5	41. 4	39. 1
1948	124	23	46	55	18. 5	37. 1	44. 4
1949	147	30	52	65	20. 4	35. 4	44. 2
1950	161	35	55	71	21. 7	34. 2	44. 1
1951	175	40	57	78	22. 9	32. 6	44. 6
1952	197	49	58	90	24. 9	29. 4	45. 7
1953	214	51	65	98	23. 8	30. 4	45. 8
1954	237	53	67	117	22. 4	28. 3	49. 3
1955	261	64	69	128	24. 5	26. 4	49. 1
1956	312	74	86	152	23. 7	27. 6	48. 7
1957	440	90	136	214	20. 5	30. 9	48. 6
1958	543	104	187	252	19. 2	34. 4	46. 4
1959	648	121	209	318	18. 7	32. 2	49. 1
1960	845	138	280	427	16. 3	33. 1	50. 5
1961	1, 045	164	346	535	15. 7	33. 1	51. 2
1962	1, 290	215	384	691	16. 7	29. 8	53. 6
1963	1, 486	250	433	803	16. 8	29. 1	54. 0
1964	1, 652	272	479	901	16. 5	29. 0	54. 5
1965	1, 841	305	537	999	16. 6	29. 2	54. 3
1966	2, 056	342	626	1, 088	16. 6	30. 0	53. 1
1967	2, 280	370	690	1, 220	16. 2	30. 3	53. 5
	Percent increase [3]						
1947–67	17. 7	16. 7	15. 9	19. 6	----------	----------	----------
1947–52	17. 8	23. 0	10. 0	21. 0	----------	----------	----------
1952–57	17. 4	12. 9	18. 6	18. 9	----------	----------	----------
1957–62	24. 0	19. 0	23. 0	26. 0	----------	----------	----------
1962–67	12. 0	11. 5	12. 4	12. 0	----------	----------	----------

[1] Coverage is limited to conduct of research and development: support of other activities, such as research training or capital outlays for research facilities, is not included.

[2] Includes research performed at State and local government agencies, educational institutions, and foreign performers.

[3] Annual compound rate of increase.

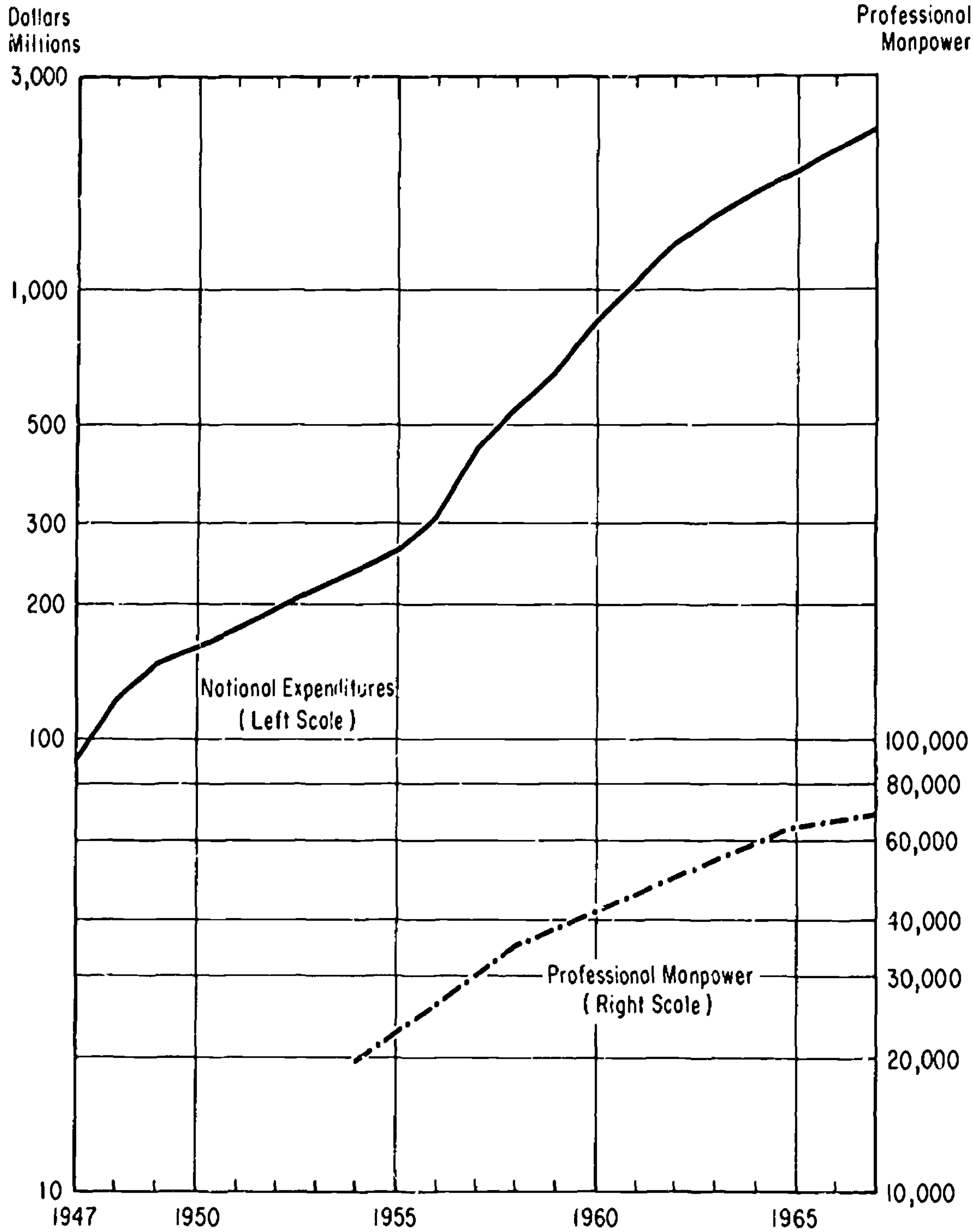
Source: National Institutes of Health.

levels that have occurred over the past decade. This increase in expenditures per professional worker is also a phenomenon of the greater participation in medical research of investigators at the doctoral level, as compared with the earlier period.

Comprehensive statistics on the numbers of principal investigators and their chief collaborators engaged in biomedical research, by level of training, and sector of employment (Government, industry, nonprofit institutions) are available for selected bench-mark years only. The estimates, based primarily on studies conducted or stimulated by the Resources Analysis Branch, Office of Program Planning and Evaluation, NIH, are summarized in table 4.

CHART 1

National Expenditures and Professional Manpower for Biomedical Research, 1947–67



Source: National Institutes of Health

RAB-OPP-NIH
May 1968

TABLE 4.—Scientific and Professional Manpower Engaged in Biomedical Research, by Sector and Level of Training, 1954–65

Item	1965	1960	1958	1954
Sector total	64,000	41,700	34,600	19,200
Government	11,800	7,800	6,900	3,700
Industry	11,900	9,200	6,500	3,400
Nonprofit institutions	40,300	24,700	21,200	12,100
Level of Training:				
Total	64,000	41,700	34,600	19,200
M.D., D.D.S., D.V.M.	17,000	11,600	10,000	(1)
Ph. D., Sc. D.	32,000	18,600	14,700	(1)
Less than doctoral (M.S., M.P.H., M.A., B.S., A.B.)	15,000	11,500	9,900	(1)

[1] Not available.

NOTE.—The data sources and statistical methodology underlying the derivation of the data for 1954, 1958, and 1960, were detailed in "Manpower for Medical Research, Requirements and Resources, 1965–70," *Resources for Medical Research*, Report No. 3, January 1963, PHS Pub. No. 1001. See app. B for derivation of 1965 estimates and 1960 revisions.

Source: National Institutes of Health.

II. THE CURRENT SITUATION

In contrast to the secular trend which depicts the steady growth of biomedical research over the past two decades, in recent years, we have witnessed a leveling off of the rate of growth of biomedical research. In addition there has been a (1) decline in Federal support for graduate education in the sciences, (2) one of the major non-Federal sources of fellowship support for graduate students has been liquidated and (3) the Military Selective Service Act of 1967 changed drastically the draft status enjoyed by graduate students for the past 15 years.

Probably one of the major forces influencing the allocation of limited resources between military and domestic programs was the growing involvement of the United States in Vietnam. Since 1964, the commitment of U.S. troops in Vietnam has mounted sharply from 21,000 to more than 500,000 at the present time. As a consequence the share of all Federal outlays allocated for military purposes rose from 52 percent in 1964 to 54 percent in fiscal year 1968. Military expenditures have risen $27 billion, increasing from $50 billion in 1964 to $77 billion in fiscal year 1968. To accommodate this substantial increase in the Federal budget, both the President and the Congress have endeavored to slow the growth of a wide range of domestic programs. The impact of these endeavors has been felt by all Federal agencies that provide support for academic science and graduate education.

A second force threatening the current situation is the Military Selective Service Act of 1967 [1] and its implementing Presidential regulations.[2] It had been anticipated that the number of graduate students would mount steeply in academic years 1968-69 and 1969-70, mirroring the post-World War II baby boom of 1946 and 1947. In October 1967, however, the American Council on Education predicted that:

"It would appear that unless changes are made by amending either the statute or the regulations, enrollment in the first 2 years of graduate and professional schools next fall will be limited to women, veterans, men physically disqualified, and those over the age of 25." [3]

The evidence is now abundantly clear that these dire consequences have thus far failed to materialize.

Less than a year ago it appeared not unlikely that the four factors characterizing the current situation might continue unaltered for the next 5 or even possibly the next 20 years. Recent events suggest a much more hopeful outlook. But what if the situation, grim and bleak as it appeared a few months ago, were to continue unchanged through 1980? What impact would this have upon requirements and supply of biomedical manpower for research, service, and education? If it is assumed that the "current" fiscal year 1968 situation were prolonged indefinitely, we could project the nadir of biomedical manpower requirements and supply for the period immediately ahead.

Four critical factors varying markedly from secular trends characterize the current situation.

A. Decline in Rate of Growth of Medical Research, 1967–69

The long-term trend in the growth of the Nation's investment for better health through research has been detailed in chapter 1. That discussion emphasized the leading role of the Congress and the Executive Branch in providing the resources to maintain and further biomedical investigations—on the broadest scientific front as well as those targeted to support specific missions and programs of Federal agencies. It was also emphasized that biomedical research has continued to attract the interest and significant contributions of funds from other sectors of the economy. To-

[1] Public Law 90-40.

[2] Executive Order 11360 signed June 30, 1967. *Federal Register*, July 4, 1967, 32-128, pp. 9787-9796.

[3] John F. Morse, Director of Commission on Federal Relations of the American Council on Education, in a Special Report to Member Institutions, Oct. 20, 1967.

gether, public and private support has increased at an annual rate of 18 percent a year, 1947–67, in current dollars; Federal funds alone at 22 percent a year.

However, this growth pattern has not been uniform over the last two decades. Within the long term pattern of growth (expressed in 1967 constant dollars to eliminate the effect of general price increases) of Federal funds of 20 percent a year, marked fluctuations have occurred when this average rate was exceeded, as new programs emerged, and scientific opportunities became ripe for exploitation, followed by other periods—some of national emergency, and others of program consolidation—when the rate of growth was considerably lower. Thus, the emergence of biomedical research, immediately after the end of World War II, as a large-scale Federal commitment, called forth a 100-percent increase in Federal funds between 1947 and 1949.

But the period of emergency that developed beginning in 1950 with the Korean conflict slowed the rate of these advances; in 1953, the terminal year of the Korean emergency, Federal support for biomedical research increased 3 percent over the sums provided in 1952. As the emergency period phased out after 1953, the rate of increase in research program funds was stepped up, strengthened further in the late 1950's by the national resolve to broaden the Nation's scientific capabilities in all fields, following the Russian success with Sputnik in 1957. For biomedical research, the annual rate of growth in Federal funds, 1953–57, was 18 percent, and 26 percent, 1957–62. While Federal support continued to increase each year during the next 5-year period, the annual rate of growth in Federal biomedical research dropped to 11 percent, 1962–67—less than one-half the rate of growth for the preceding 5-year period.

The Nation's growing involvement in Southeast Asia spurred a period of program consolidation. In the short term, the current years, 1968 and quite possibly 1969, will be marked by even more stringent budgetary constraints, necessitated by (1) mounting military expenditures and (2) the need for reducing the budget deficit. The Administration and Congress have emphasized the urgency of deferring nondefense aspects of Federal programs,[4] at the same time recognizing the need for maintaining—to some degree—program impetus and advances. While all the necessary directives have as yet not been stipulated in dollar terms, the net result may be a Federal biomedical research effort (in 1967 dollars) at a level for 1968 of about 6 percent above that of 1967; and in terms of the 1969 budget (presented to Congress in January 1968), a level for 1969 of about 4 percent over 1968.

The strength of the American economy is such that following this emergency period and our successful resolve in Vietnam, the national will and economic capability for advancing the well-being of the American people through progress in biomedical research will permit the resumption of long-term growth for this activity.

B. Decline in Federal Support for Graduate Education, 1967–69

Federal support for graduate education has been hard hit as a result of drastic changes in the political climate, stemming primarily from the need to slow the growth of "controllable"[5] civilian programs. Graduate school enrollments have been increasing at the rate of about 10 percent per year and are expected to exceed 330,000 in 1968 (although this estimate may be curtailed sharply as a consequence of the new Selective Service Act). The decline in Federal support between fiscal year 1966 and fiscal year 1968 would strike most severely at the number of first-year graduate students receiving stipend support under Federal programs.

Because of budgetary uncertainties, precise figures on Federal support for graduate education in the year ahead are not readily available. At this stage, the best estimate is that the propor-

[4] The Congress has accepted the Administration's proposal to reduce obligations below the levels presented in *The Budget of the United States Government*, fiscal year ending June 30, 1968, by passage of H.J. Res. 888, Dec. 12, 1967. In line with the Administration's proposal submitted to Congress on Nov. 29, 1967, as title II of the proposed Tax Surcharge and Expenditures Reduction Act, nondefense obligations for fiscal year 1968 will be held to:

(a) The amounts appropriated for fiscal year 1968, or
(b) The obligation estimates in the 1968 budget, reduced by: (1) 2 percent of the estimated amount for personnel compensation and benefits, and (2) 10 percent of the estimated obligations for other purposes;

whichever is less.

[5] The "controllable" civilian programs are delineated in the statement of Charles L. Schultze, Director of the Bureau of the Budget, before the House Ways and Means Committee on the President's Fiscal Program, Nov. 29, 1967.

tion of first-year graduate students receiving Federal support will be cut in half from 6 percent to 3 percent of full-time graduate enrollment. It has been estimated that the number of first-year graduate students receiving Federal fellowship or traineeship support will decline one-third—about 15,000 from fiscal year 1966 funds dipping to approximately 10,500 from fiscal year 1968 funds.[6]

The decline in Federal support coincides with the long-predicted surge in first year graduate enrollment, reaching a new peak, reflecting a similar peak in baccalaureates generated two decades ago by the post-World War II baby boom of 1946 and 1947.

In a recent interview,[7] Dr. Donald F. Hornig, Science Advisor to the President and head of the Office of Science and Technology, stated that:

> "There surely is no policy to cut back on graduate education. It is clearly recognized by everyone concerned that in an expanding technological society, and expanding society generally, every category of highly trained, highly talented persons is short."

In the same interview, however, Dr. Hornig also indicated that the general fiscal squeeze dictated cuts in university research support, which may continue through fiscal 1969.

Accepting this informed assessment that fiscal constraints are likely to continue through fiscal year 1969, it is possible that Federal support for first-year graduate students might dwindle even further as a proportion of total graduate enrollment in the 1969-70 academic year.

C. Phasing Out of Major Non-Federal Source of Support for Graduate Students

On April 9, 1967, the Ford Foundation announced that it was reducing its support of the Woodrow Wilson National Fellowship program. Under this program, approximately 1,500 graduate fellowships were awarded annually; it is estimated the number will decline sharply in the coming academic year to about 100 dissertation-type fellowships and 50 fellowships in Canadian universities. *However, the most drastic reduction will be the elimination of first-year graduate fellowships, which have approximated 1,000 per year.*

In announcing the curtailment of this fellowship program, the Foundation pointed out:

> "No Federal funds were available for graduate work in the humanities and the social sciences when the Woodrow Wilson program began; some 3,000 Federal fellowships a year are now awarded in these fields."

Six months later, the number of new fellowship awards in all fields funded by the Office of Education, under title IV of the NDEA program, was reduced nearly 50 percent, from 6,000 in 1966 to an estimated 3,325 in 1968. New fellowship awards in 1966 in the humanities, social sciences, and education together accounted for about three-fifths of the 1966 total; about 600 more than the total new awards for fellowships in all fields estimated for 1968.

If the same proportions continue for 1968, then awards in the humanities, social sciences and education will be reduced 50 percent below the 1966 level, to a total of about 1,500 to 2,000.

Simultaneously with this announcement, the Ford Foundation initiated a 7-year experimental program designed to reform doctoral education in the social sciences and humanities. Awards were made to 10 leading universities which grant 30 percent of the Ph. D.'s in these fields—Harvard, California (Berkeley) Yale, Stanford, Chicago, Cornell, Princeton, Pennsylvania, Michigan, and Wisconsin. Funds will be used mainly for student support—stipends, tuition, and dissertation expenses. The typical pattern is expected to embrace (1) 2 years of full-time course work, (2) one year as a teaching assistant financed by the university, and (3) a dissertation fellowship in the fourth year. During the 7-year period, the Ford Foundation estimates that 10,500 students in the social sciences and humanities at these 10 universities will be directly affected.

While this experimental program may, in fact, lead to reform in doctoral education in the social sciences and humanities at these top 10 universities, it clearly conflicts with expressed Presidential and Congressional concern for strengthening the graduate education capabilities of universities not included in this elite group. In particular, the elimination of first-year graduate fellowships will be

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[6] These estimates are reported in *Science*, Vol. 158, No. 3801, Nov. 3, 1967, p. 583. From other sources, it is estimated the number of first-year graduate students supported by fiscal year 1968 funds may range between 10,000 and 12,000.

[7] Reported in *The Washington Post*, Monday, Nov. 27, 1967, sec. A, p. 1.

felt keenly because the action coincides with a precipitous decline in Federal support for first-year graduate students.[8]

D. Potential Impact of Military Selective Service Upon Graduate Enrollment

Changes were made in the Military Selective Service Act and regulations in June 1967 and procedures in February 1968. These changes threatened a drastic impact on graduate school enrollments. The impact, which was expected to begin in September 1968, failed to materialize but may only have been postponed until early 1969.

As of December 1968, facts concerning reclassifications, inductions, enrollments, and changes in the composition of graduate student groups by field and level of training were being collected but had not yet become available. Also the Paris peace negotiations, the forthcoming inauguration of a new President, and changes in the upper echelons of the executive branch could lead to actions which might ameliorate the potential impact on graduate schools.

The present report assumes that the probable effect of the revised Selective Service law and regulations on the long-term total output of doctorates in the biomedical and related sciences will be transitory. In the following paragraphs a brief account is given of past events and future possibilities.

New Selective Service Law and Regulations, June 1967.—On June 30, 1967 a considerably revised Selective Service law[9] was enacted, accompanied on the same day by new Selective Service regulations.[10] The major change was the elimination of what had been virtually blanket deferment of graduate students so long as they were engaged satisfactorily in full-time graduate study. Actually seven key decisions affecting graduate students were made, including the four listed below plus three more in February 1968.

1. Bachelor's degree recipients who as undergraduates had been deferred in class II–S could no longer be deferred in class I–S(C) as graduate students. This removed the legal protection against induction in the middle of an academic term in graduate school.
2. Graduate students who were enrolled for their first year of graduate study on October 1, 1967 were allowed to be deferred in class II–S for 1 academic year only. Those enrolling later for the first time were not so covered.
3. Graduate students who were entering their second or subsequent year of graduate study on October 1, 1967 could be deferred for 1 more year to complete the master's degree or up to a total of 5 years to complete the doctorate.
4. Graduate students satisfactorily pursuing a course of graduate study in medicine, dentistry, and the allied medical specialties could be deferred in class II–S. These were the only graduate fields specifically mentioned in the new law and regulations. Extension of coverage to additional fields still remained a possibility through executive action, due to a provision in the law allowing coverage of "other subjects necessary to the maintenance of the national health, safety, or interest as are identified by the Director of Selective Service upon the advice of the National Security Council."

Additional executive actions, February 1968.—Three major questions left unresolved in June 1967 were decided in February 1968—much to the dismay of the academic community.[11] Two of these decisions were recommended by the National Security Council,[12] as follows:

5. Student deferment for graduate study was ruled out for all fields except medicine,

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[8] Presidential memorandum to heads of departments and agencies, subject: "Strengthening Academic Capability for Science throughout the Country", Sept. 13, 1965. *Eighteenth Report* of the House Committee on Government Operations, "Conflicts between the Federal Research Programs and the Nation's Goals for Higher Education." H. Rept. No. 1158, 89th Cong., 1st sess. The committee recommended (p. 45) that:

> "The system of awarding projects should be modified by adopting educational criteria so as to *diffuse awards to more institutions, in wider geographical areas.*" (Itali supplied)

[9] "Military Selective Service Act of 1967," Public Law 90-40, 81 Stat. 100, approved June 30, 1967.

[10] Executive Order 11360 "Amending the Selective Service Regulations," signed June 30, 1967, published in *Federal Register*, vol. 32, No. 128, July 4, 1967, p. 9787-9796.

[11] One observer (Fred M. Hechinger, *New York Times*, Feb. 18, 1968) wrote: "In the view of most university spokesmen [these actions] substituted a nightmare for mere sleepless tossing."

[12] National Security Council, "Memorandum of Advice Respecting Occupational and Graduate School Deferments," Feb. 15, 1968.

dentistry, and allied medical specialties on the grounds that deferments of graduate students in other fields are "not essential for the maintenance of the national health, safety, and interest."

6. The lists of essential activities and critical occupations were suspended as guidelines in making deferments, leaving only "essential community need" as the criterion. This key term shifts the basis of occupational deferments from national guidelines to the uniquely local determination of each and every draft board.

These last two decisions were transmitted the following day throughout the Selective Service System. [13] Included in the same message was a third decision that had evidently been made at the White House level, [14] as follows:

7. "The sequence of selection in filling calls will remain the same." In accordance with this determination, the oldest qualified eligibles are to be included first. This executive decision was not recommended in the National Security Council's "Memorandum of Advice," nor was it specified (although permitted) in the law of June 1967.

The combined effect of the first six changes and the continuation of the "oldest first" procedure clearly made vulnerable virtually the entire body of male graduate students, and also male bachelor's degree graduates who were potential graduate students. Thus after February 1968 it appeared inevitable that "Under the new rules, almost the entire draftable population will have achieved one or more college degrees." [15]

Predictions concerning September 1968.—In March 1968 a survey of graduate schools was conducted [16] which reflected the alarm of the academic community. A drastic reduction in graduate school enrollment was anticipated, the survey showed, to the extent of only 50 percent of normal first year classes and 77 percent of second year classes, all fields combined. The expectation by field was as follows:

Percent of Normal Classes Available for 1968-69, by Field

	First year class	Second year class
All students	50	77
Medical, dental, divinity	100	100
Biology	54	74
Mathematics	61	68
Chemistry	46	64
Physics	36	63
Engineering	38	72
Social sciences	67	77
Other science	54	67
Humanities	62	85
All other	59	71

This reduction was expected to occur as the result of drafting or enlistment of young men or of their entering employment (teaching, defense, industry, etc.) where occupational deferments might be obtained. In turn, this would produce a considerable rise in the proportion of women graduate students, from 28 percent in 1967-68 to 56 percent in the 1968-69 first year class and a lesser rise from 25 to 33 percent in the second year class, all fields combined. The breakdown by field was expected to be as follows:

Expected Changes in Percentage of Women Graduate Students, by Field

	First year class		Second year class	
	1967-68	1968-69	1967-68	1968-69
Total, all fields	28	56	25	33
Medical, dental, divinity	5	5	5	5
Biology	25	47	25	34
Mathematics	18	35	16	23
Chemistry	17	36	15	24
Physics	8	24	7	11
Engineering	2	6	2	3
Social sciences	37	55	30	40
Other science	19	36	17	25
Humanities	38	63	39	49
All other	31	53	28	37

[13] Telegram to all State directors from Director of Selective Service System, Feb. 16, 1968.

[14] In the *Washington Post*, Morton Mintz, Feb. 18, 1968, General Hershey was quoted as saying this decision "was made from the top."

[15] *Scientific-Engineering-Technical Manpower Comments*, Scientific Manpower Commission, vol. 5, special issue, Mar. 1968, p. 5.

[16] "The Impact of the Draft on Graduate Schools in 1968-69," a survey conducted by the Scientific Manpower Commission and the Council of Graduate Schools of the United States, March 1968.

Incidentally, the anticipated rise in the total first year class to a ratio of more than 50 percent women would be the first such occurrence since World War II.

Actual situation in the fall of 1968.—As noted earlier, the anticipated drastic reduction in graduate enrollments at the beginning of the 1968–69 academic year has failed to materialize. By late September this maintenance of normal levels had become apparent to the Scientific Manpower Commission and the Council of Graduate Schools,[17] and was confirmed in November.[18] The conclusion was based, however, on a spot check of graduate schools rather than on a comprehensive graduate enrollment census,[19] which will not become available until May 1969 or later from the U.S. Office of Education.

There were many reasons for this situation. Judging from some items in the list below, the depletion of young men from graduate schools may have been only postponed rather than ameliorated.

1. *Low draft calls.*—From June through December 1968 draft calls were low, ranging from 20,000 to as low as 10,000. But the call for January 1969 jumped to 26,800 and the call for February is 33,500, beginning a substantial rise that tends to occur every 18 months and could soon exceed 40,000 a month.[20]

2. *Deferment of induction through current term.*—On October 24, 1968, General Hershey issued an advisory memorandum to State Selective Service directors saying that the induction of graduate students might be postponed until the end of the school term.[21] State Director Advice No. 763 states that: "When college students are ordered to report for induction during a school term in which they are satisfactorily pursuing full-time postbaccalaureate courses, consideration should be given, on an individual case basis, to a postponement of induction until the end of the term (quarter, trimester, or semester)." [22] Although this advice was not binding on State directors, all appeared to be granting such postponements; but it was not known whether such postponements would be granted during winter quarters or spring semesters.[23]

3. *"Gamblers."*—Preliminary information showed that about 90 percent of the men classified as I-A enrolled in graduate school during September expecting to be able to complete the semester. This was, in effect, gambling tuition and other expenses on the basis of a statement made to educators in March 1968 by General Hershey that he would consider postponement of inductions in individual cases "where the facts clearly demonstrated the good faith" of a registrant who received his draft call in the middle of a semester.[24] During the early weeks of the fall term, however, such graduate students were considered not to have enrolled "in good faith" by many State directors, nor by the National Director, if induction was ordered soon after the beginning of the term.[25] As already noted, postponements have been granted in most cases since issuance of the October 24 State Director Advice.

4. *High admission rates into graduate schools.*—A number of graduate schools admitted more students than usual in September 1968, in some cases to a very considerable extent, in response to the warnings of the preceding spring.[3] This tended to balance the schools where enrollments were below normal.

5. *Slowness of reclassifications, appeals, and physical examinations.*—Local Boards were slow to reclassify graduate students from their former deferred status. The numerous appeals of those who were reclassified further slowed the process during the summer and fall of 1968.[27] In addition, budget cuts reduced the rate of giving physical examinations.[28]

6. *Federal fellowships and traineeships.*—The major Federal agencies which fund graduate education (NIH, USOE, NSF, NASA, DOD, etc.) reached an agreement that holders of their fellow-

[17] *The Chronicle of Higher Education*, Sept. 23, 1968, p. 1.

[18] *Science*, Nov. 8, 1968, p. 653.

[19] *Scientific-Engineer-Technical Manpower Comments*, December, 1968, p. 26.

[20] George C. Wilson in *The Washington Post*, Nov. 20, 1968, p. A1.

[21] *Science*, Nov. 8, 1968, p. 654.

[22] *Scientific-Engineering-Technical Manpower Comments*, Nov. 1968, p. 22.

[23] *Op. cit.*, December 1968, p. 25.

[24] *Science*, Nov. 8, 1968, p. 654.

[25] *Scientific-Engineering-Technical Manpower Comments*, December 1968, p. 26.

[26] *The Chronicle of Higher Education*, Sept. 23, 1968, p. 1.

[27] *Science*, Nov. 8, 1968, p. 654.

[28] Information from Scientific Manpower Commission.

ships or traineeships who are drafted will be able to retain them after returning from military service. This provided a strong incentive for acceptance of such awards and for enrollment, even if induction appeared imminent, since otherwise the students would have to compete again after military service.[19]

7. *New applicants.*—Preliminary information from graduate schools indicates that many applications were received, and accepted, from individuals who normally would not have applied nor been accepted. This seems to have been the result of the March and April forecasts of a drastically reduced September graduate enrollment.[20]

Probabilities for the near future.—As of mid-December 1968, a survey of graduate science departments, conducted by the Scientific Manpower Commission and its constituent societies,[21] was nearing completion. The survey showed that 37 percent of first-year and 41 percent of second-year male science graduate students were either I–A or II–S. Classification in I–A meant they were liable for draft call on "oldest first" basis, and in II–S meant subject to immediate reclassification into I–A, since the II–S classification became unavailable for graduate students except for those enrolled on or before October 1, 1967, and only for one year in the case of those who were first-year graduate students on that date. For totaled first-year and second-year students, the data showed 38 percent in I–A or II–S for all such students, and 46 percent for American students (excluding foreign nationals). The complete results of the survey were released early in January, 1969.[22]

Information about engineering has already been released by the Engineering Manpower Commission. "Total numbers of graduate students actually enrolled (in enginering) have not changed much, but the composition of the group is changing drastically." Many bachelor's degree graduates have gone into industry, hoping for occupational deferment or awaiting the draft, or directly into military service. Their places have been filled by men ineligible for induction for physical or family reasons, and by a further increase in the number of foreign nationals.[23]

In the meantime, the mix of draftees has been changing and is expected to change much more. During fiscal year 1968 about 5 percent of draftees were college graduates. By October 1968 the ratio had risen to 20 percent. By early 1969, Pentagon manpower specialists expected it to rise to 30 percent or higher.[24] Some non-government manpower experts believe it will rise to 90 percent by February or March, if there are no changes in the rules.[25]

Possibilities for ameliorating the impact.—When the peace talks in Paris produce a cease-fire in Vietnam, and when this is followed by a partial or complete withdrawal of troops, these hoped-for events should soon be followed by a reduction in both draft calls and enlistments. The timing and extent of such a reduction cannot, of course, be foreseen. Moreover it is not possible to predict the effect of a new President and Cabinet on these events.

A second means of ameliorating the effect on the graduate student population would be to change the "oldest first" order of call. This is within the power of the President acting as President, as Chairman of the National Security Council, or as Commander in Chief of the Armed Forces.[26] The mode would probably be designation by the President of a "prime age group" as provided in the Military Selective Service Act of 1967[27] and adoption of the so-called "Modified Young Age System" referred to in the following segment of a letter from Congressman L. Mendel Rivers to Gen. Lewis B. Hershey:

> "I was also disturbed by the failure of the National Security Council or the President to make any recommendations on changing the sequence of selection in filling future draft calls. As you will recall, the Department of Defense;

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[19] *Science*, Nov. 8, 1968, p. 654.

[20] Information from the Scientific Manpower Commission.

[21] *Scientific-Engineering-Technical Manpower Comments*, October 1968, p. 18; December 1968, p. 27. The eleven member societies represent astronomy, biological and agricultural sciences, chemistry, geology, mathematics, physics, and psychology.

[22] Issued while the present report was in press, titled "A Survey of the Draft Status of First and Second Year Science Graduate Students (Fall—1968)," prepared by the Scientific Manpower Commission, January 1969.

[23] *Engineer*, November-December 1968, p. 8.

[24] George C. Wilson in *The Washington Post*, Nov. 26, 1968, p. A1.

[25] Information from the Scientific Manpower Commission.

[26] *Scientific-Engineering-Technical Manpower Comments*, December 1968, p. 25.

[27] Public Law 90-40, Section (6).

the Marshall Commission; the Clark Panel; the House of Representatives; and the Senate all concurred in the desirability of adopting the so-called 'Modified Young Age System' which would identify the 19-20 year age group as the prime age group for induction. The President of the United States, on March 6, 1967, in his Message to the Congress on proposed changes to the Selective Service Act, also indicated his intention of adopting this modification in the order of call. Yet, for reasons that are not quite clear, a decision has apparently been made by the President to either defer action on this recommendation or abandon it altogether. * * *"[38]

The effect would be to dilute very considerably the present exclusive impact on men approaching age 26, who are primarily college graduates and graduate students granted deferment through college to the bachelor's degree, and who would legally remain eligible for induction. This effect would apply across all fields of graduate study.

A third action, also within the power of the President, would be selective as to field, based on the section of the Military Selective Service Act of 1967 which concerns National Security Council advice on

> "* * * the identification, selection, and deferment of needed professional and scientific personnel and those engaged in, *and preparing for*, critical skills and other professional occupations."[39]

It was under this provision that the National Security Council in its memorandum of February 15, 1968, referred to earlier, ruled out deferments for graduate study except in medicine, dentistry, and allied medical specialties. Under the same provision, the new incoming NSC could broaden deferment policy to cover other fields in the national interest.

A fourth method which would dilute overemphasis on college graduates and graduate students would be a lottery system. But this would require legislation, and both the Senate and House Armed Services Committees are on record against such a system.

A fifth solution—elimination of the draft after the requirements of the Vietnam war are past—was promised in the Republican platform adopted in Miami Beach in August of 1968:

> "For greater equity we will further revise Selective Service policies and reduce the number of years during which a young man can be considered for the draft, thereby providing some certainty to those liable for military service. When military manpower needs can be appreciably reduced, we will place the Selective Service System on standby and substitute a voluntary force obtained through adequate pay and career incentives."[40]

This would obviously require legislation. Unless such legislation were given high priority and acted upon almost instantaneously, it would not help the short term situation.

There are many other possibilities. But both the political and military situations are too unpredictable to warrant productive speculation as of mid-December 1968.

Some compensating factors.—It seems reasonable to speculate that *if* no changes are made in the Selective Service procedures now in effect, and *if* concurrently the expected cyclical rise in draft calls is prolonged—an "iffy" situation—increased numbers of present and potential male graduate students will probably enter military service by induction or enlistment, or will seek employment rather than graduate study. But this expected flow could, after a short period or a long period, be reduced or virtually eliminated almost overnight by executive or legislative action or more slowly as the result of international events.

However, if the flow does become heavy and does extend over a period of months or years, there would nevertheless be some factors tending to compensate for the reduced graduate enrollments.

The first among these factors has already been noted in the field of engineering (see footnote 33). Declining graduate enrollments due to military service and industrial employment have been compensated by men who are nondraftable for family, physical or other reasons and by foreign nationals. Whether or not the same pattern is occurring in the science departments of graduate schools to the extent to which such a trend can compensate numerically for the losses is unknown. The degree of

[38] Letter dated Feb. 20, 1968, from Chairman of House Committee on Armed Services to Director of Selective Service System.

[39] Public Law 90-40, sec. (2). Italics added.

[40] *Congressional Quarterly*, Aug. 9, 1968, p. 2128.

effect on the quality of graduate students is likewise unknown.

A second compensating factor would be an increase in both the number and the proportion of women earning advanced degrees. This is much more likely to occur and be significant in fields other than engineering, where the number of women can be expected to remain very low.

What could conceivably turn out to be an historical parallel case occurred in the decade 1940 to 1950 during and after World War II. During that period the number of doctorates granted to men dropped drastically and eventually recovered, as can be seen in the following table.

Production of Doctorates During and After World War II, Shown by Sex[1]

Year	All fields			Biological sciences			Physical sciences		
	Male	Female	Percent female	Male	Female	Percent female	Male	Female	Percent female
1940	2, 824	421	13	627	86	12	789	47	6
1941	3, 161	405	11	652	64	9	966	34	3
1942	2, 968	418	12	653	74	10	850	38	4
1943	2, 174	390	15	506	54	10	686	35	5
1944	1, 611	328	17	309	71	19	563	29	5
1945	1, 296	333	20	244	65	21	372	26	7
1946	1, 608	380	19	248	68	22	438	45	9
1947	2, 538	411	14	447	81	15	704	46	6
1948	3, 428	455	12	603	86	12	967	47	5
1959	4, 855	541	10	853	89	9	1, 468	60	4
1950	5, 904	613	9	998	113	10	1, 721	57	3

[1] *Doctorate Production in United States Universities, 1920-61*, National Academy of Sciences, Pub. No. 1142, 1963, table 26, pages 50-53. Engineering is not included in the Physical Sciences.

It can also be seen, discouragingly, that the number of women who were granted doctorates actually declined during the war, though not as drastically as the more than 50 percent drop for men. The production of neither women nor men doctorates recovered to the 1940 level until about 1948. This was true for both the biological and physical sciences, as well as for all fields combined.

A comparison with the decade of the 1940's is provided by the following table which shows the most recent decade. (Note that the first lines are each 3-year averages.)

Production of Doctorates, 1960–67[1]

Year	All fields			Biological sciences			Physical sciences		
	Male	Female	Percent female	Male	Female	Percent female	Male	Female	Percent female
1958-60	8, 236	1, 003	11	1, 492	153	9	1, 971	72	4
1961-63	10, 294	1, 251	11	1, 757	187	10	2, 472	102	4
1964-66	14, 368	1, 796	11	2, 350	287	11	3, 320	165	3
1967	17, 880	2, 415	12	2, 704	412	13	3, 884	211	5

[1] *Doctorate Recipients from United States Universities, 1958-66* and *Summary Report 1967*, National Academy of Sciences. The numbers for 1958-60, 1961-63, and 1964-66 are 3-year averages, because single-year data by sex and by this science grouping were not available; the data are from pp. 52 and 170. Engineering is not included in the physical sciences.

It can be seen from this table that the percentage of women among total doctorates during the 1960's has remained roughly comparable to that during the first and last parts of the 1940's. But the total number of Ph. D.'s awarded to women in the biological sciences has increased more than 2½ times over the decade, accompanied by a steadily rising percentage of women.

More important than past production of women doctorates, however, is the large pool of women baccalaureates from whom potential Ph. D. candidates could be drawn. The following table (not strictly comparable to the preceding tables due to the different source) shows the numbers and proportions for 1967.

Numbers and Percentages of Men and Women Receiving College and University Degrees, 1966-67 [1]

Degree	All fields			Biological sciences			Physical sciences		
	Male	Female	Percent female	Male	Female	Percent female	Male	Female	Percent female
Bachelor	355, 300	239, 562	40	20, 942	8, 051	28	15, 392	2, 402	13
Master	103, 179	54, 713	35	3, 721	1, 282	26	4, 859	553	10
Doctorate	18, 164	2, 457	12	1, 914	342	15	3, 300	162	5

[1] Data from annual survey by U.S. Office of Education, not yet published in final form. First professional degrees such as the M.D. are included among bachelor's degrees, not at the master's or doctorate level; such degrees are likewise not included among the doctorates surveyed by the National Academy of Sciences. The Office of Education and National Academy of Sciences surveys differ in their definitions of biological sciences and physical sciences, and also slightly in their coverage of total doctorates.

Women received more than one-fourth of all the baccalaureate degrees and master's degrees awarded in the biological sciences. However, less than one-half as many women with undergraduate majors in biology proceeded to the doctorate as did men, and only one-third as many in the physical sciences. This is shown in the following table of percentages derived from the same data.

Percentage of Male and Female Baccalaureates Receiving Master's and Doctorate Degrees

	All fields		Biological sciences		Physical sciences	
	Male	Female	Male	Female	Male	Female
Master	29	23	18	16	32	23
Doctorate	5	1	9	4	21	7

In the event of a dearth of men in graduate schools, perhaps a larger number of well-qualified women could be encouraged to pursue training beyond the master's degree and continue to the doctorate. Fellowships and traineeships, coupled with positive recruitment efforts, might increase the number substantially.

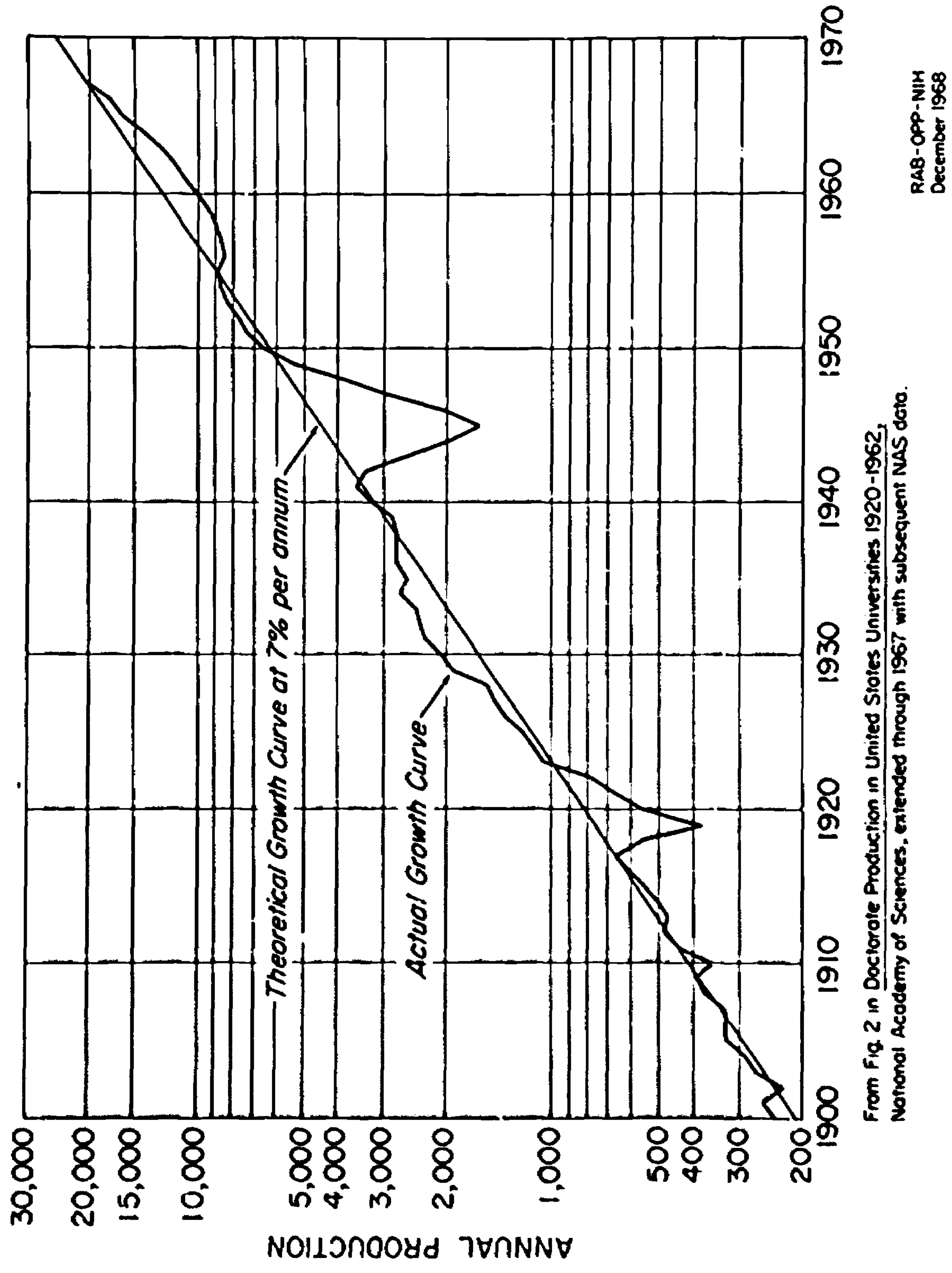
There is one final compensating factor if total doctorate production does in fact decline sharply for a significant time. This would be a period of overproduction following the period of underproduction.

Possible historical parallels are shown in chart 2. During and after World War I there was a sharp drop beneath the trend line for 5 years (1918–22), followed by a slight rise above the trend line for 6 years (1923–28). The even sharper 8-year drop during and after World War II (1942–49) was likewise followed by a 6-year compensation period (1950–55) of small overproduction. The 9-year period of "overproduction" (1929–37) and the 11-year period of "underproduction" (1956–66) seem to have been due to other factors, e.g., the great depression and the low birthrate of the thirties. The point to be emphasized, however, is that compensatory overproduction after these two major wars never approached the magnitude of the loss.

In summary, the decimation of graduate enrollment anticipated a scant 6 months ago has not occurred. The initiation of the Paris peace talks and the advent of a new Administration contribute to the fluidity of the situation. While it is probable that graduate enrollment may be affected in the short run as draft calls rise, it is unlikely that a short-term perturbation will result in diminished Ph. D. output during the decades ahead.

CHART 2

Doctorate Production in U.S. Universities, 1900 to 1967



From Fig. 2 in Doctorate Production in United States Universities 1920-1962, National Academy of Sciences, extended through 1967 with subsequent NAS data.

III. MANPOWER NEEDS FOR THE FUTURE

A. Uncertainty of Current Situation

Until recently, a general malaise of pessimism has permeated the current situation. It is a fact that the rate of growth of national biomedical research expenditures has declined in recent years; it is a fact that Federal support for graduate education is diminishing; it is a fact that the major non-Federal program for support of graduate students is being phased out; it is a fact that the 1967 amendments to the Selective Service Law may have the impact of substantially reducing male graduate enrollment in 1968 and 1969—years when peak enrollments were anticipated. These are hard, stubborn facts which make it difficult to take an optimistic view of the near future.

But it would be unreasonable to assume that these facts in the current situation will continue unchanged into the indefinite future. It is expected that the share of the Federal budget and the GNP devoted to the civilian sector will be enlarged when foreign policy objectives in Vietnam are achieved. However, uncertainty dominates the current scene; uncertainty as to when and how foreign policy objectives will be achieved; uncertainty as to when a larger share of the Federal budget and the GNP will become available for the pursuit of domestic objectives in general, and increased support for medical research, education, and health services, in particular; and uncertainty as to what proportion of a steadily rising GNP will be allocated to each of the domestic programs such as health, research, education, urban development, transportation, and economic development.

Taking full account of the hard realities of the current situation and recognizing the inherent uncertainty of the future, the soundest approach to estimating manpower needs for the future for biomedical research, education, and related service activities is to (1) appraise critically the long-term prospects for the growth of biomedical research, (2) examine the implications of such growth for manpower needs, (3) isolate the high priority functional requirements so that training programs can be targeted to urgent and specific manpower needs, and (4) identify the critical shortage categories.

B. Long-Term Prospects for Growth of Biomedical Research

Projections of manpower needs are essential to provide guidance for development of NIH training programs and to pinpoint problems which warrant special consideration, e.g., institutional development, emerging areas of science, critical shortages. More than 6 years ago, the National Institutes of Health prepared an assessment of *Manpower Resources and Requirements, 1965–70*,[1] for the House Appropriations Committee. Since then, the Resources Analysis Branch of the Office of Program Planning and Evaluation, NIH, has: (1) Continued a systematic assessment of research manpower needs; (2) Initiated analyses of NIH training programs; (3) Developed projections of enrollment and output; and (4) Initiated studies aimed at identifying probable expansions in graduate and medical education and probable faculty staffing needs for the future.

In the brief span of 6 years, many changes, both anticipated and unforeseen, have taken place in the aspirations and commitments of the American people. The broader social, economic, and political changes can best be summarized as (1) the enactment of legislation aimed at achieving the Great Society, and (2) the mounting involvement since 1965 of the United States in the war in Vietnam with the inevitable concomitant of fiscal restraint upon the growth of civilian programs.

It is instructive, however, to examine retrospectively the 1961 projections, comparing them with actual experience, notwithstanding the significant unforeseen changes that have occurred in the period since they were prepared.

[1] *Resources for Medical Research* report No. 3, "Manpower for Medical Research, Requirements and Resources, 1965–70," January 1963, PHS Pub. No. 1001

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The projections reflected explicit assumptions as to (1) the probable rate of growth of biomedical research, (2) the probable increase in expenditure per professional worker, (3) the probable distribution of biomedical research by sectoral performers—government, industry, and nonprofit organizations, (4) the probable number of professional research workers required by 1970, and (5) the increment required between 1960 and 1970 to meet the projection, taking into account deaths, retirement, and shifts to other activities.

The projection of manpower requirements by 1970 was based upon the moderate assumption that the level of national expenditures for biomedical research, expressed in 1958 constant dollars, would approximate $3 billion by 1970. The projections also indicated the alternative possibilities of a more rapid rate of growth, rising to $3.3 billion in 1970, and of a less rapid rate of growth reaching only $2.3 billion by 1970.

Comparison between projections and actual experience.—Chart 3 compares these projections with actual experience. In 1960 and 1961, the growth rate (in constant 1958 dollars) exceeded the rapid projection. In 1962 and 1963, the growth rate exceeded the moderate projection but fell below the rapid projection. Since 1964, the growth rate has dropped below the moderate projection but has continued to exceed the low projection. Thus, it appears likely that national expenditures for biomedical research will reach $2.5 billion (expressed in 1958 constant dollars) in 1970. This is slightly above the low projection and $300 million short of the moderate projection. Expressed in current dollars, however, it now appears that the Nation's investment in biomedical research may approximate $3 billion in 1970.

Three factors account for the gap between projection and experience:

1. All Federal research programs have been subjected to more rigorous review both within the legislative and the executive branches.
2. Many new and urgently needed programs have been launched in the civilian sector thereby forcing greater competition with research programs, especially those funded by the Federal Government.
3. While these two factors are significant in themselves and likely to continue for the indefinite future, the dominant consideration impeding the rate of growth of biomedical research is derivative of a fundamental foreign policy decision. One inevitable consequence of this decision has been an absolute increase of $30 billion for national defense in the Federal budget from 1965 to 1968.

Between 1960 and 1965, prior to the substantial expansion of national defense expenditures, the Nation's investment in biomedical research increased at a compound rate of 15 percent per annum (in constant 1958 dollars). If one conjectures that this rate of increase might have continued through the 1965-70 period, then national expenditures for biomedical research would have reached $3.4 billion (expressed in 1958 constant dollars)—a shade above the rapid growth projection presented in *Manpower Resources and Requirements for Medical Research, 1965-70*.

In this earlier report, it was explicity stated that:

"An effort to look ahead for a decade is an undertaking obviously fraught with uncertainty. Many as yet unforeseen factors will influence the growth of research expenditures during the sixties. Thus, it should be emphasized that the $3 billion projection is not set forth as a goal or target of this Administration. With these qualifications clearly identified, the National Institutes of Health has utilized the $3 billion projection—about three times the current effort—as a reasonable and feasible basis for estimating research manpower needs."

With respect to projections of manpower requirements, it was noted that:

"The primary factor determining medical research manpower needs is the growth of medical research itself. Research expenditures constitute the best single quantitative measure of such growth."

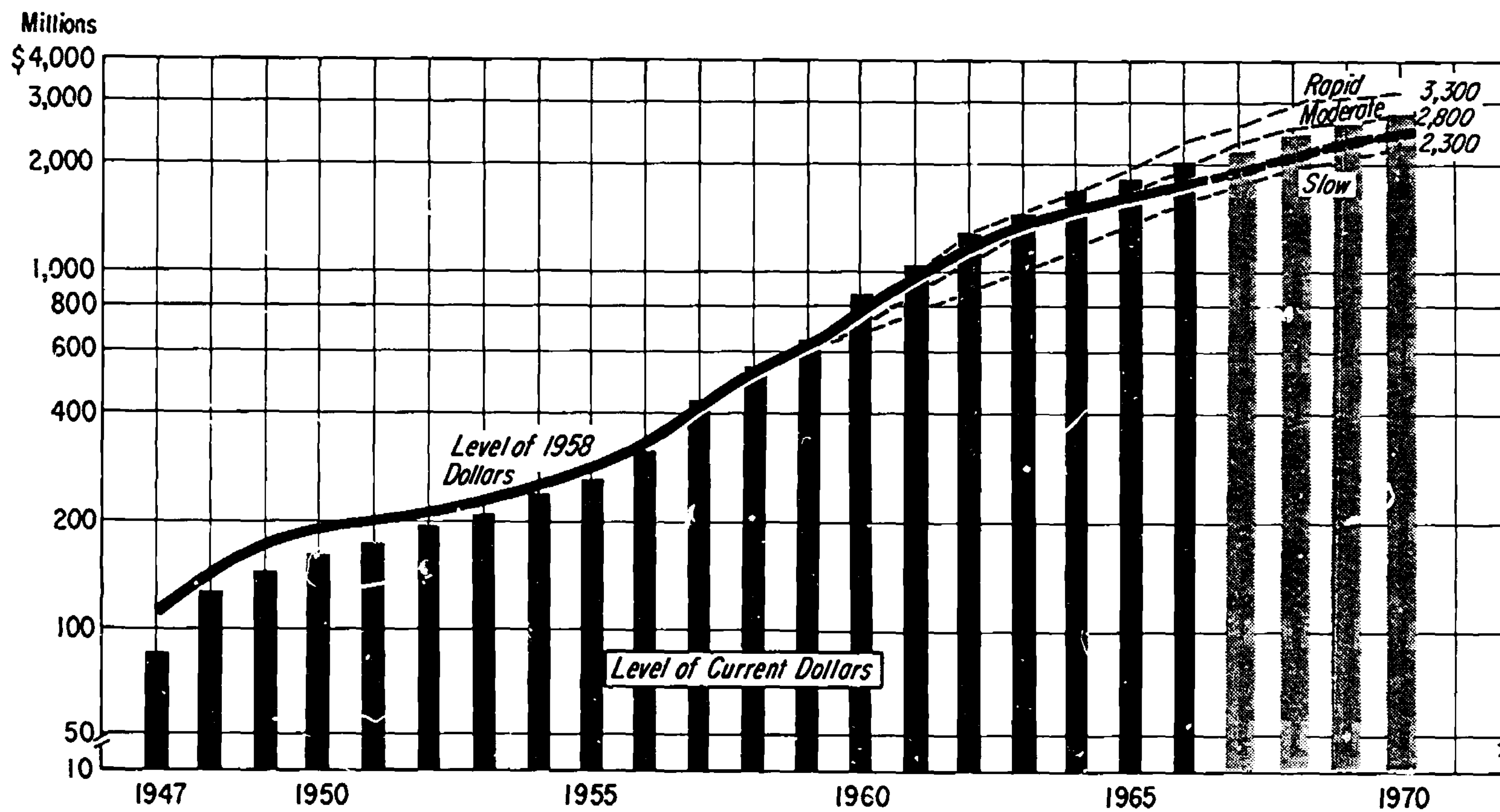
The earlier report noted further that:

"Such projections are useful in establishing probable ranges of future expenditures in terms of general orders of magnitude; they are essential to any appraisal of the probable future demand for research manpower. Inevitably, such projections draw upon past experience, take account of prevailing trends, and then reflect the best judgment of the person or institution making the projection. The crucial question is: 'What is the probability that the projections provide a sufficiently close forecast of the future

CHART 3

Projections of National Expenditures for Biomedical Research Compared with Actual Experience

1960–66, and Estimates 1967–70



*Manpower for Medical Research, Requirements and Resources, 1965-1970.
Source: National Institutes of Health.

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as to be useful in planning policies and developing programs?' "

"While only the historian of the future can give us the final answer to this question, we can: (1) Examine experience since the projections were developed, (2) Scrutinize critically the assumptions used in arriving at the alternative projections, and (3) Consider the influence of other factors bearing upon the growth of medical research."

With respect to these considerations, actual experience strongly confirms the utility of such projections in estimating future manpower requirements. Experience also confirms the critical significance of explicitly stated assumptions and, vis-a-vis Vietnam, the extent to which assumptions may be affected by unforeseen contingencies. Moreover, events of the past 7 years and clear challenges which loom ahead argue for consideration of alternative methods of approach to the projection of biomedical research and teaching manpower requirements which take into account more specifically the predictable and expected demands of the future.

Background of Projections

The projections of manpower for biomedical research presented in this report have been prepared under different assumptions concerning the future availability of funds for biomedical research—a view of the economic capability for supporting research—which will govern the numbers of professional workers whose investigators can be supported. To place these alternative projections in perspective, however, the dynamics of scientific achievements and opportunities for research, the availability of trained manpower and research institutions, and the institutional arrangements for the coupling of the conduct of research and the delivery of health services, must also be considered.

The Prospects for Biomedical Research in the Next Two Decades

The dynamics of scientific achievements and opportunities.—The relation of the past trends in biomedical research funds to economic capability, as shown by its growing proportion of the GNP (outlined in ch. I), should be construed as only one of many forces that have influenced the magnitude, pace, and composition of biomedical research. Another major force is the dynamics of research momentum.

The progress of science in the postwar years has:

- Revolutionized the range of diagnostic, therapeutic, and preventive capability available for medical and health services;
- Eliminated a number of infectious diseases as important causes of disability and death; greatly modified the prospects of a substantial proportion of patients with prospective or actual cardiovascular disease and cancer; made available a number of therapeutic agents which are now able to moderate a number of other diseases which heretofore were accompanied by substantial disability or high mortality rates;
- Opened penetrating insights into the nature of life, the functioning of biological systems, the basic character of disease, degenerative processes, and the conditions of health which provide the basis for the further advances of medical science and practice.

But the most recent report of the House Committee on Appropriations, discussing proposed research programs of the National Institutes of Health, indicated that:

"Despite the heartening progress [in medical research]—the areas of ignorance remain more extensive than the areas of knowledge. The dismal catalog of the many diseases and disabilities whose cause is not known or for which no effective treatment or preventive measure has yet been discovered underscores the continuing need for intensive work on the many unresolved problems." [2]

What are the areas in which the projected growth in research can presently be envisaged for the next two decades?

Fundamental to this is the observation by Dr. James A. Shannon, former Director of the National Institutes of Health, that:

"Despite the great strides forward in recent years, the biomedical sciences are still in a primitive stage of development. The lack of understanding of underlying causes is still the main

[2] Report of the House Committee on Appropriations on the Departments of Labor, and Health, Education, and Welfare, and Related Agencies Appropriation Bill, 1968, 90th Cong., 1st sess., House Rept. No. 271, p. 18 (bracketed phrase added).

barrier to the solution of the major chronic illnesses. Much of biological research must continue to be descriptive and observational and its approach to the solution of problems is still, necessarily, empirical. The unifying and clarifying principles and 'laws' that transformed alchemy into chemistry and natural philosophy into physics have yet to be uncovered in the life sciences. A major step forward brings into view still larger—and more forbidding—areas of unknown territory. For example, the success in combating bacterial infectious diseases laid bare, for all to see, the puzzling roles that seem to be played by viruses in both acute and chronic diseases.

"For the chronic diseases with which medical research is now primarily concerned—heart disease, cancer, an array of metabolic and neurological diseases, and congenital defects—the valleys of ignorance are broader than the peaks of knowledge. The exploration of the cause of these diseases or defects—which must precede the development of wholly effective treatment and preventive measures—is most formidable. In fact, many of these diseases probably have no single cause. Rather, the cause of disease and the determinants of the rate of progress in dealing with it are likely to be a combination of chemical and biological, environmental and developmental, and behavioral and sociological factors. A total understanding of these diseases will require research in many disciplines and in many directions." [3]

The "new look" in medical research is the move towards the intensive study of human development—viewing man as a single complex unit and his progression from conception to death as a biological, intellectual, and emotional continuum. There is ample reason to believe that such an integrated approach will (1) shed fresh light on the origin, causes, and courses of some diseases and disabilities, and (2) make unique contributions to preventive medicine and to the solution of congenital and environmental health problems.

The opportunity for fruitful scientific inquiry is limitless, and from future biomedical investigation will emerge the new scientific approaches and the intensified application of existing techniques and knowledge for the solution of the ever-present and constantly changing problems of human disease and disability, within reasonable limits established by the Nation's economic capability.

The prospect for even more revolutionary findings, coupled with the need for the transformation of both current and new information into diagnostic, therapeutic and preventive technology, plus the need to secure the effective utilization of these advances in the delivery of services, will compel greater and broader research efforts.

Areas of burgeoning significance for health include (1) those fundamental to advancing general knowledge concerning man, and (2) specific diseases and disabilities calling for "targeted" research investigations.

Future explorations in the basic area will be concerned with—

- The genetic basis of biological replication and differentiation;
- Virology and molecular biology in relation to the fundamentals of cell biology;
- Immunology and transplantation of biological materials;
- The processes of reproduction, development, and decline;
- The interaction of chemical, physical, and biological phenomena as the fundamental basis of nutrition, therapeutics, toxicology, and environmental health.

The "targeted" areas will include—

- The intensification and expansion of the application of engineering, mathematics, and physical sciences coupled with the life sciences to the solution of problems in health, such as (*a*) the development of improved and new artificial implants to replace diseased or malfunctioning vital organs and other parts of the body (heart, kidney, teeth), (*b*) the elimination of environmental poisons, not only the contaminants of water and air, but the cumulative effects of all kinds of chemicals and drugs, which are breathed, swallowed, or touched;
- Further advancement against diseases suspected to be of viral origin, such as cancer, and the further search for specific chemotherapeutic agents in the treatment and control of this dread disease;

[3] Statement by Director, National Institutes of Health. In *Hearings before Subcommittee of the Committee on Appropriations, Departments of Labor, and Health, Education, and Welfare Appropriations for 1968*, Pt. 5, 90th Cong. 1st sess., April, 1967, pp. 4 and 5.

- Exploration of new approaches directed toward the alleviation and eventual prevention of myocardial infarction, hypertension, and other cardiovascular complications;
- Development of vaccines effective against a broadening array of infectious diseases, some of which are displaying new forms against which existing controls are ineffective;
- Exploration of the behavioral factors in the cause of disease, calling forth effective interdisciplinary and heterogeneous approaches towards a fuller understanding of the complex interaction—physiological and psychological—of man and all aspects of his environment.

Finally, a common feature in the current developments in medical research and one of increasing exploitation for the future is the highly effective use of the concepts, methods, and instrumentalities not traditionally associated with biology and medicine. These new approaches, adapted from the physical sciences, include translation of biological phenomena into mathematical models, utilization of computer techniques for the solution of problems in biology, the application of miniaturized electronic equipment, and the increased use of epidemiological studies and population surveys to yield valuable results unobtainable through normal laboratory research or clinical investigations.

In summary, the scope and momentum of current scientific efforts, the continuing challenge of the unknown and the prospects of new and revolutionary capabilities are powerful influences bearing upon the further development of biomedical research.

Dynamics of the population, trained manpower, and the institutional base of biomedical science.—The national medical research scene is now being influenced by the results of the rapid expansion of national medical research training programs starting in the latter part of the 1950's. Increasing numbers of scientists trained through these mechanisms are now initiating or in the beginning stages of their careers. (These developments are detailed in chs. IV and V.)

The first postwar birth cohort (1946) will reach age 22 in 1968. For that and subsequent years, there is the prospect of substantial increases in potential graduate and professional school enrollment, the primary source for professional trained investigators. This trend will be reflected in pressure for increased graduate and professional educational capacity, through expansion of existing facilities and creation of new ones with attendant faculty, resource, and support requirements. In addition to the prospect of this substantial expansion, the Nation faces critical problems in sustaining the vigor and stability of existing institutions and substantially upgrading the quality of the weaker and less capable components. At the same time, there are urgent needs to expand resources to meet urgent national objectives in health-related areas as well as to bring about a more equitable geographic distribution of the relevant educational resources and scientific capability.

The prospect of continued expansion of biomedical research and national programs affecting the character, stability, and development of academic institutions clearly emphasizes the need to develop a more unified and more rational framework for the relationships between the Federal Government and academic institutions involved in the biomedical sciences. This framework should permit a logical, systematic, and unified approach to the following matters:

- The further advance of undirected academic science;
- The sound development of the fundamental educational processes;
- The strengthening and enhancement of existing institutions as well as the expansion of institutional resources related to national and geographical needs;
- A meaningful distinction between the development of national programs requiring university capability and the Federal support and advancement of higher and professional education as a fundamental social function;
- The development of appropriate coupling arrangements between centers of scientific and academic medicine and the framework of community health services.

The support of academic science.—Three-quarters of the expenditures of NIH research grant funds take place in colleges and universities. The support for academic science will continue to be a dominant area of biomedical research activity since the advance of the fundamental sciences will continue to be crucial to the successful engagement with the problems of disease and health. The requirements for research support in this area will derive directly from the intrinsic processes of growth and the cost influences affecting the development of graduate research and education and the basic academic framework of the Nation. These dynamics of growth and change in the academic scene are the consequence of a set of general but independent forces, such as the rate of population growth expressed in the moving wave of undergraduate, graduate, and postdoctoral students; the concomitant expansion of academic and research institutions with their additional faculty and staff demands; the upward trends in prices and wages; and the effects of advancing sophistication and technology upon the substantive costs of research. A basic requirement, therefore, in the overall management of NIH programs is the evolution of a stable—but not static—support relationship to this impelling pattern of academic growth and change.

The coupling of academic science and the community health scene.—The extent to which the knowledge, capability, and new technology emerging from research is being brought into effective use in the clinical and health service scene has been a matter of acute concern for some period of time.

The prospect of a vast improvement in the quality of health services that can be made generally available is derived from the demonstration of the rapid application of new knowledge, within a sphere of high professional competence, such as is characteristic of the good university medical center. The event that has made possible the most direct attack upon this problem has been the development of regional medical programs under the Heart Disease, Cancer, and Stroke Amendments of 1965.[4] The innovative concepts underlying this program involve the development of direct linkage of the centers of scientific and academic medicine with community hospitals and community medical services in order to bridge the critical gaps in the most effective and meaningful manner. In a very real sense, this development parallels the extension service which has served so successfully to transform the knowledge and technology generated in agricultural schools and experiment stations into radical improvements in production and distribution of agricultural products. This development is now being adapted to improve medical care through extending the functions of academic medicine and their relationship with community medical services under regional medical programs.

Each regional medical complex encompasses a medical center having major teaching functions, one or more specialized research centers, and an array of community facilities. These entities will be linked by staff exchanges, integrated research and training activities, and programs of continuing education and demonstration. Such arrangements can provide for the direct and expeditious flow of knowledge, capability and technology outward from the centers of academic and scientific medicine and the speedy referral of patients (either physically or through the use of enhanced computer capabilities) for specialized diagnostic, therapeutic, and research purposes inward from the community medical care framework.

In summary, despite the enormous progress in medicine and health, the scientific base of knowledge and technology remains critically limited. Society has utilized specific knowledge at a rate which roughly equals its production. The beginnings of broad generalizations are just emerging. The broad scientific base needed to cope definitively with disease, disability, the ravages of the aging process and understanding the conditions of physical, mental, and social well-being, are in many areas perilously marginal, if not nonexistent. Beyond the limitations of knowledge, the prospects for health for large segments of the Nation's population are seriously marred by the inadequacy and maldistribution of health services, by quality differentials, high costs and motivational and attitudinal deterrents. At the same time, advances in the social, economic, and scientific capability of the Nation have substantially accelerated public and private expectations of the extent to which these problems can be diminished through further public action. But action at the governmental level alone will not be sufficient to overcome these difficulties. The President's National Advisory Commission on Health Manpower has indicated that:

> "We are convinced that just as it is true for so many of our Nation's gravest difficulties, *government alone is not big enough to solve the problems of health care for the American people.* For all its great size, the capabilities of the Federal Government, even when united with State and local governments, are small compared with the combined resources and experience of the private sector. These include the professions, voluntary agencies, religious and educational institutions, hospitals, or-

[4] Public Law 89-239, Oct. 6, 1965.

ganized labor, business and industry, and concerned citizens. Our recommendations require that the resources of each of these very powerful forces be applied to reshape effectively the health care system."[5]

It is these circumstances that create a continuing condition of public demand for progress in both the science and practice of medicine.

C. Projections of Biomedical Research Expenditures and Manpower

It is within this frame of reference, and with this perspective of scientific challenges, and opportunities, and human needs and aspirations for improved health care that expenditures and manpower needs for biomedical research have been projected to 1985. Because the simplest way to calculate biomedical research manpower requirements is to project the probable future levels of medical research, national expenditures for biomedical research have been projected from 1967 to 1985, in constant 1967 dollars, under different assumptions of the relationship of this effort to the gross national product. The usefulness of the results of this approach to indicate projected levels of effort has been discussed earlier in this chapter. That discussion emphasized the importance of the assumptions and relevant factors on which projections are based. Moreover, in emphasizing the very uncertainty of forecasting the future, it was noted that projections are to be viewed as general-order-of-magnitude estimates, providing guides to probable levels of expectation.

In addition to (1) the alternative projections developed on the basis of varying relationships of biomedical research expenditures to GNP, manpower projections have also been prepared, based (2) upon the full utilization in research of manpower trained in the health sciences, and (3) on the high priority staffing requirements of major research and teaching components in the nonprofit sector (sec. E).

Alternatives based on GNP.—The projections provide a range of levels for biomedical research expenditures to 1985, based upon different relationships to GNP. Each of these alternatives, however, is based on the same projection of GNP.

For the purpose of this report, the real growth (in constant dollars) in the gross national product is assumed to increase at a rate of 4 percent a year from 1967 to 1985. This assumption, tied with the national objective of limiting unemployment to 4 percent, is based upon an analysis prepared for the Subcommittee on Economic Progress of the Joint Economic Committee.[6] While the Committee's study did not venture beyond 1975, a continuation of this rate of growth is one of the determinants used in projecting biomedical research expenditures to 1985 for the purposes of this report.

In summarizing the results of its study, the Joint Economic Committee staff indicated that:

> "The U.S. economy has a potential for a rate of economic growth of between 4 and 4½ percent per year between 1965 and 1975. This is between one-third and one-half the rate prevailing in the first two-thirds of this century, and is substantially above the 3.5 percent prevailing over the 17 years from 1948 to 1965. This higher rate of growth will not be achieved automatically, and will require improvements and adjustments in economic policies, both public and private, if it is to be achieved in a manner that does not generate undesirable inflationary byproducts."[7]

Thus, the 4 percent growth rate is the lower of the two alternatives the Joint Economic Committee's study provided. The assumptions and methodology underlying these alternatives have been detailed in the Committee report. Acceptance of the 4 percent growth rate (rather than the historical 3.5 percent or the 4.5 percent alternative growth rate) is a midpoint in possible rates of growth, and reflects a conservative view of the potential capabilities of the national economy over the next two decades.

The alternative projections of biomedical research expenditures based on relationships to GNP are presented in Table 5.

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[5] *Report of the National Advisory Commission on Health Manpower*, vol. 1, November 1967, p. 3.

[6] Joint Economic Committee, *U.S. Economic Growth to 1975: Potentials and Problems*, Joint Committee Print, 89th Cong., 2d Sess. Projections of future economic developments have been prepared by other organizations, for instance, National Planning Association, *Federal Budget Projections*, which also indicate that the 4 percent growth rate is a goal for the future. In a more recent study, the National Planning Association has used a 4.4 percent annual growth rate in real GNP, *National Economic Projections to 1977/78*, report No. 67-N-1.

[7] Op. cit., p. 1.

TABLE 5.—Alternative Projections of National Expenditures for Biomedical Research, 1970–85, Based Upon Varying Assumptions of Proportion of GNP Allocated for Biomedical Research

[In 1967 Dollars]

Year	GNP (billions)	Best judgment [1]		Alternative A [2]		Alternative B [3]		Alternative C [4]	
		Proportion of GNP	Amount (billions)	Proportion of GNP	Amount (billions)	Proportion of GNP	Amount (billions)	Proportion of GNP	Amount (billions)
1965	$710	.27	$1.9						
1967	785	.29	2.3						
PROJECTIONS									
1970	886	.33	2.9	.33	$2.9	.33	$2.9	.29	$2.6
1975	1,077	.51	5.5	.48	5.2	.42	4.5	.29	3.1
1980	1,310	.74	9.7	.65	8.5	.50	6.6	.29	3.8
1985	1,594	.98	15.7	.80	12.7	.60	9.5	.29	4.6
	Growth rates (annual compound rate of increase) [5]								
1965–70			8.4		8.4		8.4		5.8
1970–75			14.0		12.8		9.4		4.0
1975–80			12.0		10.1		8.1		4.0
1980–85			10.0		8.4		7.5		4.0

[1] Best judgment projection based on assumption that national biomedical research expenditures will increase as a proportion of GNP from 0.29 of 1 persent in 1967, and 0.33 of 1 percent in 1970, to 0.98 of 1 percent in 1985.

[2] Alternative A is based on the assumption that from 1970 to 1985 national biomedical research expenditures will increase uniformly as a proportion of GNP from 0.33 of 1 percent in 1970, to 0.8 of 1 percent by 1985 (approximately 0.03 of 1 percent a year).

[3] Alternative B is based on the assumption that from 1970 to 1985, national biomedical research expenditures will increase uniformly as a proportion of GNP from 0.33 of 1 percent in 1970 to 0.60 of 1 percent in 1985 (approximately 0.018 of 1 percent a year).

[4] Alternative C is based on the assumption that national biomedical research expenditures, as a proportion of GNP, will remain constant, 1970–85, at the 1967 proportion of 0.29 of 1 percent of GNP.

[5] Computed from unrounded figures.

Source: National Institutes of Health.

The *best judgment* projection of biomedical research expenditures is believed to be the most reasonable long-term summation of the forces that may shape the future course of biomedical research—in terms of the scientific needs and opportunities, the related research manpower capable to exploit these opportunities, and the economic capability of the Nation to provide the necessary resources. The assumptions underlying this best judgment estimate are presented below. It must be emphasized that basic to this best judgment projection is the assumption that the concerted and intensive drive in Southeast Asia—requiring large-scale commitments of national resources—will come to a successful conclusion within the next few years. The national will to improve the well-being of the American people will then dictate the increasing allocation of resources for this purpose, in line with historical growth patterns. This best judgment estimate is to be considered, therefore, as indicative of long-term growth, with the probability that the estimates implied for the years clustering around 1970 may overstate the possible.

(An alternative projection (pp. 41 ff) is provided which assumes a continuation to 1985, of the stringent budgetary conditions governing the current situation for Federal agencies.)

1. Total national expenditures for biomedical research will continue to grow as a proportion of the gross national product. They have in the past and there is no intrinsic scientific, economic, or technological reason why they should not grow in the future. The historical growth shows a rise from .04 of one percent in 1947 to .29 of one percent in 1967 (table 6). Extrapolation of this growth at a reduced rate of increase brings the level to one percent of GNP by 1985, with the major thrust occur-

ring in the early seventies and continuing through the decade.

2. The proportion of the national biomedical research total performed in the industrial sector will probably increase substantially and could rise from 30 percent in 1967 to 34 percent by 1975 and 36 percent by 1985. This assumption is based on the prospect of a major increase in technological development, especially in the emerging area of engineering as applied to biology and medicine.
3. It is assumed that Government outlays for national security will decline by 1975. In a world now torn by conflict and tensions, this assumption is inevitably speculative. Nevertheless, only a few years back, the Administration gave serious consideration to the probable consequences of a reduction in national defense spending and the allocation of an increasing share of the Federal budget to civilian purposes. Looking ahead, it seems reasonable to assume that such a reduction may occur between now and 1975.

TABLE 6.—Biomedical Research and Relation to the Gross National Product for Selected Years, 1947–67, and Projections to 1985

[In 1967 dollars]

Year	GNP (in billions)	Biomedical research: Amount (in millions)	Biomedical research: Percent of GNP
1947	$359	$135	.04
1952	457	261	.06
1957	523	522	.10
1962	613	1,411	.23
1965	710	1,920	.27
1967 est	785	2,280	.29
1970	886	[1] 2,870	.33
1975	1,077	[1] 5,525	.51
1980	1,310	[1] 9,737	.74
1985	1,594	[1] 15,682	.98
	Growth rates (annual compound rate of increase)		
1947–52	4.9	14.0	--------
1952–57	2.7	14.9	--------
1957–62	3.2	22.0	--------
1962–67	5.0	10.0	--------
1965–70	4.5	8.4	--------
1970–75	4.0	14.0	--------
1975–80	4.0	12.0	--------
1980–85	4.0	10.0	--------

[1] Best judgment projection.

Source: *Gross National Product:* Based on current dollar series for 1947–65, Department of Commerce, and 1967 estimate, Council of Economic Advisers; converted to 1967 dollars by use of GNP deflator. Projections from 1970 to 1985 based on 4 percent growth rate from 1967 provided in an analysis prepared for the Subcommittee on Economic Progress of the Joint Economic Committee, *U.S. Economic Growth to 1975: Potentials and Problems. Biomedical research:* National Institute of Health.

Assuming further that the Federal budget remained relatively constant as a proportion of GNP, funds available for civilian programs would increase substantially.

The best judgment projection suggests an increase in national expenditures (in 1967 constant dollars) for biomedical research from $1.9 billion in 1965 to $5.5 billion in 1975 and, looking toward the more dimly perceived future, $16 billion—roughly 1 percent (.98) of GNP—by 1985. What growth rates are implicit in these projections? Do they appear feasible in the light of past experience and future research opportunities? What are the implications of these projections for manpower requirements, by sector of employment, and by level of training? And what are the implications of these projected levels of expenditures in terms of the providers of the projected funds, and the sectoral performers of medical research?

Growth rates for best judgment estimate.—The past is not necessarily a prologue to the future but an examination of historical growth rates for biomedical research may suggest the feasibility of the projected rates for the future. The historical data for 1947–67 are summarized in table 7.

The growth rate (in 1958 constant dollars) hovered at 14–15 percent, 1947–57, rose to 22 percent for the 1957–62 period, and then dropped sharply to less than 10 percent for the most recent period, 1962–67. The 1967–72 period will be heavily weighted by the fiscal restraints which have operated to allow only minimal increases in research in fiscal year 1967 and 1968 with a corresponding outlook for the next budget cycle. Looking beyond these short-term fiscal constraints growth rates (in 1967 constant dollars) for 1970–75, 1975–80, and 1980–85 have been projected at 14 percent, 12 percent, and 10 percent respectively.

TABLE 7.—National Expenditures for Biomedical Research, 1947–67, Current and Constant 1958 Dollars

[Millions]

Year	Current dollars	1958 dollars [1]
1947	$87	$117
1948	124	156
1949	147	186
1950	161	201
1951	175	204
1952	197	225
1953	214	242
1954	237	265
1955	261	287
1956	312	332
1957	440	451
1958	543	543
1959	648	638
1960	845	818
1961	1,045	999
1962	1,290	1,219
1963	1,486	1,386
1964	1,652	1,517
1965	1,841	1,660
1966	2,056	1,805
1967 est.	2,280	1,944
	Growth rates (annual compound rate of increase)	
1947–52	17.8	14.0
1952–57	17.4	14.9
1957–62	24.0	22.0
1962–67	12.0	9.8

[1] Based on gross national product deflator, 1958=100; U.S. Department of Commerce and Joint Economic Committee, *U.S. Economic Growth to 1975: Potentials and Problems.*

Source: National Institutes of Health.

These growth rates reflect seven broad assumptions:

1. A continuously growing biomedical research effort is in the national interest because pursuit of scientific knowledge in these areas on a large scale is necessary in order to solve major disease problems;
2. In science-based professions, such as medicine, high quality professional education, and graduate education in the health sciences can be provided only by institutions where the faculty is heavily involved in research;
3. Growing participation of industry, especially in biomedical engineering and related technological development;
4. The expansion of existing medical schools and graduate schools, the creation of 25 new medical schools and 150 new graduate schools in the 1965–75 decade, and a sharply rising supply of doctoral-trained scientists throughout the seventies;
5. The expansion of specialized research centers concentrating upon health and disease problems of urgent national interest such as cardiovascular research and training centers, dental research institutes, pharmacology-toxicology research centers, eye research institutes, environmental health sciences research centers, regional primate research centers, institutes for the study of aging, and mental retardation research centers;
6. The operation of more than 50 regional medical programs spanning the Nation, linking the country's major medical research centers with a network ultimately involving 3,000–4,000 community hospitals, to bring to the ill in all parts of the country the possibility for receiving the benefits of the latest research developments.
7. The intensification and expansion of research aimed at improving the system for the delivery of health services. The President's Advisory Commission has underscored the need for a research program of broad scope in this area:

"* * * while medicine has participated in the scientific revolution, the provision of care has been little affected by the technological changes. Computers are now a major aid to management in almost every industry, but not in the health care sector. Increasing substitution of capital for labor, and advances in communication and transportation have taken place in many service industries, but not in medical care. Yet, it is only by exploiting the innovations and technologies of other sectors and by developing new techniques appropriate to its own problems that the health care system can adequately respond to social change and scientific advance."

"*Financial support should be made available for large-scale experimental projects* *of integrated health service systems under a variety of auspices including physicians in private practice, universities, hospitals, voluntary agencies, and government. These systems should include, but not be limited to, programs, which are comprehensive, serve a cross-section of socio-economic groups on a community or areawide basis, and emphasize organized services for ambulatory patients.*"[8]

Sources of funds for biomedical research (best judgment estimate).—About two-thirds of the funds for biomedical research are currently supplied by agencies of the Federal Government. By 1985, the proportion is projected to increase to 75 percent.

The assumption that a greater proportion of funds for biomedical research will be required of Federal agencies reflects primarily an increased participation by the National Institutes of Health, as the principal Federal medical research agency, as well as other agencies of the Federal Government supporting medical research germane to their agency missions—such as research to support the life systems required for further explorations in space, the need for further research to combat the hazards of atomic energy development, and the requirements of the defense agencies in maintaining the health of Armed Forces for deployment in other areas of the world.

Moreover, over the next 20 years, a greater utilization of the research capabilities of industrial organizations will be required.[9] But the costliness (and the uncertain payoffs) of this research probably will require the Federal Government to provide an increased proportion of the funds supporting biomedical research in industry, just as the Federal Government now supports almost 90 percent of *all* research performed in the aircraft and missile industry, and three-fifths in the electrical equipment and communications industries.[10]

[8] *Report of the National Advisory Commission on Health Manpower*, Vol. 1, November 1967, pp. 74, 75.

[9] See the report prepared by the Aerospace Corp. for the Director of the National Institutes of Health, *Medical Engineering Development and the Role of the Federal Government*, July 1967, and the report prepared for the U.S. Arms Control and Disarmament Agency, evaluating the use of *Defense Systems Resources in the Civil Sector*, July 1967.

[10] National Science Foundation, *Basic Research, Applied Research, and Development in Industry, 1965*, June 1967, p. 28.

Finally, almost all the biomedical research conducted in the nonprofit sector is currently supported by the Federal Government, and this trend will continue over the next two decades.

Is this a reasonable assumption in relation to the fiscal capability of the Federal Government to provide these seemingly large sums?

Currently, about 1 percent of the Federal budget supports the biomedical research missions of all Federal agencies. Assuming that the Federal budget will approximate about 16 percent of the GNP in the 1970-85 period (the same ratio experienced in the 1957-67 period) then Federal medical research would increase from 1 percent of the Federal budget in 1967 to 2.3 percent by 1975, and 4.6 percent by 1985 (table 8). This would appear to be well within a national commitment for increased support of Federal programs that are aimed at the improvement of the health of the American people.

TABLE 8.—Federally Supported Biomedical Research in Relation to the Federal Budget, 1957–67 and Projections to 1985

Year	GNP (billions)	Administrative budget		Federal biomedical research	
		Amount (billions)	Percent of GNP	Amount (billions)	[Pe]rcent of administrative budget
Current dollars:					
1957	$441	$69	16.0	$.2	.3
1962	560	88	16.0	.8	.9
1967	785	127	16.0	1.5	1.2
1967 dollars:					
1970	886	142	16.0	2.0	1.4
1975	1,077	172	16.0	4.0	2.3
1980	1,310	210	16.0	7.1	3.4
1985	1,594	255	16.0	11.7	4.6

Source: *Gross National Product*—Tables 1 and 6. *Administrative Budget*—1957–67: The Budget of the United States Government, fiscal year ending June 30, 1968, p. 460; 1970–80 based on 16 percent of GNP. *Federal biomedical research*—National Institutes of Health.

Relation of biomedical research expenditures to total health expenditures.—In 1965, national expenditures for health totaled $39 billion (in current dollars); in that year biomedical research expenditures of $1.8 billion (in current dollars) represented 5 percent of total health expenditures.

By 1975, total expenditures for health may exceed $100 billion (in current dollars) based on the estimates for health services and supplies of $94 billion (the major component of the total health bill, excluding research and construction, made by the President's Commission on Health Manpower [11]). In current dollars, biomedical research expenditures under the best judgment projection are estimated at $6.2 billion, by 1975, or about 6 percent of the projected health expenditures total. In terms of this relationship, therefore, the projected biomedical research expenditures also appear to be well within the commitment for better health for the American people.

Performers of medical research, 1970–85 (best judgment estimate).—How will the total biomedical research effort, in terms of dollar expenditures, be reflected by the research performed by each of the three major sectoral performers, Government, industry, and the nonprofit sector?

Historically, and projected for the period to 1985, the preponderance of support for medical research will be provided by the agencies of the Federal Government. But Federal agencies will continue to look to investigators in the nonprofit research sector and in American industry for an increasing proportion of the biomedical research necessary to further agency missions and objectives. In 1967, about 16 percent of all biomedical research was performed by federally employed scientists: this proportion is projected to decline to 12 percent by 1985.

The greater involvement of engineering and the physical sciences in research leading to the development of and application of new medical products and processes will require a greater participation by industry in the performance of biomedical research. The proportion of biomedical research funds accounted for in the industrial sector is conservatively projected to increase from 30 percent in 1967 to 36 percent by 1985, reflecting not only the increased *levels* of biomedical research performed in this sector, but also the higher costs of developmental research as compared with investigations of a more fundamental nature.

By 1985, investigators in the Nation's institutions of higher education, hospitals, and nonprofit research institutes will have available about the same proportion of the Nation's investment in medical research as in 1967. Currently, about 54 percent of the dollar total supports these explorations in the nonprofit sector, by 1985 it is projected to 52 percent. These projections are detailed in table 9.

Professional manpower for biomedical research, projections to 1985.—Having developed projected estimates of the level of *dollar* expenditures available for biomedical research in each of the major sectoral performers, it is now possible to estimate *the numbers of professional manpower required.* The procedure followed in projecting biomedical research manpower to be supported by the projected level of biomedical research expenditures is as follows:

TABLE 9.—National Support for Performance of Biomedical Research, by Sector, 1967, and Best Judgment Projection to 1985

[In 1967 dollars]

Year	Amount (billions)				Percent of total [1]			
	Total	Federal	Industry	Nonprofit institutions	Total	Federal	Industry	Nonprofit institutions
1967	$2.3	$.4	$.7	$1.2	100	16	30	54
1970	2.9	.4	.9	1.6	100	15	30	55
1975	5.5	.8	1.9	2.8	100	14	34	52
1980	9.7	1.3	3.4	5.0	100	13	35	52
1985	15.7	1.9	5.6	8.2	100	12	36	52

[1] Computed on the unrounded data.

Source: National Institutes of Health.

[11] *Report of the National Advisory Commission on Health Manpower*, vol. 1, November 1967, p. 35.

In 1965, there were 64,000 professional workers [12] engaged in biomedical research in Government, industry, and the nonprofit sector which encompasses academic institutions as well as research institutes and hospitals. (See app. B.)

For each of the three sectors, a professional manpower total for 1965 was established. By relating these numbers of manpower to the dollar totals for each of the sectors, the expenditures per professional worker (in 1967 dollars) in 1965 for each of the three sectors have been derived. In projecting manpower requirements, a careful examination has been made of the best data available on cost per professional research worker in each of these sectors. These costs have been increasing at a rate of 6 percent per annum and 7 percent per annum in Government and industry, respectively, where the preponderance of those engaged in biomedical research devote full-time to such activities. In the nonprofit sector, the bulk of professional workers engaged in research combine this activity with teaching or service or both. The best data available for research in academic institutions developed by the National Science Foundation suggests that cost per man soared roughly 10 percent per annum between 1958 and 1964.[13]

In developing manpower projections under the best judgment projection of biomedical research expenditures, it has been assumed that cost per professional worker engaged in biomedical research in the nonprofit sector will continue to rise 6 percent per annum, in constant dollars, 1965–85; 6 percent in the Government sector, and 7 percent in the industry sector. This assumption appears to be a prudent view of the future; it is considerably beneath the 10 percent per annum increase (which includes *all* staff engaged in research) reported as experience data by the National Science Foundation.

The increase in cost per worker in the industrial sector reflects the result of manpower studies conducted jointly by the Pharmaceutical Manufacturers Association and the National Institutes of Health of research manpower in the pharmaceutical industry.[14]

Expenditures per professional worker will continue to rise to 1985 as a reflection of the following factors:

- greater use of more complex, automated, and precise instrumentation and other costly research equipment
- the operation of large-scale clinical research facilities and the conduct of large-scale population studies requiring use of computerized techniques
- greater involvement of technicians and supporting staff for the efficient conduct of research by the principal investigator and his collaborators.

The projected estimates of expenditures per professional worker, as shown in table 10, were then related to the dollar totals for each of the sectors for the 5-year periods, 1970, 1975, 1980.

The methodology can be translated into a simple formula:

$$\frac{\text{Projected national expenditures for biomedical research (given sector)}}{\text{Projected expenditures per professional worker (given sector)}} = \text{Projected number of professional workers needed (given sector)}$$

By 1970, about 71,000 professional workers will be engaged in medical research; the number is projected to increase to 100,000 in 1975, to 130,000 in 1980, and 150,000 in 1985.

The methodology followed for the derivation of professional manpower had been utilized in previous studies. In the most recent of these, expenditure per professional worker was estimated to increase eight percent a year. However, recent indications of increases in costs substantiate the more conservative cost estimates used in this report.

[12] The term "professional worker" means M.D.'s, Ph. D.'s and others with less than doctoral training *who functioned as principal investigator and collaborators*. In general, it does not include persons with such training who performed as research assistant; it also excludes technicians and all other supporting personnel. It should be noted, however, that this definition of professional manpower in the Government and industrial sectors could not be so rigorously applied because classification systems for Government personnel and industrial employment practices do not clearly distinguish between these two categories.

[13] National Science Foundation, "Resources for Scientific Activities at Universities and Colleges, 1964." *Reviews of Data on Science Resources*, No. 9, August 1966.

[14] National Institutes of Health, "Trends in R. & D. Manpower in the Pharmaceutical Industry, 1959–65, and 1968," *Resources for Medical Research*, Report No. 8, March 1966.

TABLE 10.—Professional Manpower Engaged in Biomedical Research, and Expenditure Per Worker in 1967 Dollars, by Sector, 1965, and Best Judgment Projection to 1985

[Thousands]

Year	Professional manpower		Federal Government		Industry		Nonprofit	
	Total number	Expenditure per worker	Number	Expenditure per worker	Number	Expenditure per worker	Number	Expenditure per worker
1965	64.0	$30.0	11.8	$25.9	11.9	$46.8	40.3	$20.1
1970	71.0	41.0	12.5	34.7	13.2	65.5	45.3	35.0
1975	100.0	55.5	17.0	46.4	20.7	92.0	62.3	46.9
1980	130.0	75.0	20.8	62.1	26.9	129.1	82.3	62.7
1985	150.0	104.5	22.5	83.1	31.0	181.1	96.5	84.0

NOTE.—Expenditures per professional worker computed on unrounded figures for numbers of workers and biomedical research expenditures by sector.

Source: National Institutes of Health.

TABLE 11.—Total Professional Manpower for Biomedical Research, 1965, and Additions to the Medical Research Professional Labor Force, Best Judgment Projection to 1985

[Thousands]

Item	1965/1970	1970/1975	1975/1980	1980/1985
a. Professional manpower, beginning of period	64.0	71.0	100.0	130.0
b. Plus: Total additions in 5-year period for	15.3	38.8	43.0	37.0
c. Less: (1) Replacement of losses for the 5-year period due to deaths, retirements, occupation shifts of professional manpower (shown on line a)	7.9	8.7	11.8	16.0
d. Less: (2) Replacement of losses for the 5-year period, due to deaths, occupation shifts of additions to manpower (shown on line b)	.4	1.1	1.2	1.0
e. (3) New additions to manpower	7.0	29.0	30.0	20.0
f. Equals:				
Professional manpower at end of period (also sum of lines a + e)	71.0	100.0	130.0	150.0

Note on Methodology.

The numbers of principal investigators and their collaborators in biomedical research at the end of each 5-year period were derived by relating the estimated dollar total for the performance of medical research by sector—Government, industry, nonprofit institutions—to the estimated expenditure per professional worker in each of these performer categories, for each of the 5-year periods. The differences between the numbers of persons actually engaged in medical research at the end of the successive 5-year periods represent only a portion of the actual manpower additions, since replacements are also required for those who have died, who have retired, or have given up their research work for some other activity. The numbers required as replacements for these attrition losses were estimated as follows:

1. An age distribution of the professional workers in medical research at the end of 1965 (designated as cohort 1) was derived from data provided by the National Science Foundation register of scientists, and from tabulations prepared by the American Association of Medical Colleges.

For each of the 5-year periods from 1965 to 1985, the number of deaths among the cohort 1 workers was based on the 1964 life tables published by the National Center for Health Statistics. Retirement from research was fixed at age 65. The estimates for shifts in occupation were based on the changes in occupation among Ph. D. degree holders published in *Profiles of Ph. D.'s in the Sciences*, a summary report on followup of doctorate cohorts, 1935-60, National Academy of Sciences, Pub. 1293.

2. Persons engaged in medical research for the first time after 1965 (cohort 2) were estimated to be at an average age of 30 at time of entering into biomedical research. Deaths for this group were also computed for each of the next 5-year periods, and occupation shifts for this cohort were also based on the experience reported in *Profiles of Ph. D.'s in the Sciences*. (Of course, no retirements for this and successive cohorts were estimated for the entire period, i.e., none of these groups will have reached the retirement age before 1985.)

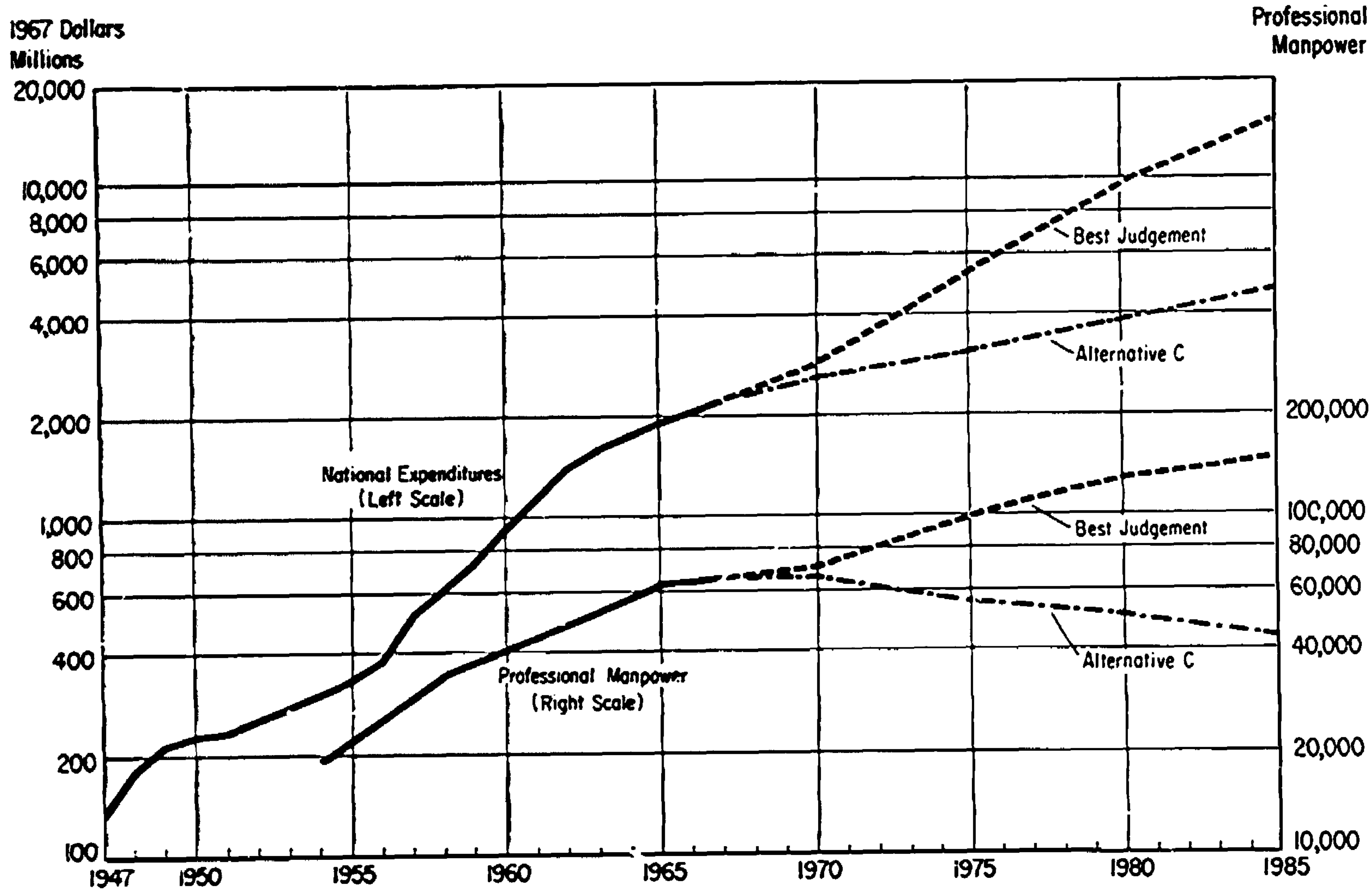
3. For each of the successive cohorts (cohort 3—entering biomedical research after 1970 at an average age of 29, cohort 4—entering after 1975 at an average age of 28, and cohort 5—entering after 1980, at an average age of 27), the same methodology was used to estimate deaths and occupation shifts for the periods 1970 to 1985.

Losses due to attrition approximate 2 percent of the work force per year for the period 1965-85.

Source: National Institutes of Health.

CHART 4

National Expenditures and Professional Manpower for Biomedical Research, 1947–67 and Projections to 1985[1]



1/ In Constant 1967 Dollars

Source: National Institutes of Health

TABLE 12.—Professional Manpower for Biomedical Research, 1965, Attrition and Additions, by Sector, Best Judgment Projection to 1985

[Thousands]

Item	Total	Government	Industry	Nonprofit institutions
1965 total	64.0	11.8	11.9	40.3
Less: attrition	8.3	1.6	1.6	5.1
Plus: additions	15.3	2.3	2.9	10.1
Equals 1970 total	71.0	12.5	13.2	45.3
Less: attrition	9.8	1.7	2.0	6.1
Plus: additions	38.8	3.2	9.5	23.1
Equals 1975 total	100.0	17.0	20.7	62.3
Less: attrition	13.0	2.3	2.5	8.2
Plus: additions	43.0	6.1	8.7	28.2
Equals 1980 total	130.0	20.8	26.9	82.3
Less: attrition	17.0	2.9	3.3	10.8
Plus: additions	37.0	4.6	7.4	25.0
Equals 1985 total	150.0	22.5	31.0	96.5
Summary:				
Attrition, 1965–85	48.1	8.5	9.4	30.2
Additions, 1965–85	134.1	19.2	28.5	86.4

Source: National Institutes of Health.

It is recognized that the rate of increase in expenditure per professional worker is a critical element in projecting manpower requirements. If the true expenditures per worker turn out to have been overestimated, then the projected number will have been underestimated; conversely, if the actual expenditures per worker are underestimated, then the projected manpower requirements are too high.

Based upon these assumptions, 150,000 professional workers would be needed by 1985, if the level of national expenditures for biomedical research reaches 1 percent of GNP (chart 4). But that level of participation in medical research will require 134,000 additional professional workers between 1965 and 1985 (chart 5). Of this number, approximately 48,000 will replace those lost through attrition (death, retirement, and shift to other activities) in the 1965–85 period; 86,000 will be net new additions to provide for expansion in line with the projections, from 64,000 in 1965 to 150,000 by 1985.

The number required to enter medical research by 5-year intervals, 1965–85, is indicated in table 11 which also shows the numbers needed for replacement, and for expansion. A distribution of these additions, by sector, is shown in table 12 and by level of training in table 13.

The composition of the professional work force for medical research in terms of the entering cohorts is shown in chart 6. Of the 64,000 in medical research in 1965 (cohort 1), it is estimated that 30,000 will still be active by 1985; they will then constitute one-fifth of the 150,000 estimated total for that year. Of the 15,000 entering medical research as principal investigators after 1965 (cohort 2), about 12,000 will remain in the field by 1985 or about 8 percent of the 1985 total. Approximately three-fourths of the 1985 professional manpower force will thus be made up of persons with 15 years or less of top-level research experience—33,000 drawn from cohort 3 (entering after 1970); 39,000 from cohort 4 (entering after 1975); and 36,000 from cohort 5 (entering after 1980).

TABLE 13.—Professional Manpower for Biomedical Research, 1965, Attrition and Additions, with Estimated Distribution by Degree Level, Best Judgment Projection to 1985

[Thousands]

Item	Total	M.D.	Ph. D. bio-sciences	Ph. D. other	Less than doctoral
1965 Total	64.0	17.0	21.3	10.7	15.0
Less: attrition	8.3	1.8	3.3	1.7	1.5
Plus: additions	15.3	4.6	5.5	3.6	1.6
Equals 1970 total	71.0	19.8	23.5	12.6	15.1
Less: attrition	9.8	2.6	3.6	1.8	1.8
Plus: additions	38.8	6.5	15.5	7.5	9.3
Equals 1975 total	100.0	23.7	35.4	18.[illegible]	22.6
Less: attrition	13.0	3.3	4.8	2.5	2.4
Plus: additions	43.0	7.0	20.8	11.2	4.0
Equals 1980 total	130.0	27.4	51.4	27.0	24.2
Less: attrition	17.0	4.2	6.4	3.5	2.9
Plus: additions	37.0	6.4	17.9	9.7	3.0
Equals 1985 total	150.0	29.6	62.9	33.2	24.3
Summary:					
Attrition, 1965–85	48.1	11.9	18.1	9.5	8.6
Additions, 1965–85	134.1	24.5	59.7	32.0	17.9

NOTE.—The age distribution of Ph. D.'s in research, 1965, is derived from the National Register for Scientists and Engineers. The age distribution of M.D.'s in research is assumed to be comparable to the age distribution of full-time M.D. faculty in medical school based upon the faculty roster maintained by AAMC. The notes to table 11 set forth attrition methodology. It should be emphasized that this is assumed attrition. Empirical studies are needed to provide a sounder base for estimating (1) how many M.D.'s enter research, (2) how long they remain active in research, (3) when they shift to other activities such as full-time clinical practice or administration, and (4) what the actual attrition rate is for this subpopulation.
Source: National Institutes of Health.

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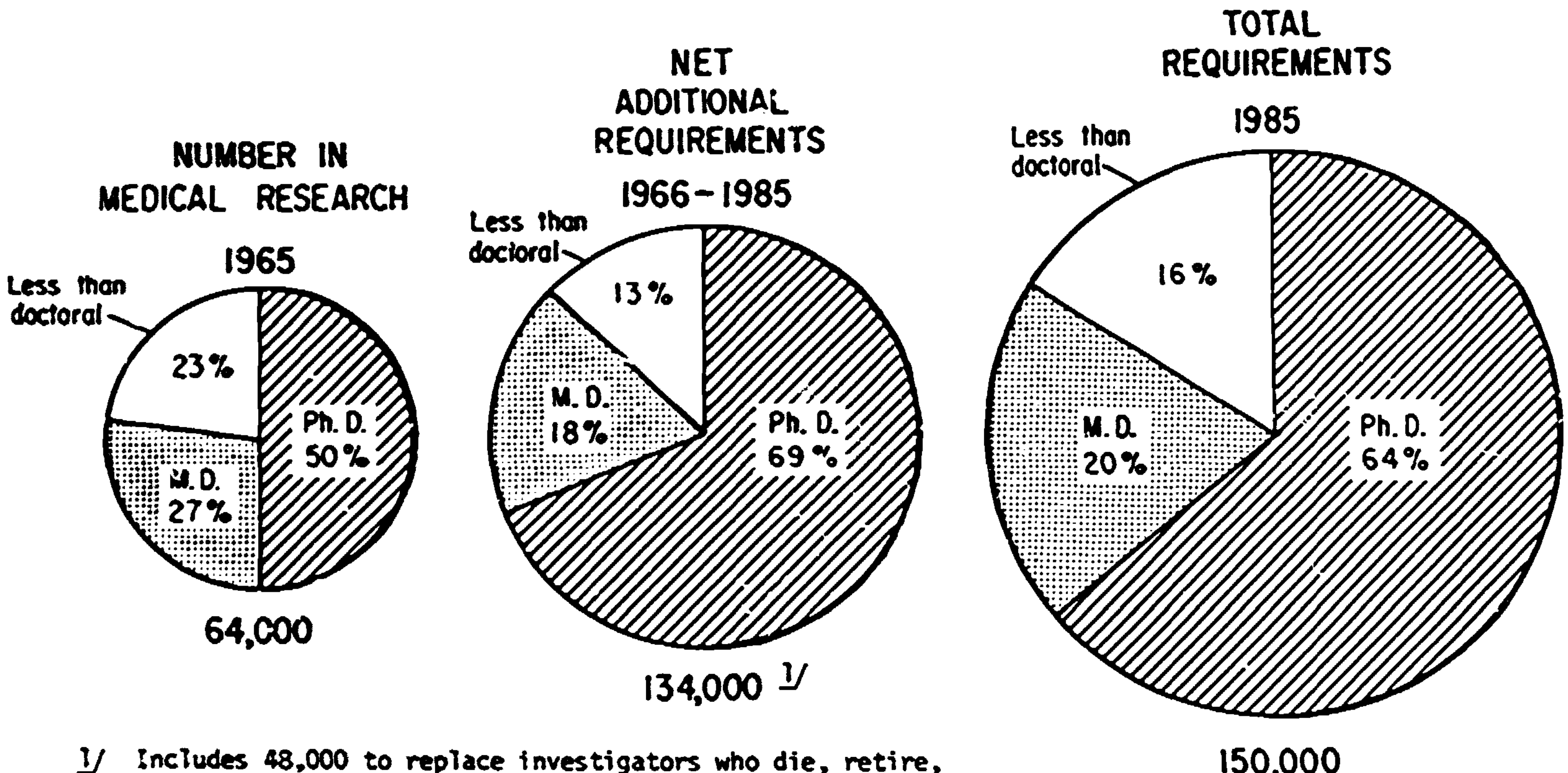
CHART 5

Manpower for Biomedical Research with Distribution by Degree, 1965–85



1/ Includes 48,000 to replace investigators who die, retire, or shift to some other occupation, and 86,000 needed for expansion of research manpower labor force.

Source: National Institutes of Health

RAB-OPP-NIH
May 1968

Other alternative projections.—Before accepting the best judgment estimate, several alternative approaches to estimating biomedical research manpower needs were explored. First, it has already been indicated that an alternative projection was developed, assuming that the stringent budgetary restrictions on nondefense Federal expenditures would continue indefinitely. The proposed Federal support of medical research for 1968 (in 1967 dollars), when coupled with best estimates of funds provided from non-Federal sources indicates an increase of 6 percent over 1967 in national investment for medical research; for 1969, an increase of 4 percent over 1968 is projected. Since this 4 percent increase is consonent with the 4 percent projected increase in GNP, positing a continuation of the 4 percent per annum rate of growth for biomedical research means that national biomedical research expenditures would remain as a constant proportion (.29 of 1 percent) of GNP from 1967 through 1985. What are the implications for manpower requirements under this alternative?

Secondly, what would be the consequences of a diminished growth rate, as compared with the best judgment projection, whereby national expenditures for biomedical research reached .6 or .8 of 1 percent of GNP by 1985?

Thirdly, what level of biomedical research expenditures would be commensurable with the utilization of the total supply of doctoral trained manpower? Fourthly, what would be necessary to meet the high priority staffing requirements of the nonprofit sector by 1975? Each of the varying assumptions has been examined in terms of their probable consquences for biomedical manpower requirements for research, teaching, and related service activities.

In the discussion relating to the best judgment projection, it has been assumed that national expenditures for biomedical research would grow at a considerably less rapid rate than it did during the 20 years following World War II, reaching 1 percent of GNP by 1985. While the 1 percent assumption appears reasonable, alternative assumptions would result in different estimates of (1) the 1985 level of national expenditures for biomedical research, and (2) manpower requirements for biomedical research, teaching, and related activities, 1967–85. Consequently, the manpower implications of each of three alternative assumptions relating projections of national expenditures for biomedical research to GNP projections have been examined.

If national expenditures for biomedical research remain constant as a proportion of GNP (alternative C), the Nation's investment in health research would rise from the present level of $2.3 billion to $4.6 billion in 1967 constant dollars by 1985—an increase approximately 55 percent over an 18-year period (chart 4). However, as indicated in table 5, the compound growth rate under this assumption would drop to 4 percent—2 percent less than the 6 percent annual increment in cost per professional worker. The consequences flowing from this assumption are stark and clear:

1. Twenty thousand fewer professional workers would be involved in biomedical research, training, and related service activities in 1985 than in 1967 (table 14).
2. The average annual increment (1970–85) in national expenditures for biomedical research from all sources—public and private—would approximate $130 million.

If it is assumed that biomedical research expenditures rise to .6 of 1 percent of GNP by 1985, a level of $9.5 billion would be reached by 1985 as indicated in table 5; if this proportion increases to .8 of 1 percent, then national expenditures for biomedical research would approach $13 billion ($12.7 billion) by 1985.

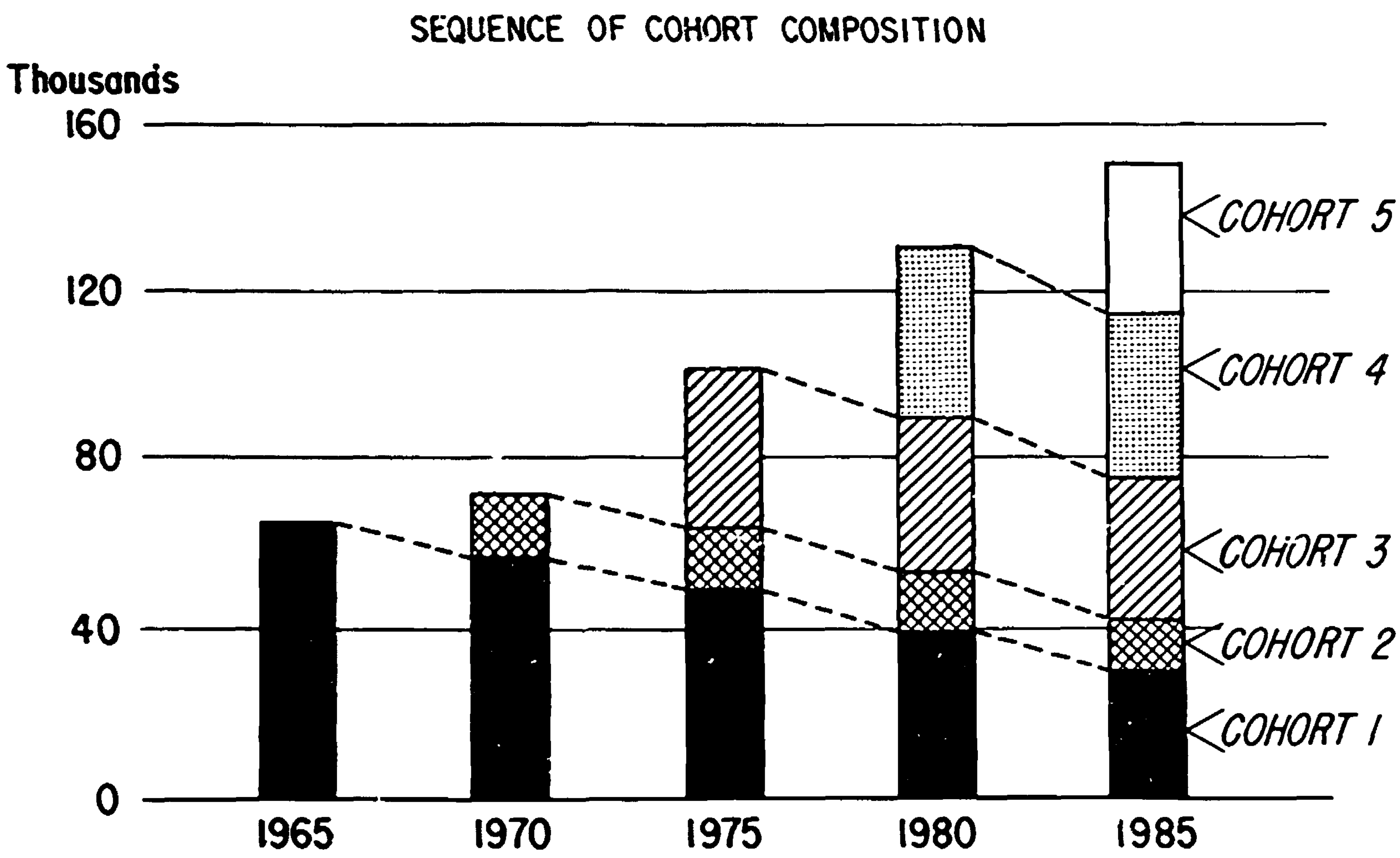
The implications of these three alternative assumptions for biomedical manpower requirements for research, teaching, and related service activities are summarized below (table 14) in relation

TABLE 14.—Alternative Projections of Biomedical Research Manpower Requirements, 1965–85

Biomedical research manpower requirements	Assumptions			
	1985 National expenditures for biomedical research as percent of GNP			
	Best judgment (1 percent)	Alternative A (.8 of 1 percent)	Alternative B (.6 of 1 percent)	Alternative C (.29 of 1 percent)
	Manpower (in thousands)			
1. Gross additions, 1965–85	134	104	70	17
2. Attrition, 1965–85	48	46	43	37
3. Net additions, 1965–85	86	58	27	−20

CHART 6

Professional Manpower for Medical and Health-Related Research, 1965–85



Source: National Institutes of Health

RAB-OPP-NIH
May 1968

TABLE 15.—Professional Manpower Requirements, 1965, and Projected Attrition and Additions—Based upon Alternative Estimates of Biomedical Research as a Proportion of GNP

[Thousands]

Item	Best judgment [1]	Alternative A [2]	Alternative B [3]	Alternative C [4]
1965 total	64.0	64.0	64.0	64.0
Less: attrition	8.3	8.3	8.3	8.1
Plus: additions	15.3	15.3	15.3	7.5
Equals 1970 total	71.0	71.0	71.0	63.4
Less: attrition	9.8	9.7	9.3	8.3
Plus: additions	38.8	32.4	19.3	.9
Equals 1975 total	100.0	93.7	81.0	56.0
Less: attrition	13.0	12.3	11.2	9.2
Plus: additions	43.0	31.9	18.2	3.9
Equals 1980 total	130.0	113.3	88.0	50.7
Less: attrition	17.0	15.7	13.9	11.1
Plus: additions	37.0	23.9	16.9	4.4
Equals 1985 total	150.0	121.5	91.0	44.0
Gross manpower additions: 1965–85	134.1	103.5	69.7	16.7
Attrition: 1965–85	48.1	46.0	42.7	36.7
Net manpower additions	86.0	57.5	27.0	−20.0

[1] Best judgment projection based on assumption that national biomedical research expenditures will increase as a proportion of GNP from .29 of 1 percent in 1967, and .33 of 1 percent in 1970, to .98 of 1 percent in 1985.
[2] Alternative A is based on the assumption that from 1970 to 1985 national biomedical research expenditures will increase uniformly as a proportion of GNP from .33 of 1 percent in 1970, to .8 of 1 percent by 1985 (approximately .03 of 1 percent a year).
[3] Alternative B is based on the assumption that from 1970 to 1985, national biomedical research expenditures will increase uniformly as a proportion of GNP from .33 of 1 percent in 1970 to .60 of 1 percent) in 1985 (approximately .018 of 1 percent a year).
[4] Alternative C is based on the assumption that national biomedical research expenditures, as a proportion of GNP, will remain constant, 1970–85, at the 1967 proportion of .29 of 1 percent of GNP.

Source: National Institutes of Health.

to the earlier assumption that national expenditures for biomedical research might reach 1 percent of GNP by 1985.

The difference in net additions would range from a reduction of 20,000 (assuming national biomedical research expenditures as a constant proportion of GNP) to 86,000 (assuming that the projected level of 1 percent of GNP by 1985 is realized).

Table 15 provides detail by 5-year periods of professional biomedical manpower requirements (including attrition and additions), under each of the alternative projections.

Projecting biomedical research expenditures as a function of manpower supply.—None of these foregoing projections takes into account manpower supply—the probable size of the doctorally trained labor force likely to be available for biomedical research, teaching, and related service activities. If the intermediate output estimates of M.D.'s, and the projected supply of Ph. D.'s in the sciences are realized, then approximately 170,000 professional workers would be available for employment in these activities by 1985. This would represent an increase of 20,000 professional workers—one-seventh above the number needed by the 1 percent of GNP estimate. The composition of this larger group is shown in table 16.

Approximately 170,000 professional workers at $104,500 cost per man in 1985 would result in a national expenditure for biomedical research of $17.8 billion—roughly 1.1 percent of 1985 GNP.

TABLE 16.—Alternative Estimate of Biomedical Research Manpower Requirements, Based on Manpower Supply, 1985

[Thousands]

Item		1985
Total in biomedical research, 1985		170.8
M.D.'s (including D.O., D.D.S., and D.V.M.) in medical research, 1965	17.0	
Plus: intermediate output estimate, 1966–85	[1] 30.8	
Less: attrition (due to deaths, retirements, etc.)	13.8	
Equals: M.D.'s in research, 1985		34.0
Ph. D.'s—		
Biosciences in medical research, 1965	21.3	
Plus: high output 1966–85:		
Basic medical sciences	[2] 54.5	
Other biosciences	[3] 14.4	
Less: attrition (due to death, retirements, etc.)	21.1	
Equals: Ph. D.'s in biosciences in research, 1985		69.1
Other fields in medical research, 1965	10.7	
Plus: additions, 1966–85	[4] 44.4	
Less: attrition (due to deaths, retirements, etc.)	11.6	
Equals: Ph. D.'s in other fields in research, 1985		43.4
Less than doctoral in medical research, 1965	15.0	
Plus: additions, 1966–85	[5] 17.9	
Less: attrition (due to deaths, retirements, etc.)	8.6	
Equals: less than doctoral manpower in research, 1985		24.3

[1] App. E, table 3A.
[2] App. E, table 4A.
[3] App. E, table 5.
[4] Composed of 15,100 from behavioral sciences (app. E, table 6); 14,200 from physical sciences (app. E, table 7); 3,900 from mathematics and statistics (app. E, table 8); 8,200 from engineering (app. E, table 9).
[5] Table 13.

Source: National Institutes of Health.

CHART 7

Medical Schools in the United States

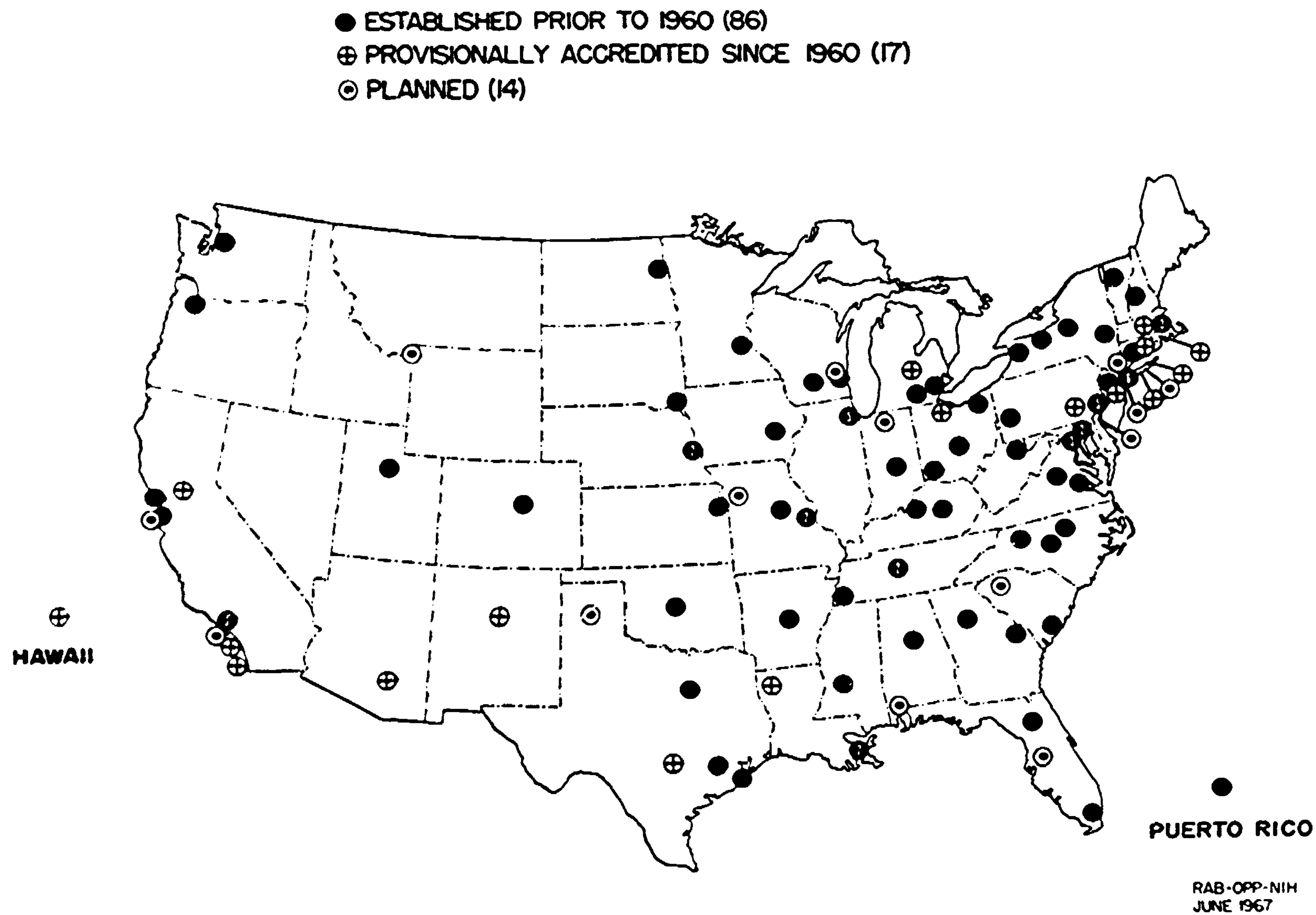
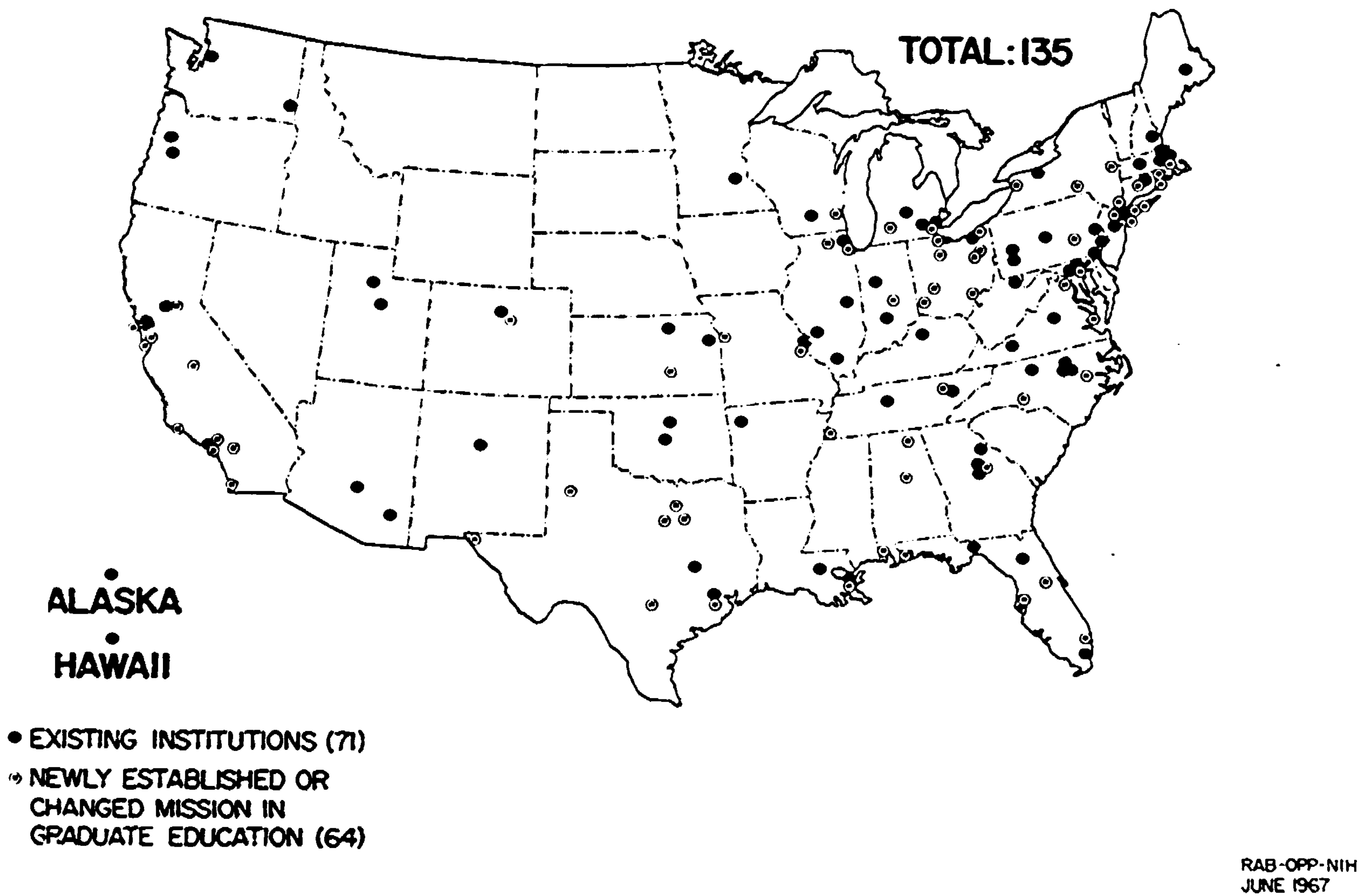


CHART 8

Probable Major Expansions in Graduate Education, 1965–80



This labor force approach yields a projection—in terms of the expenditures for biomedical research—of about 15 percent greater than that derived from the 1 percent of GNP projection.

A note on inflation.—The projected estimates for biomedical research expenditures have been expressed in terms of 1967 dollars. However, expenditures for medical research are usually reported and budgeted in current dollars of the year to which they relate. The GNP real growth rate of 4 percent a year used in this report was coupled by the Joint Economic Committee staff with a projected increase of 1.5 percent a year in prices.[15] If the increase in prices of 1.5 percent a year is projected to 1985, then the constant 1967 dollar best judgment estimates for biomedical research can be converted to current dollars. In 1970, the current dollar estimate for biomedical research will approximate $3.0 billion, as compared with $2.9 billion in 1967 dollars. For 1975, the estimates are $6.2 billion in current dollars compared with $5.5 billion in 1967 dollars; for 1980, $11.8 billion and $9.7 billion, and for 1985, $20.5 billion and $15.7 billion.

D. Anticipated Changes in Medical Education, Graduate Education, Postdoctoral Training, and Continuing Education

Great changes are occurring in the Nation's structure for higher education. To obtain more precise information on the nature and geographic location of these changes, the National Institutes of Health has contracted for a study [16] of the probable major expansions in graduate and professional education, 1965–80. While results from this study will not become available until later this year, progress reports thus far confirm the dimension and character of the probable expansions likely to occur during the decade ahead.

Expansion in numbers of institutions.—Most existing medical schools and graduate schools plan to expand their faculties in the health sciences. In addition, it is expected that a minimum of *25 new* medical schools will be established during the 1965–75 decade. Seventeen of these schools (including the California College of Medicine, converted from the California College of Osteopathy) have already received their provisional accreditation from the Association of American Medical Colleges; [17] seven of the new schools admitted their first classes between 1963 and 1967.[18] Five schools (California-Davis, California-San Diego, Connecticut, Mt. Sinai, and Texas-San Antonio) expect to admit their first students in 1968. Louisiana State-Shreveport and Toledo anticipate students in 1969, Massachusetts in 1970, and New York-Stony Brook in 1971.[19]

Chart 7 shows (1) the existing medical schools as of 1960, (2) the 17 new schools provisionally accredited since 1960, and (3) the possible locations of an additional 10–15 new medical schools. Twenty-five new schools will represent a 30 percent expansion in the number of medical schools.

During the same period, it appears likely that a minimum of 135 major expansions will occur in graduate education (chart 8). Nearly 50 (47) of these major expansions will be located in five States: California (13), Texas (9), New York (9), Ohio (9), and Florida (7). Virtually all of these expansions are taking place in public institutions; in California, Texas, and Florida, they are responsive to rapid growth in population; in New York and Ohio, they reflect implementation of State master plans for higher education substantially enlarging the number and dispersing public institutions on a better geographic distribution within these States.

Some of these expansions reflect the emergence of institutions now granting master's degrees or even doctor's degrees in a few programs into full-fledged universities; some represent the growing tendency of large public institutions to establish

[15] The Joint Economic Committee staff report also projected an annual growth rate of 4.5 percent for GNP, with a 2 percent annual increase in prices. If this growth rate is achieved, then a larger GNP would provide the possibility for allocations of funds for biomedical research exceeding the levels projected in the best judgment estimate.

[16] Cosponsored by the Office of Education, the National Science Foundation, and the Bureau of Health Manpower, DHEW.

[17] *Journal of the American Medical Association*, vol. 198, No. 8, Nov. 21, 1966, p. 851.

[18] Arizona, Brown, Hawaii, Michigan State, New Mexico, Penn State, and Rutgers.

[19] *Journal of the American Medical Association*, vol. 202, No. 8, Nov. 20, 1967, p. 736.

branches in major urban centers; e.g., University of Illinois at Chicago, University of Missouri at Kansas City, University of South Florida at Tampa, University of Wisconsin at Milwaukee; some represent conversions from private institutions to public institutions, e.g., Temple, University of Houston, State University of New York at Buffalo; some represent new institutions established in accordance with State master plans for higher education. It is encouraging to note that many of these newer institutions are giving high priority to the establishment of Ph. D. programs in the health sciences and in the environmental sciences.

Expansion of capacity in existing medical centers.—The recent *Report of the National Advisory Commission on Health Manpower* recommends that "the production of physicians should be increased beyond presently planned levels." [20] The Commission urges that primary dependence must be placed upon expanding the capacity of existing medical schools. The report also emphasizes that:

> "Although faculties of medical schools often resist expansion because they believe it may lower the quality of education, a recent summary of available studies shows that class size is unrelated to academic aptitude of students, achievement on National Board Examinations, attrition rates or ultimate career choices. We see few drawbacks to expansion, and great advantages in terms of saving time, reducing initial investment and overhead expense, and conserving teachers."

Changing role of the university medical center.—As noted in the Coggeshall report,[21] important substantive changes have occurred in medical education:

- Medical education has increased in complexity as the center of attention has shifted from the disease itself to the patient, his environment, and the mechanism of the disease process;
- Patient care has become a major medical school responsibility. As medical schools have assumed responsibility for caring for increasing numbers of patients, they have developed their own hospitals or established controlling affiliations with hospitals sponsored by others;
- Research has grown dramatically in the medical center setting. More and more, research is is considered an essential ingredient in the preparation of a young physician for future professional life, whether he intends to engage in academic activities or practice as a generalist or a specialist.

As this fundamental core has evolved in the modern medical center, integrating education, research, and service, NIH has become increasingly concerned with the support of the academic and institutional base of the medical sciences. However, as depicted on chart 9, national purposes and the emergence of broad social programs have involved the establishment of specialized research institutes in the medical school environment and separately organized health service arrangements which strengthen the linkage and transfer functions between the centers of scientific and academic medicine and community health practice. The specialized research institute in the medical school environment directly reinforces the scientific research activities carried on as one of three basic missions of the school and indirectly strengthens its educational and service capabilities. Similarly, the separately organized health service component of the school, considerably enlarged to meet the mounting demands imposed by Medicare, Medicaid, OEO Neighborhood Health Centers, and Regional Medical Programs, directly fortifies the traditional service responsibilities and indirectly but substantially buttresses the educational and scientific research functions.

To increase the production of physicians and to improve the quality of their professional education, the *Report of the National Advisory Commission* (p. 20) emphasizes the need for:

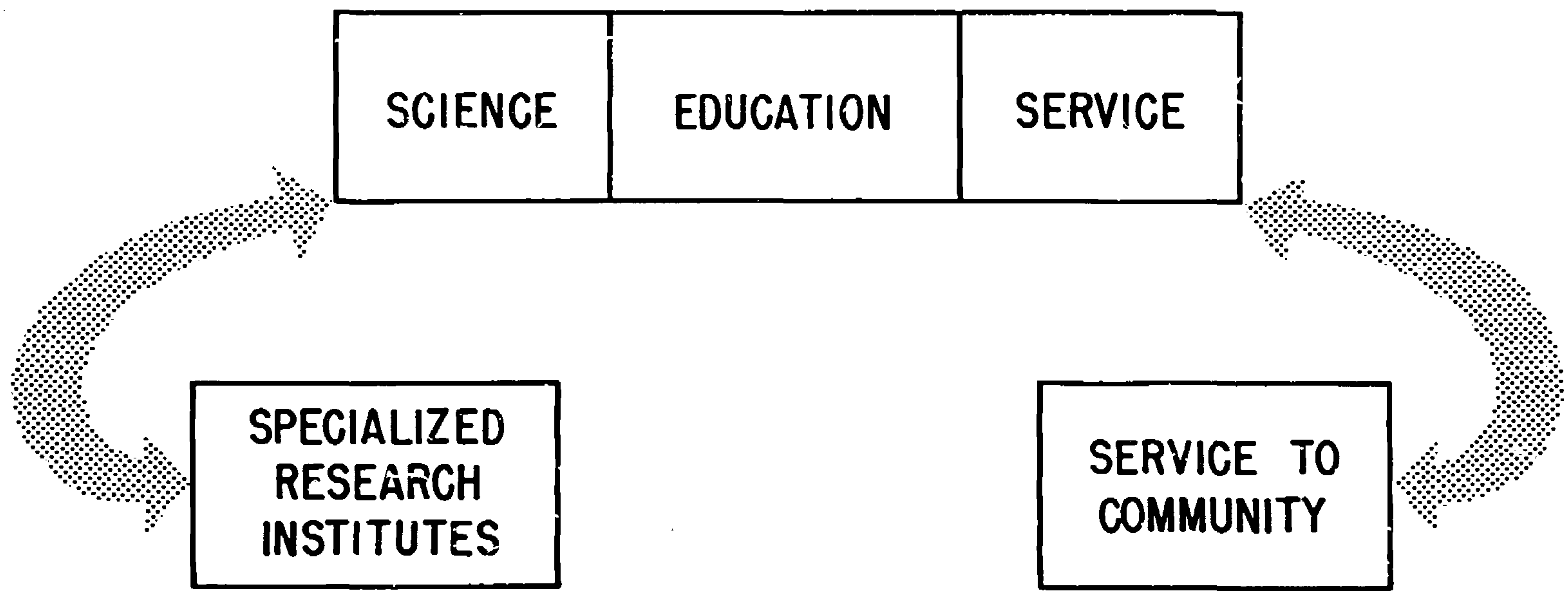
> "Curriculum review aimed at reducing both the length of formal medical education and the length of specialty training * * * an integral part of any expansion plan. By lessening the delay in earning power, such a revision would help to attract additional highly qualified individuals who would otherwise be unable to consider medicine as a career choice. More important, it would release substantial quantities of teaching and physical resources that could then be used to expand educational capacity."

[20] Vol. I, November 1967, p. 19.

[21] Lowell T. Coggeshall, M.D., *Planning for Medical Progress Through Education*, 1965.

CHART 9

Functions of a Modern Medical Center



RAB-OPP-NIH
May 1968

Prospective effect of anticipated curriculum changes in the basic sciences.—Curriculum changes should also be responsive to the changing content of the sciences involved, changes in media and educational technology, and changes in the preparation of students at the secondary school and college level.

At the graduate level, to a large extent, the classical scientific disciplines are being remolded from within. That is, the anatomical sciences and pathology are heavily involved with cellular and molecular biology, and, in significant instances, with the neurosciences. Pharmacology is rapidly being converted to biochemical pharmacology. Microbiology is heavily involved with biochemistry and genetics. Biochemistry is concerned with highly sophisticated bio-organic and biophysical chemistry. Physiology is becoming rapidly oriented towards systems biology and bioengineering. Sensitive to these developments, it is likely that an increasing number of institutions will fuse their departments of anatomy, biochemistry, microbiology, and physiology into modern departments of molecular biology, cellular biology, and systems biology. Other schools may meet these problems by establishing new departments of genetics, biophysics, bioengineering, and the neurosciences. Still others may provide broad graduate training in departments of biology, allowing for specialization as the student's interests and capabilities crystallize.

It is likely that sweeping curriculum changes will be initiated at the college level. Secondary school training in chemistry, mathematics, physics, and biology has been radically upgraded in the post-Sputnik era. In many instances, college students are eager and well prepared for courses in physiology, biochemistry, and biophysics now taught at the graduate level. These new developments are especially pertinent for the planning of NIH training programs in three respects:

1. Teachers will be needed in substantial numbers to provide this advanced undergraduate training;
2. Advanced undergraduate training in the biomedical sciences offers NIH the opportunity to interest a high proportion of talented college students in careers in the health sciences and medicine;
3. Well-planned undergraduate programs can lead to significant improvements in the quality of graduate and medical training and shorten the period required.

Continuing education.—The need for institutionalizing lifetime learning through more effective continuing education programs in the health and scientific fields is widely acknowledged. Within NIH, responsibility for fostering continuing education is shared by Institutes which support specialized continuing education programs, the Bureau of Health Manpower and the National Library of Medicine.

The National Institutes of Health together with the newly formed Health Services and Mental Health Administration provide Federal leadership for continuing education in the biomedical sciences and the health professions. In this connection, the creation of regional cooperative arrangements through the regional medical programs may provide significant new opportunities for the development of effective continuing education activities. The regional nature of the programs can also provide other assets to continuing education and training by providing (1) the opportunity for a close relation of teacher and learner, (2) accessibility of programs, and (3) opportunity to build together links between education and health care.

However, as the report of the National Advisory Commission notes, simply making opportunities for continuing education available will not assure their utilization by busy physicians. To provide an incentive for the physician to keep abreast of the latest medical knowledge, the Commission recommends that:

> "Professional societies and State governments should explore the possibility of periodic relicensing of physicians and other health professionals. Relicensure should be granted either upon certification of acceptable performance in continuing education programs or upon the basis of challenge examinations in the practitioner's specialty."

Whether or not relicensing procedures become a potent consideration, it is likely that the recommendation itself will elicit greater participation in formal continuing education programs. Cooperative arrangements among medical centers, research institutions, and hospitals developed through the regional medical programs should contribute significantly to the quality and scope of continuing education.

E. High Priority Functional Requirements

The aggregate approaches to projecting manpower requirements fail to show explicitly the relationship between (1) aggregate manpower needs, (2) specific manpower needs required to staff specific activities in the national interest, and (3) the graduate education and training programs through which individuals acquire the skills needed to perform such activities. In contrast to these aggregate approaches to projecting future requirements, it is fruitful to concentrate upon a microanalysis of the high priority staffing needs of the crucial nonprofit sector where research, teaching, and service are so inextricably linked.

The use of a microanalytic approach is particularly relevant in considering specific manpower needs in the nonprofit sector. In both Government and in industry the preponderance of those engaged in biomedical research work full time in this activity. In contrast, the preponderance of those conducting biomedical research in the nonprofit sector also teach or render health services or both. Thus, a microanalytic approach can take explicit account of specific high priority staffing needs in the nonprofit sector, especially as these needs are dictated by broad considerations of national interest.

In his memorandum of September 13, 1965, addressed to the heads of all Cabinet Departments and independent agencies, the President enjoined all mission-oriented agencies to contribute to the strengthening of higher education and science. As a consequence of the post-World War II baby boom, the numbers of persons seeking careers coupling biomedical research, teaching, and service will expand rapidly. This surge will be reflected in (1) the expansion of existing centers of excellence, (2) the need for upgrading biomedical training capabilities in schools of lesser quality seeking to realize their potential, and (3) the creation of 25 new medical schools (16 of which are now provisionally accredited) and 150 new graduate schools, of which about one-half plan graduate programs in the biomedical sciences.

Table 17 provides a partial framework for assessing the probable magnitude of these needs in the nonprofit sector, primarily, but not exclusively, for personnel trained through the doctoral level. It should be emphasized that the estimates are *illustrative* of specific high priority staffing needs which can now be anticipated; it is likely that these requirements will be modified both quantitatively and qualitatively as the future unfolds. These staffing needs are directly related to (1) the staffing and upgrading of existing institutions and the establishment of new schools and (2) the pursuit of national biomedical research objectives through a nationwide network of specialized research institutes.

1. *Staffing of medical schools.*—At the present moment, there are approximately *22,500* full-time faculty members in existing medical schools plus an additional 1,000 scattered among the 16 provisionally accredited new medical schools.[22] In the past 15 years, from 1951 to 1966, the full-time faculty in medical schools increased from *4,000* to approximately *18,000*—more than a threefold gain. During this period, the full-time basic science faculty has increased from 1,500 to nearly 6,000. This has permitted an increase in the average number of staff members per basic science department from 3.2 to 9.6.

This expansion in full-time faculty has (1) enabled the schools to provide a higher quality of medical and graduate education than could be accomplished by the use of part-time staff and (2) permitted the mounting of extensive research programs which have now become an integral characteristic of the medical school environment. It is to this full-time staff of scientists, engineers, and academic physicians that the Nation must now look in the decades ahead for innovation in the development of new systems of health care that will provide new tools to the physician, such as the automation of diagnostic methods, the use of computers to provide new sources of scientific knowledge to the physician engrossed in the immediate problems of patient care, and for the development of sophisticated techniques by which the latest advances in medical research can be brought directly to bear on the delivery of health services.

Looking ahead one can foresee staffing requirements to (1) facilitate the expansion of existing schools, (2) foster the upgrading of existing schools, and (3) enable the establishment of new schools.

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[22] Based upon data reported by medical schools for medical school faculty roster, 1965–66, maintained by AAMC. The 1965–66 totals have been increased by 7 percent to reflect the probable increment in 1966–67.

TABLE 17.—Illustrative List of High Priority Staffing Needs for Nonprofit Sector, 1967–75

Area of need	Number of institutions		Professional manpower	
	1967 base	1967–1975	1967 base	Needed by 1975
I. Medical Schools				
A. Expansion of existing schools	87	87	22,500	36,000
B. Upgrading of existing schools	40	40	(6,000)	[1] (11,000)
C. Establishment of new schools	16	25	1,000	6,000
II. Other Health Professional Schools [2]				
A. Expansion of existing schools	75	75	2,200	4,000
B. Upgrading of existing schools	25	25	(450)	(900)
C. Establishment of new schools	5	20	100	1,000
III. Biomedical Components of Graduate Schools [3]				
A. Expansion of existing schools	75	75	5,000	8,000
B. Upgrading of existing schools	25	25	(1,000)	(2,000)
C. Establishment of new schools	25	75	400	2,000
IV. Staffing of Specialized Biomedical Research Centers				
A. Cancer research centers	3	10	(000)	(2,000)
B. Myocardial infarction research units [4]	5	12	(60)	(650)
C. Cardiovascular research and training centers	1	12	(50)	(1,400)
D. Eye research institutes	13	20	(150)	(400)
E. Head injury research centers	4	12	(40)	(180)
F. Dental research institutes [5]	0	9	0	(1,350)
G. Pharmacology-toxicology research centers	3	12	(75)	(500)
H. Environmental health research and training centers	3	25	(50)	(400)
I. Mental retardation research centers [6]	0	12	0	(900)
J. Institutes for the study of aging	0	4	0	(360)
K. General clinical research centers	91	125	(400)	(1,000)
L. Biomedical computing centers	43	60	(250)	(500)
M. Biochemical, instrumentation, biological materials production, and scientific information centers	16	30	(200)	(360)
N. Regional primate research centers	7	10	(150)	(300)
V. Research and Continuing Education Staffing of Community Hospitals in Regional Medical Program Network	0	4,000	0	[7] 6,000
VI. Biomedical Faculty for Advanced Undergraduate Education	0	200	0	1,000
Total			[8] 31,200	[8] 64,000

[1] Numbers in parentheses () are not additive; they are already encompassed in national estimates for biomedical research or they involve part-time faculty participation.

[2] Other health professional schools include schools of dentistry, veterinary science, pharmacy and public health. Data for 1967 are projected forward from the 1965 base. For the short-term needs of dental schools, see *Manpower for Dental Research*, 1963, 1970, National Institute of Dental Research, May 1962.

[3] Biomedical components include graduate programs in anatomy, biochemistry, molecular biology, cell biology, genetics, pharmacology, physiology, pathology, bioengineering, behavioral sciences (excluding clinical psychology), neurosciences, biomathematics, and environmental sciences. Programs planned by new graduate schools are discussed in a progress report to NIH on the *Study of the Future of Higher Education, 1965–1985*, Academy for Eductional Development, Inc., Oct. 1, 1967 (unpublished). The final report of this study dealing with probable major expansions of graduate and professional education, should be available early in 1969.

[4] The total of 13 myocardial infarction research units by 1975 is expected to be supplemented by about 50 clinical testing units. The total staff for both types of units is expected to be 650 by 1975.

[5] The first five Dental Research Institutes were funded in fiscal year 1967, staffing not begun.

[6] All 12 centers have been funded for construction on a 3 to 1 matching basis by the National Institute of Child Health and Human Development.

[7] The estimate of 6,000 full-time equivalent professional workers for research and continuing education staffing of community hospitals in the regional medical program network by 1975 is believed to be conservative. It is estimated that 1½ to 2 full-time equivalent health and medical professional personnel will be involved per hospital. Staff of the division of regional medical programs estimates that the number of community hospitals participating in the RMP network may well exceed 4,000 and reach 5,000 by 1975; if this estimate proves valid, an additional 2,000 full-time equivalent professional workers would be needed.

[8] The professional manpower estimates of 64,000 by 1975 for the high priority staffing needs (and the related 1967 base of 31,200) cover only the designated components of the nonprofit sector and, therefore, do not encompass total requirements for professional research manpower in this sector. Specifically omitted from the 1967 total are investigators who are exclusively engaged in biomedical research in the hospital setting, in undergraduate science departments of liberal arts colleges and universities, in nonprofit research institutes, and scientific associations. However, a considerable proportion of these additional requirements for 1975 are included implicitly in the needs of the high-priority group since it may be assumed that investigators conducting research in these settings, will increasingly hold staff appointments at another component of the nonprofit sector, i.e. a combination of a staff appointment at a medical school and participation in biomedical research at a hospital.

Enrollment at existing schools could double, as a conservative estimate, by 1975. This includes medical students, graduate students, and postdoctoral fellows. If medical student enrollment nears the high estimate, the increase in total enrollment would approximate 125–150 percent. To accommodate this doubling of enrollment, it is estimated that 36,000 faculty members—a 60 percent increase over 1967—would be required by 1975. This assumes that approximately 8,500 would be needed by the top 37 schools—an average of 230 per school or 40 per year, 1967–75.

About 5,000 additional faculty would be needed to upgrade the bottom 40 schools. The estimate of 5,000 additional faculty assumes that each of these schools will reach the minimum critical mass of $1.5 million in medical research (in 1967 constant dollars) by 1975. A minimum of 75 biomedical scientists—an average of three per department—would be needed by each of these institutions (75×40=3,000). An additional 50 faculty members per school would be needed to improve the quality of medical education and to meet rising service needs.

The total of 6,000 faculty for the 25 new medical schools assumes an average of 250 full-time faculty per new school by 1975. The study of six new medical schools established during the fifties suggested a need for 400 faculty per school.[23] While the lower figure of 250 seems more realistic for 1975, because only 13 of the 25 new schools will have admitted their first class before 1970, more rapid growth in staffing toward an average of 400 per school is a slim but not unlikely possibility.

2. *Staffing other health professional schools.*—At the present time, there are 49 schools of dentistry, 75 schools of pharmacy, 18 schools of veterinary medicine, 13 schools of public health, and five schools of osteopathy.[24] Last year, 79 of these other health professional schools each had less than a $1.5 million research base (49 dental schools, 11 schools of veterinary medicine, six schools of public health, eight schools of pharmacy, and five schools of osteopathy). These 79 schools already receiving General Research Support awards from NIH (reduced to 75, assuming that four schools reached the critical research mass of $1.5 million this year) were taken as the base of existing institutions.

To accommodate expanding enrollment and to strengthen the science base in these existing schools, it is estimated that 4,000 faculty will be needed by 1975. This represents an increment of 1,350 faculty members at the top 50 of these schools—a 60 percent increase, averaging 27 per school, or three to four per year.

The increment for upgrading the bottom 25 of these schools (weakest in biomedical research) represents a 100 percent increase, averaging about 18 per school—or slightly better than two faculty additions per year.

It is estimated that 20 new other health professional schools will require about 50 faculty per school, totalling 1,000.

3. *Staffing biomedical components of graduate schools.*—It is estimated that graduate enrollment in the biomedical sciences will double 1967–75.[25] To cope with this surge in enrollment, it is estimated that an increase of 60 percent in the number of faculty will be needed (5,000 in 1967 to 8,000 in 1975). It is suggested that one-third of the increase be allocated to upgrading the bottom 25 graduate schools with significant programs in the biomedical sciences.

A progress report on *The Future of Higher Education, 1965–1985*[26] pinpoints the major planned expansions in graduate and professional education. It is estimated that 150 new graduate schools will be established during this period.[27] Of these, about one-half will offer Ph. D. programs in the health sciences and the environmental sciences. NIH has primary responsibility for training future faculty in disciplines central to the accomplishment of NIH missions. Illustrative of these disciplines leading to the Ph. D. degree are anatomy, biochemistry, molecular biology, cell biology, pharmacology, physiology, pathology,

[23] National Institutes of Health, *Development of Staffing Patterns in Six New Medical Schools Established 1952–1960*, November 1965.

[24] U.S. Department of Health, Education, and Welfare, *Health Resources Statistics*, 1965, PHS Pub. No. 1509. Numbers of schools of public health reported in *Hearings before Subcommittee of the Committee on Appropriations, Departments of Labor, and Health, Education, and Welfare Appropriations for 1968*, pt. 4, 90th Cong., 1st sess., April 1967, p. 247.

[25] See ch. IV, table 22.

[26] Prepared for the National Institutes of Health by the Academy for Educational Development, Inc., October 1967 (unpublished).

[27] See app. D for a listing of locations of new graduate schools.

bioengineering, behavioral sciences (excluding clinical psychology), biomathematics, and the environmental sciences.

Spread over these disciplines, approximately 3,000 faculty will be needed by existing institutions (1,000 of whom will contribute to the upgrading of existing institutions with significant potential for advancement) and an increment of about 1,600 will be required by the newly established biomedical components of graduate schools.

It is assumed that the 75 new graduate schools will offer Ph. D. work in an average of five biomedical disciplines—some in two disciplines, others in eight or more disciplines. Thus, the estimate of 2,000 faculty for 75 new graduate schools assumes an average of five to six faculty per department in each of five departments.

4. *Staffing of specialized biomedical research centers.*—Some of the specialized research centers indicated on table 17 have been functioning for five years or more; others are in the initiation phase; still others have been authorized by the Congress and the executive branch. It should be noted that the staffing figures are not regarded as additive; they are already encompassed either in national expenditures for biomedical research or they involve part-time faculty participation. These estimates have been derived from the sources indicated below:

A. *Cancer Research Centers*

Three are currently in operation. A total of 10 such centers were recommended by the President's Commission on Heart Disease, Cancer, and Stroke.[28]

B. *Myocardial Infarction Research Units*

Five are currently in operation; the National Heart Institute projects a total of 12 by 1975. These research units would be supplemented by 48–50 clinical testing units.

C. *Cardiovascular Research and Training Centers*

One is currently in operation; 12 are proposed by 1975 by the National Heart Institute.[29]

D. *Eye Research Institutes*

Thirteen eye research institutes now supported by the National Institute of Neurological Diseases and Blindness[30] are staffed by 150 professionals. According to NINDB, the staff is expected to rise to about 400 by 1975 when 20 of these institutes are in full operation.

E. *Head Injury Research Centers*

Four head injury research centers supported by the National Institute of Neurological Diseases and Blindness now employ about 40 professionals. By 1975 NINDB proposes to expand the number of such centers to 12—possibly to 15.

F. *Dental Research Institutes*

Five dental research institutes are to be established in Alabama, Michigan, North Carolina, Pennsylvania, and the State of Washington. The National Institute of Dental Research expects that they will be fully operational by 1972. NIDR also anticipates that by 1975 there will be a total of nine such institutes.

G. *Pharmacology-Toxicology Centers*

At present there are three pharmacology-toxicology research centers. The National Institute of General Medical Sciences estimates that by 1975 there will be 12 such centers, staffed by 500 professionals.

H. *Environmental Health Research and Training Centers*

According to the Division of Environmental Health Sciences, there are three such centers in 1967; 25 are planned by 1975.

I. *Mental Retardation Research Centers*

The construction of 12 such centers has already been funded by the National Institute of Child Health and Human Development; it is expected that all of them will be in operation by 1975.

J. *Institutes for the Study of Aging*

The National Institute of Child Health and Human Development estimates that four institutes for the study of aging will be in operation by 1975.

K. *General Clinical Research Centers*

L. *Biomedical Computing Centers*

[28] *A National Program to Conquer Heart Disease, Cancer, and Stroke*, 1964, p. 49.

[29] House of Representatives, Subcommittee of the Committee on Appropriations. *Hearings on Departments of Labor, and Health, Education and Welfare Appropriations for 1968*, pt. 5, 90th Cong., 1st sess., April 1967.

[30] The National Institute of Neurological Diseases and Blindness became the National Institute of Neurological Diseases and Stroke. Public Law 90–639, Oct. 24, 1968. Public Law 90–489, Aug. 16, 1968, created the National Eye Institute.

M. *Biochemical, Instrumentation, Biological Materials Production, and Scientific Information Centers*

N. *Regional Primate Research Centers*

There are now currently in operation: 91 general clinical research centers, 43 biomedical computing centers, 16 biochemical, instrumentation, biological materials production, and scientific information centers, and seven regional primate research centers.

In the spring of 1968 the Division of Research Facilities and Resources estimated that by 1975 the number of such centers will expand to 125, 60, 30, and 10, respectively.

5. *Research and continuing education staffing of community hospitals in the regional medical programs network.*—Planning grants have been awarded to 53 different regions for Regional Medical Programs; it is estimated that the total number of regions may increase to 60–65 by 1975. The core planning and administrative staff may approximate 1,000 individuals, of whom about one-third are professional. In addition, there will be a considerable amount of part-time professional assistance from individuals at the medical center; this could be equal to 1,000 full-time equivalents.

The number of community hospitals participating in Regional Medical Programs is estimated at 1,500 for 1970, rising to 4,000 conservatively by 1975—possibly 5,000. This estimate assumes a Federal appropriation for this program in the neighborhood of $500 million by 1975.

The Regional Medical Programs will accelerate the flow and use of new knowledge and techniques in diagnosis and care. These programs will also serve as foci for research and continuing education in areas concerned with heart diseases, cancer, stroke, and related diseases.

It is anticipated that most of the professional personnel working in these facilities will be *part-time*. Assuming an average of 1½ to 2 full-time equivalent health and medical professional personnel per hospital, 6,000 full-time equivalents would be required for 4,000 community hospitals, 8,000 for 5,000 hospitals.

6. *Biomedical faculty for advanced undergraduate education.*—Experience during the past 10 years has demonstrated that many of the problems in training biomedical scientists arise from deficiencies in their undergraduate background—deficiencies which increase the cost of graduate training by needlessly prolonging the time required to train a first-rate scientist, and slow the pace and excitement of the effort for faculty and students alike. Many of these deficiencies arise from the obsolescence of college science faculty and curricula, from the mass approach to undergraduate science education in the large universities, and from the highly discipline-oriented structure of undergraduate education.

The liberal arts college is among the victims of the advancing scope and technology of scientific research. In the absence of highly sophisticated equipment and research programs, the liberal arts college is having increasing difficulty in attracting bright young scientists to the faculty. Despite these limitations, liberal arts colleges retain a degree of student-faculty contact and a perspective that are difficult to obtain in a large university. For this reason they continue to attract many able students to their campuses, some of whom have excellent research potential.

The universities in the past have been concerned with the education of the exceptional and the good student. Now, under current social pressures, they are also being asked to educate the average-to-poor student. Faced with a burgeoning enrollment, reaching 30,000–50,000 in some large universities, the outstanding undergraduate finds himself entrapped in a vast machine created to process large numbers of young people with relatively little regard for quality or individual creativity. If under this changing social environment biomedical research is to assure itself of a continuing source of potential young scientists, it must assist universities in finding more effective ways of identifying these young students early and of providing them challenging and creative opportunities during the undergraduate period. Moreover, if biology and medicine are to gain their share of the excellent young minds coming from mathematics and the physical sciences, ways must be found to expose them to the challenges of modern biology while they are still undergraduates.

For the reasons indicated above, and because of the great advances in the content of science courses in secondary schools, there is an urgent need to strengthen biomedical research and teaching capabilities for advanced work at the undergraduate college level, building upon well-tested experimental programs and extending them to approximately 200 undergraduate institutions. If initiated, programs undoubtedly would vary widely from institution to institution, perhaps with an average increment of five new faculty members per school—a total of 1,000 new faculty for teaching advanced biomedical courses at the undergraduate college level by 1975. NIH experience with experimental training grants at Haverford and Providence Colleges, for example, suggests that this estimate of five per institution is reasonable.

By 1975 there will be a minimum of 3,000 institutions offering undergraduate education. Of this large number, it is estimated that a minimum of 200 will comprise the top quality liberal arts schools, the top quality technological schools, and the top quality Ph. D.-producing institutions with strong undergraduate colleges. Thus, the estimate on table 17 assumes that support of advanced undergraduate training in the biodmedical sciences would be concentrated in these institutions which represent low-risk, high-potential investments. Any action in this direction should build upon well-tested experimental programs which, after evaluation and modification, could be extended to these approximately 200 undergraduate institutions.

7. *Staffing for existing research institutes and teaching hospitals.*—The above listing of high-priority staffing needs for the nonprofit sector does not explicitly provide for increments to professional workers now engaged in biomedical research, primarily at hospitals, and research institutes.

Between now and 1975 additional research manpower requirements primarily for hospitals and research institutes may, however, to an increasing extent be met through more extensive affiliation of those professional workers who also contribute to teaching and service activities in the multiple setting of hospital-research institute-academic institution.

8. *Critical shortage categories.*—The above listing of high priority staffing needs for the nonprofit sector does not explicitly provide for meeting manpower requirements in critical shortage categories. To a limited extent, these critical shortage categories are already encompassed in each of the specific high priority staffing needs summarized in table 17, p. 51. Nevertheless, these critical shortage categories are delineated below, even though it is not possible to estimate precisely how many scientists will be needed in each of them. The discussion of "critical shortage categories" is illustrative and selective. It includes disciplines and medical specialties which were identified as critical shortage categories with respect to the training plans of Institutes and Divisions of NIH; it does not focus upon the more general problem of the doctor shortage and the urgent need for expanding the supply of physicians to meet the health service needs of the American people.

Bioengineering.—This newly emerging field fusing science and technology brings the approaches of systems analysis to bear on the study of how the various systems of the body operate together effectively in a coordinated manner. Bioengineering encompasses (1) the use of systems concepts in the study of human biology, and (2) the design of systems for delivery of health care. Although a flourishing start has been made in systems analysis of the over-all integration of biological events in an understanding of human biology and how these events are altered in disease, further progress is impeded by the critical shortage of trained bioengineers. Equally urgent is the use of the systems approach to develop more efficient and effective systems of health care,[31] to provide more accurate information to physicians for data storage and retrieval, and to automate clinical laboratories for biochemical, pathological, radiological, and other clinical diagnostic procedures.

As the supply of bioengineers enlarges, the systems approach will increasingly permeate the daily work of each physician as he goes about the routine problems of patient care, the taking of medical histories, and executing procedures of physical diagnosis. Many of these procedures can be automated with greater accuracy and reliability thereby (1) providing more accurate data storage and retrieval and (2) utilizing the already existing body of knowledge to assist the physician in making more accurate diagnoses.

Behavioral sciences.—The domain of biomedical research has broadened beyond the core concern with biological determinants of disease and health and now embraces the social, intellectual, emotional, and economic factors which influence well-being. Questions concerning growth and development, the behavioral determinants of biological systems, and social pathology fall within the joint

[31] In its recent *Report*, the National Advisory Commission on Health Manpower stressed that "Unless we improve the system through which health care is provided, care will continue to become less satisfactory, even though there are massive increases in cost and in numbers of health personnel." vol. I, p. 2, November 1967.

330-549 O—69——5

domain of the behavioral and medical sciences. More effective application of the behavioral sciences should also contribute to a better understanding of the social and economic health systems and of the attitudes and motivations toward health of society and of individuals. While the need is great, the scientific basis for understanding many of these behavioral factors compares with the status of biological knowledge in the 1930's—developing rapidly but still fairly primitive.

Thus, the behavioral sciences comprise a critical shortage category for biomedical research. And the incorporation of the behavioral sciences into the medical school curriculum and the establishment of research and faculty posts in medical schools has been almost universally neglected, with few exceptions. Thus, the demand for behavioral scientists in the health research, teaching, and service milieu is bound to rise sharply.

Recognizing this situation, the National Institutes of Health, in collaboration with the National Academy of Sciences and the Social Science Research Council, is sponsoring a comprehensive assessment of the present position, promise, and future requirements of the behavioral and social sciences in the United States.

Selected environmental health sciences.—The complexity of the environment and the ways that it can influence man's health have been greatly enlarged as a result of population growth, urbanization, industrialization, and the multiplied use of chemical substances. The penalties to be paid for a rapidly advancing technology are delayed and less visible than the large, tangible, and immediate rewards, but are nonetheless serious. Contamination of our environment now threatens the health and character, if not the very existence, of life forms.[12] These hazards are ubiquitous and they present relatively new types of health problems.

It is the total and cumulative exposure of the individual to harmful environmental agents that is now recognized to be important, whether accumulated through contact via air, water, food, skin or through radiation. The situation is further complicated by the fact that the emergence of disease is frequently not identified clearly as a cause-and-effect relationship with individual environmental toxicants, but may be caused by a series of agents and frequently by different agents acting in concert, thus the toxic effects of certain chemicals are multiplied many times by the simultaneous presence of another substance—a synergistic or enhancing effect—even though the additional substance may not in itself be harmful.

The complexities of research in environmental health are great. Not only must the approach of the past be used in determining: (1) the hazard, (2) the transmitting vehicle, and (3) particular population groups affected; but, *reduction* of environmental hazards demands (4) vigorous and integrated study of all facets of environmental effects upon human health and productivity, and (5) rapid progress toward providing basic information upon which realistic control measures can be devised and adjusted to continual changes in both the environment and the population.

The diverse needs for professional research and teaching manpower reflect the breadth and complexity of environmental research. To cope with these environmental health research needs, new fields of science are emerging with a profound emphasis upon interdisciplinary collaboration. Among the more critical shortage categories are *environmental toxicology*, *stress physiology*, and *ecology*. The supply of scientists in each of these categories must be enlarged so that research may contribute to maintaining a better balance between urbanized man and hostile environmental changes which threaten health and the quality of life.

Clinical investigators.—The supply of well qualified clinical investigators has become increasingly critical for the progress of biomedical research. Only about a quarter of those entering clinical investigative training programs do sufficiently well to qualify as investigators, and considerably fewer develop into unit leaders with investigative stature adequate to seek and achieve support as head of a research and postdoctoral training activity. Consequently, this critical shortage category continues to be the limiting factor in staffing clinical research units focusing upon heart, cancer, stroke, and related diseases. The availability of qualified investigators continues to be the limiting factor in the establishment of new clinical research units.

Experience indicates that training programs in clinical investigation have three tracks:

1. One-year yielding a "graduate" who will function as a specialist and community leader:
2. Two-year, whose "graduate" may function in

[12] "America's Changing Environment", *Daedalus*, Fall 1967, vol. 96, No. 4, of the Proceedings of the American Academy of Arts and Sciences.

a teaching and nonindependent investigative capacity and contribute to staffing needs of the Regional Medical Programs;

3. The 4-year "graduate" who will realize a productive career in clinical investigation.

Necessarily skilled as a clinician, the 4-year "graduate" is rarely the individual to step directly into the role of leader of a small investigative unit in a medical center, responsible for integration of patient care, teaching, and research, both laboratory-based and clinical. In aiming at the earliest possible recognition as investigators, their other skills may have to be neglected in the process. Consequently, the emerging investigator is more likely to be able to establish himself if he can work for an extended period in a career development position.

The experience of the National Institute of Arthritis and Metabolic Diseases has shown that (1) the new unit director spends about 10 years in research training and career development posts and (2) the rate of appearance of individuals with these qualifications has been close to 10 per year. It is readily apparent that these key personnel are emerging at too slow a rate. Given the limiting factors of (1) long lead time and (2) high attrition rate, it is imperative that this critical shortage category of clinical investigators be expanded substantially to meet foreseeable biomedical research needs.

Clinical pharmacology in cancer research.—Rapid progress in drug development and in clinical drug evaluation programs is directly and causally related to alleviating the shortage of qualified clinical pharmacologists, particularly in cancer research. To develop better guidelines and better predictive systems for the selection of agents for trials in man, information concerning antitumor drugs derived from studies of human pharmacology must be correlated with pharmacodynamic data obtained in animals, with respect to such factors as metabolic pathways, toxicity, antitumor effects, differences in metabolism of these drugs between animals and man, effects of long-term administration, and optimum methods for administration.

This critical shortage of clinical pharmacologists concerned with the evaluation of carcinogenic conditions could be alleviated by strengthening and expanding existing training programs. Thus, the necessary increased output could be achieved with only a moderate increase in the number of participating institutions.

Clinical anesthesiology and diagnostic radiology.—It is estimated that there are less than one-half of the necessary number of anesthesiologists performing anesthesia in the currently available operating rooms in the United States. Mounting needs for X-ray diagnosis have placed a similar restriction on the number of highly trained radiologists. The soaring service responsibilities of medicare and the Regional Medical Programs, coupled with the increase in population, increases the demand for these two critical shortage categories. In addition, academic research faculty will be needed for (1) the expansion of existing medical schools and (2) the creation of 25 new schools in the next decade.

Radiation therapy.—In 1960, the National Institutes of Health recognized the magnitude of the shortage of qualified radiation therapists in the United States and concluded that training programs in that specialty were totally inadequate. Since that time, NIH has vigorously endeavored to enlarge the supply of radiation therapists. To meet this mounting need, it is estimated that the number of individuals in training must increase fivefold over the next 7 years.

Neurological sciences.—The neurological diseases include stroke, Parkinson's Disease, multiple sclerosis, muscular dystrophy, epilepsy, cerebral palsy, brain tumors, head injury, paraplegia, and the many handicapping disorders of vision, speech, and hearing. The resulting economic burden of the neurologically handicapped runs into billions of dollars annually. Progress in prevention and successful therapy depends heavily upon advances in research which, in turn, requires a substantial enlargement in the supply of highly skilled neurological scientists.

An estimated 10 percent of patients have primary or major diseases affecting the nervous system. Yet only 1 percent of medical graduates currently choose neurology as a specialty. As a result, vast numbers of patients with neurological diseases and injuries do not receive attention from skilled neurologists. In academic and research positions, highly trained professional specialists are urgently needed in five critical shortage categories: (1) clinical neurology, (2) neurosurgery, (3) neurosciences (nonclinical), (4) otolaryngology, and (5) ophthalmology.

Clinical neurology.—If there were a reasonably adequate number of neurological specialists in private practice, there would be not the current

1,200 but more than 3,000, a ratio of one per 68,000 population. In addition, some 1,900 clinical neurologists would be engaged in teaching-research activities.

A net increment of slightly more than 1,000 clinical neurologists per year would be needed to meet this ratio. But the best that can be realistically expected will be an increment of 78 in 1968 to an increment of 288 in 1975. This estimate assumes (1) a gradual increase from the current 1 percent of M.D. graduates entering 3-year training for neurology, to 2 percent by 1975, and (2) a doubling of M.D. graduates from about 8,000 in 1968 to 16,000 which is the high estimate for 1975. If the Nation is to provide adequate medical care for the wide range of neurological disorders, the supply of clinical neurologists must be increased substantially above these estimates.

Neurosurgery.—About 1,475 neurosurgeons are now in clinical practice as compared with 2,550 needed to provide a ratio of one per 80,000 population. This disparity is not as great as in the case of clinical neurologists. But the potential output of neurosurgeons per year is proportionally more discouraging. Even assuming 16,000 M.D. graduates per year by 1975, the projected annual output would rise only from 82 in 1968 to 133 in 1975. This discouraging prognosis reflects (1) the lengthy post-M.D. training period of 5 to 7 years, and (2) an expectation that the proportion of M.D. graduates choosing neurosurgery as a specialty will not rise above the current 1 percent unless specific measures are taken to enlarge supply in this critical shortage category.

Neurosciences.—The nonclinical sciences directly relevant to neurology may be grouped under the term "neurosciences." There are 36 different, self-identified disciplines listed by the 750 neuroscientists now in training. Among the more important are neuroanatomy, neurophysiology, and neuropathology.

An adequate ratio of nonclinical neuroscientists would be twice the current ratio of 10 to 100 M.D. graduates. The alleviation of this critical shortage is within reach if training programs can be geared to (1) rising graduate enrollment in the sciences and (2) expansion of institutional capabilities.

Otolaryngology.—Four percent of the young adult population suffers from deafness or serious hearing disabilities, rising to 25 percent for those age 75 and over. This disability strikes about 2 percent of the Nation's children. But the impact upon children is heightened by disorders of speech arising from physical and other causes as well as from loss of hearing, thereby inflicting communicative disorders on about 10 percent of all children. In addition, disorders of the nose and throat afflict persons at all ages.

To deal with the medical aspects of these problems, there should be 6,000 specialists—a 40 percent increase above the 4,300 otolaryngologists currently practicing. And, there are only 120 full-time teacher-researchers in this field. By 1975, the Nation will need 7,000 practicing specialists and 600 full-time and pa .-time teacher-researchers in otolaryngology.

Ophthalmology.—Over 400,000 Americans are legally blind and more than 1 million are unable to read newsprint. Research has contributed to the prevention of blindness, for example, in the virtual elimination of retrolental fibroplasia among prematurely born infants. Significant advances in therapy have resulted from eye research relating to virus infection of the cornea, cataract surgery, corneal transplants, and glaucoma. Further advances, in large measure, depend upon increasing the supply of ophthalmologists in research and teaching.

9. *Summary.*—This analysis of high priority staffing needs illustrates (1) urgent biomedical research and teaching needs in the burgeoning academic community, (2) the projected manpower needs of the specialized research activities (indicated in table 17), and (3) the additional needs for manpower for research, service, and continuing education in an estimated 4,000 community hospitals participating in regional medical programs by 1975 (in addition to core staffs required for the administration of such programs in 50-75 medical centers).

In summary, this alternative approach to estimating biomedical manpower needs for research, teaching, and related service activities in the nonprofit sector illustrates that approximately 64,000 professional workers may be required in the nonprofit sector by 1975. This estimate compares closely with the projection of 62,300 derived from the aggregate technique of projecting biomedical research expenditures and cost per man. (See table 12.)

Thus, these estimates, coupled with the identification of critical shortage categories, provide a basis for aligning manpower requirements with the future development of training programs, including those funded primarily or exclusively by NIH.

IV. THE LONG RANGE OUTLOOK FOR OUTPUT OF M.D.'s AND PH. D.'s

Three basic factors—long lead-time, future needs, and a unique educational and manpower opportunity—impel an intensive analysis of the outlook for production of new M.D.'s and Ph. D.'s. Such an analysis shows that action is needed *now* and that it is *feasible*.

First, the *long lead-time* required for development of qualified biomedical investigators and faculty is shown by the fact that new M.D.'s require 5 to 15 years of additional training and experience before entering the research manpower pool as principal investigators, and new Ph. D.'s require 3 to 10 years. Thus, those who have just received their M.D.'s in 1967 will not even begin to enter productive research and teaching in significant numbers until 1972, and few of those awarded the Ph. D. in 1967 will begin to enter the biomedical manpower pool as independent investigators prior to 1970.

The second factor, the clearly evident *future need* for qualified biomedical manpower for research, teaching, and related service activities has already been discussed at length in chapter III. Meeting this need will call for more effective utilization of the present staff of medical schools and graduate schools. When trained, however, these new professionals will not only help fill the need for biomedical research manpower but will also provide potential faculty essential for (1) the expansion of existing medical schools and biomedical components of graduate schools, (2) the upgrading of weaker health professional schools and health sciences programs in graduate schools, and (3) the creation of 25 new medical schools and 150 new graduate schools that America needs now and probably will have by 1975. In addition, a significantly enlarged supply of biomedical manpower will be needed to (1) staff the rapidly growing network of Regional Medical Programs, (2) provide scientific leadership for specialized research institutes to meet national needs, and (3) alleviate the problems posed by critical shortage categories such as bioengineering, the environmental health sciences, the neurological sciences, and the behavioral sciences.

The unique *educational and manpower opportunity*, listed above as the third basic factor influencing the long-range outlook for the output of M.D.'s and Ph. D.'s, is embodied in the surge of 22-year-olds (the cohorts of the post-World War II baby boom) seeking (1) graduate education and, subsequently, postdoctoral training, and (2) careers in medicine and the allied health professions.

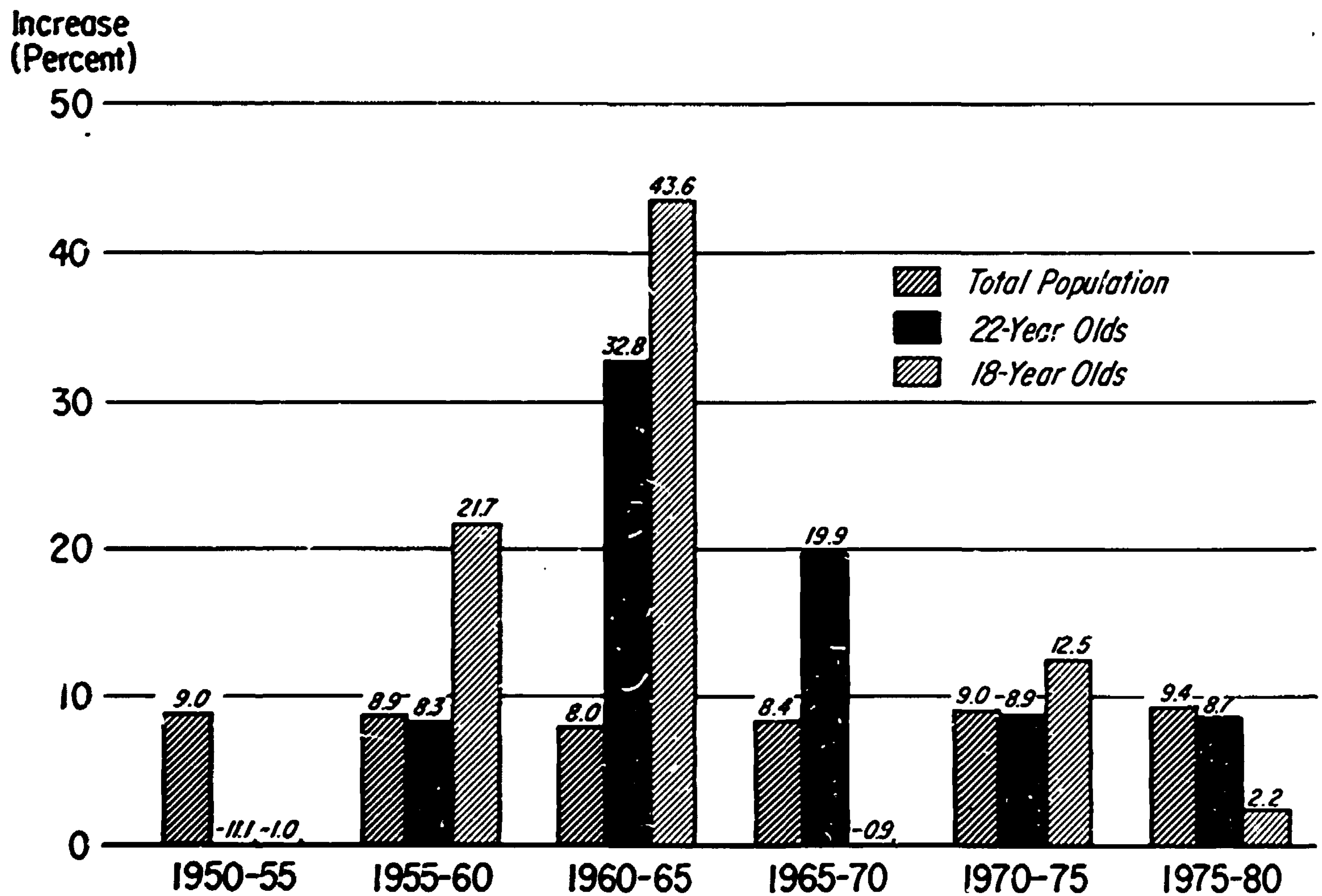
A. Uncertainty of Current Situation

Uncertainty permeates the current national situation which temporarily constricts the continued expansion of biomedical research programs to meet the health needs of the American people. As indicated in chapter II, the current situation, primarily responsive to mounting involvement of the United States in the Vietnam War, is reflected in (1) a decline in rate of growth of medical research, (2) a precipitous drop in Federal support for graduate education, and (3) the new Selective Service law and regulations. While the duration of the current situation is unpredictable, the new Selective Service law has introduced a major element of uncertainty into forecasts of graduate enrollment and Ph. D. output.[1] This element looms large with respect to (1) immediacy of threat, (2) severity of potential impact, and (3) uncertainty as to changes in the near future. The possible effects on graduate enrollments and hence, on Ph. D. output, have been discussed in chapter II, pp. 15 ff. Next in importance is the recent decline of both Federal and non-Federal support of graduate education. Unless new patterns and levels of financial support for graduate students emerge, this development could reduce or stretch out Ph. D. output in the basic medical sciences, other biomedical sciences, and the broad spectrum of dis-

[1] See article by James Reston in *New York Times*, Feb. 11, 1968.

CHART 10

Percent Increases in Population Base for College and Graduate Education



Source: Bureau of the Census

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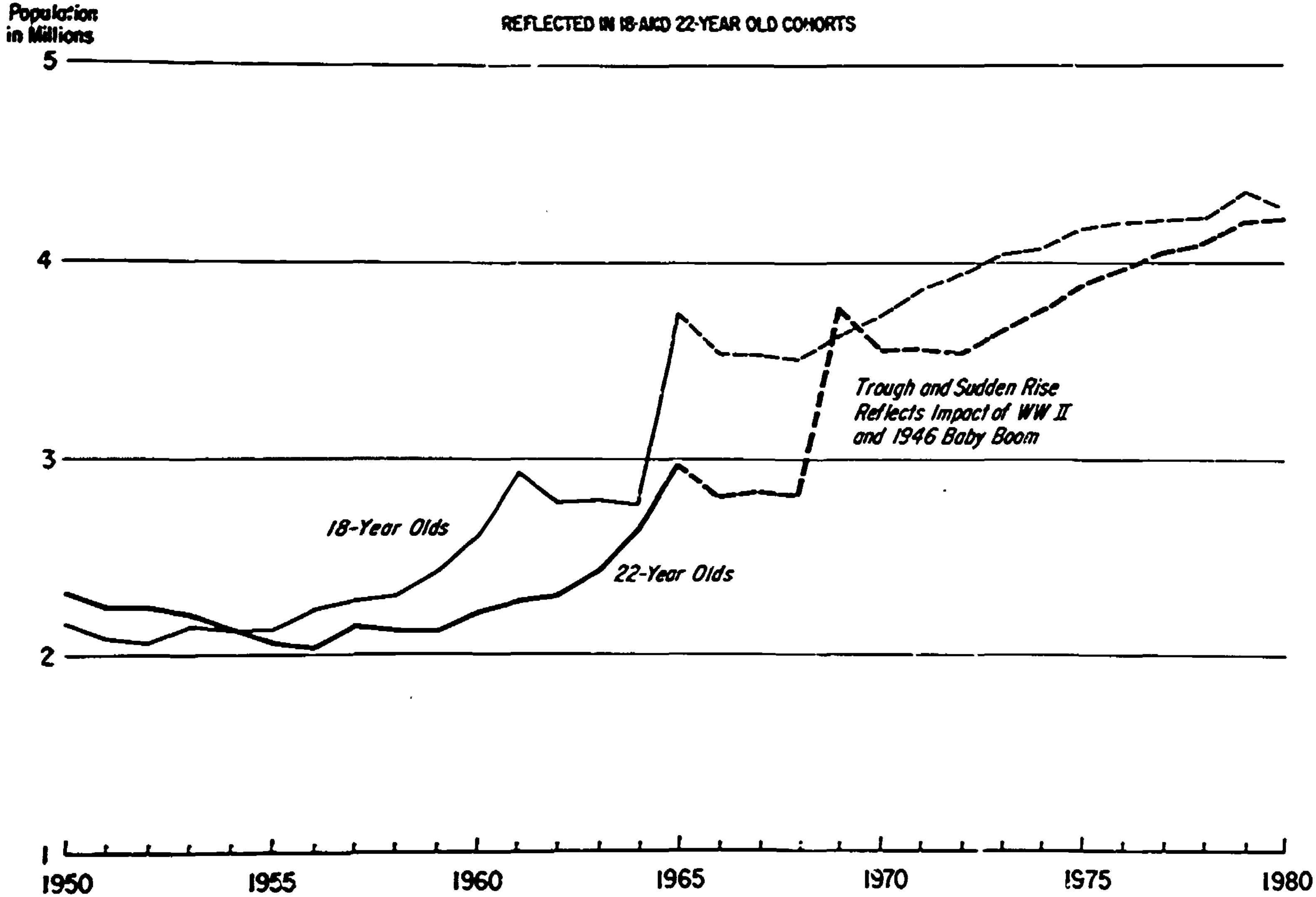
CHART 11

Expansion of Population Base for College and Graduate School

REFLECTED IN 18-AND 22-YEAR OLD COHORTS



Source: Bureau of the Census

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May 1968

ciplines contributing to biomedical research. Finally, the decline in the rate of growth of biomedical research, if perpetuated, could deter young scientists from seeking careers in biomedical research, teaching and related service activities.

Contrasting sharply with these negative aspects of the current situation is the dramatic surge in college and university educated manpower potentially available as the resource base for future growth in biomedical research, teaching, and related service activities.

B. The Resource Base for Future Growth, 1965–80

The resource base available for the needed expansion of biomedical research manpower will be substantially enlarged beginning in 1968 and continuing until about 1980. This is due to three factors which now exist: (1) significant increases in the 22-year-old group of the population, especially the sharp expansion between 1968 and 1969, and subsequently, in the midseventies; (2) mounting college enrollment; and (3) rising educational aspirations resulting in a significant expansion of graduate enrollment in all fields.

Although there is no doubt or qualification as to the demographic existence of this resource base, there is doubt concerning availability. Although the bachelor's degree population is sure to rise in accordance with expectations under current draft policies, the graduate student population could be reduced considerably over the short run unless (1) the new Selective Service regulations or legislation are changed in the next few months, or (2) peace negotiations with North Vietnam prove successful. On the other hand, it is possible that a considerable drop in graduate enrollment beginning in the fall of 1968 might be compensated in later years by return to graduate school of young men supported by veterans' training benefits.

Due to both the short-range and long-range uncertainties in the situation, the following discussion of the manpower resource base and Ph. D. output does not speculate upon the potential perturbations of the trends due to effects of the draft; the options still open for modification are so great as to preclude a reasonable judgment of the long-term effects over the next decade.

The key 22-year-old group.—Twenty-two-year-olds comprise the key to expanding the pool of future biomedical research manpower, since this is the usual age for graduation from college. From these must be drawn expanded enrollments in medical and graduate schools for production of new M.D.'s and Ph. D.'s.

Between 1950 and 1955 the number of 22-year-olds (the low birth cohorts of the depression years) actualy declined 11 percent. Between 1955 and 1960, the number of 22-year-olds increased about 8 percent. However, the numbers in this critical age group mounted steeply between 1960 and 1965—rising *33 percent*. This age cohort will continue to increase substantially between 1965 and 1970, rising *20 percent*, then tapering off to about 9 percent in 1970–75 and again, in 1975–80 (chart 10).

But this analysis by 5-year intervals masks the even more dramatic year-by-year details. More precisely, *the number of 22-year-olds increased roughly 350,000 between 1964 and 1965; tapers off through 1968; and then skyrockets between 1968 and 1969, adding roughly . million persons in that 1 year* (chart 11). The number dips slightly between 1969 and 1972, *then rises steadily from 3.5 million persons to 4.2 million by 1980. The Nation is about to reap the educational harvest of the post-World War II baby boom. The population explosion in the 22-year-old cohort that we have been predicting for the past 20 years is now upon us. Such an educational opportunity could not possibly recur till the end of this century.*

This population explosion of 22-year-olds is important in that it represents the typical age of entrants into medical schools and graduate schools. For planning purposes, however, the demographic facts of life must be coupled with evidence of rising college enrollments and graduations, availability for medical school entrance, and prospects for graduate school entrance.

Rising college enrollment.—Since 1955, college enrollment has been rising steadily. This steady increase in the face of a relatively constant population base indicates rising aspirations and expectations as a growing proportion of the Nation's youth complete high school and continue on to college. This is demonstrated by the fact that four out of every 10 (37.8 percent) of the pupils who were in the fifth grade 3 years ago entered college in 1965, as compared with three out of 10 in the fifth grade in 1953 and only about one out of 10 in the fifth grade in 1925 (table 18).

TABLE 18.—Trends in Relationship Between Fifth Grade Pupils, 1925–59, and First-Time College Students 8 Years Later, 1933–67

Of every 1,000 pupils entering fifth grade in	High schools graduated, 8 years later	And colleges admitted first-time students		
Year	Number	Year	Number	Percent of high school graduates
1925	316	1933	112	35
1930	417	1938	148	35
1935	439	1943	119	27
1940	481	1948	(1)	(1)
1945	524	1953	266	51
1950	582	1958	308	53
1951	597	1959	315	53
1952	621	1960	328	53
1953	637	1961	328	51
1954	642	1962	343	53
1955	657	1963	351	53
1956	676	1964	362	54
1957	692	1965	378	55
1958	717	1966	394	55
1959	721	1967	400	55

[1] Retention rates not calculated because of the influx of veterans in institutions of higher education.

Source: Office of Education.

Enlargement of the college enrollment base is further indicated by the fact that three-fourths of the 17-year-old cohort in 1966 were high school graduates as compared with one-half in 1940, and one-sixth in 1920 (table 19).

In the fall of 1967, there were approximately 6.5 million students enrolled in colleges and universities. This represents an increase of over 125 percent since 1956 or 7.5 percent a year, compounded (table 20). More important, the *9.3 percent* spurt between 1966 and 1967 indicates continued rapid expansion of enrollment.

For all practical purposes, the freshman class of 1965 sets the upper limit on those likely to enter the medical research manpower pool by 1974. The freshman class of 1965–66 will graduate in June 1969. Those who go on for graduate or professional training will not receive Ph. D. or M.D. degrees before June 1972 at the earliest; many will not complete their doctoral studies until after 1974. Even for those who receive doctoral degrees in 1972, postdoctoral training for Ph. D.'s and internship and residency for M.D.'s will defer their entrance into the medical research manpower pool as principal investigators until 1974—and beyond.

Rising number of bachelor's degrees conferred.—From 1960 to 1966, the number of bachelor's degrees conferred in the United States increased from 359,000 to 520,000, or 45 percent. (table 21). This growth averaged 6.3 percent a year in the size of the cohorts from which persons eligible for further study and training leading to careers in medical research, education, and services will be drawn.

TABLE 19.—Trends in Relationship Between High School Graduates and Persons 17 Years of Age, 1920–67

School year ending	Total (thousands)	As a percent of persons 17 years of age
1920	311	16.8
1930	667	29.0
1940	1,221	50.8
1950	1,200	59.0
1958	1,506	64.8
1960	1,864	65.1
1962	1,925	69.5
1964	2,290	76.3
1965	2,638	71.9
1966	2,644	75.0
1967 [1]	2,650	75.3

[1] Based on preliminary data.

Source: High school graduates—Office of Education, *Digest of Educational Statistics*, 1967, p. 52, and unpublished data.

TABLE 20.—Opening Enrollment For Baccalaureate and Higher Degrees, 1956–66

Year	Enrollment	
	Total (thousands)	Percent increase year/year
1956	2,947	....
1957	3,068	4.1
1958	3,259	6.2
1959	3,402	4.4
1960	3,610	6.1
1961	3,891	7.8
1962	4,207	8.1
1963	4,529	7.7
1964	4,988	10.1
1965	5,526	10.8
1966 estimate	5,947	7.6
1967 estimate	6,500	9.3

Source: 1956–65—Office of Education in "Opening Fall Enrollment in Higher Education" annual issues; 1966–67—Office of Education.
Growth rate: 1956–67: 7.5 percent per annum.

The numbers of bachelor's degrees to be conferred in the next decade have been independently projected by the Office of Education and for the Commission on Human Resources and Advanced Education;[3] these estimates are also presented in table 21. Both projections begin with estimates for 1965-66 that differ from the preliminary actual figures for that year released by the Office of Education subsequent to the publication of the projected series; the OE estimate for 1965-66 of 490,000 is lower than the preliminary actual figure of 520,000; the Human Resources projection of 522,000 is only slightly higher.

Since the cohorts of persons receiving bachelors degrees provide the pool from which graduate enrollment will be drawn, the assumptions underlying the Office of Education, and the Folger projections of bachelors degrees conferred are critical for an assessment of the projection of graduate enrollment provided by the Office of Education.

The Office of Education projection of bachelor's degrees conferred are, for the short-term, lower than the actual numbers of bachelors degrees conferred. The reliance by the Office of Education for this projection upon past trends of the proportion of bachelor's degree holders to the population has not fully reflected the growing aspirations of all sectors of the population for higher education, and beyond that for continued training at the graduate level. The projection published by Folger, on the other hand, attempts to (1) accommodate the burgeoning growth in junior colleges, and (2) to take into account the tumultuous demand for college careers from groups which in the past did not have the opportunity or incentive for pursuing higher education.

Because of these deficiencies, the Office of Education projection of graduate enrollment has been modified by an overall percentage increase of 10 percent a year. This percentage modification is less than the percentage difference, 1971-75, between the Office of Education and Folger projections of bachelor's degrees conferred.

[3] Projections presented by John K. Folger, formerly the Director of the Commission on Human Resources and Advanced Education, in "The Balance Between Supply and Demand for College Graduates," *The Journal of Human Resources*, vol. II, No. 2, Spring 1967, pp. 143-175, particularly table 1, p. 146.

TABLE 21.—Bachelors Degrees Conferred, 1959-60 to 1965-66, and Projections, 1965-66 to 1974-75

[Thousands]

Year	Actual data[1]	Projections: Office of Education[2]	Projections: Folger[3]	Difference—Folger/OE: Number	Difference—Folger/OE: Percent
1959-60	359	-----	-----	-----	-----
1960-61	365	-----	-----	-----	-----
1961-62	382	-----	-----	-----	-----
1962-63	410	-----	-----	-----	-----
1963-64	456	-----	-----	-----	-----
1964-65	490	-----	-----	-----	-----
1965-66	520	490	522	32	6.5
1966-67	-----	522	550	28	5.4
1967-68	-----	616	651	35	5.7
1968-69	-----	676	713	37	5.5
1969-70	-----	673	742	69	10.3
1970-71	-----	686	753	67	9.8
1971-72	-----	713	816	103	14.4
1972-73	-----	747	844	97	13.0
1973-74	-----	783	888	105	13.4
1974-75	-----	818	927	109	13.3

[1] Office of Education, publications on *Earned Degrees Conferred by Institutions of Higher Education*. The degree data published by the Office of Education include in the same category bachelor's and *first professional degrees*; the Office of Education series has been modified by NIH to exclude first professional degrees.

[2] Office of Education, *Projections of Educational Statistics to 1975-76, 1966*, table 17, p. 27. Projections of bachelor's and first professional degrees have been reduced by 8.5 percent to exclude first-professional degrees. (See footnote 2 to O.E. table 17.)

[3] Projections presented by John K. Folger, formerly the Director of Commission on Human Resources and Advanced Education, in "The Balance Between Supply and Demand for College Graduates", *The Journal of Human Resources*, vol. II, No. 2, Spring 1967, pp. 143-175, particularly table 1, p. 146.

Graduate enrollment—past trends.—If total college enrollment and the numbers receiving bachelor's degrees have been rising, what has been happening to total graduate enrollment for advanced degrees, and more specifically, to graduate enrollment in the science fields of greatest relevance for medical research!

Total graduate enrollment for advanced degrees in institutions of higher education increased from 314,000 for the academic year 1960-61, to 535,000, 1965-66, about 70 percent for the 5-year period, or at the rate of 11.3 percent a year (table 22).

In the same period, enrollment for advanced degrees in science fields relevant to medical research, education, and service increased from 103,000 to 163,000, about 9.8 percent a year. For the biosciences only, the numbers increased from 15,000 to 27,000, or 12.9 percent a year.

Graduate enrollment—future trends.—A projection to 1975 of total graduate enrollment has been published by the Office of Education based upon past trends of the relationship between graduate enrollment to total enrollment (graduate plus undergraduate). As already noted, Office of Education projections of bachelor's degrees conferred, which will affect the numbers enrolled for graduate study, have fallen short of the actual experience. Futhermore, past trends in graduate enrollment will be further affected by the mounting interest of recent college graduates in pursuing graduate education. These trends are illuminated by two studies of the intentions and follow-through of college seniors with respect to graduate and professional study. The National Institutes of Health supported a longitudinal study of the 1961 college senior class, with followup inquiries each year through 1965. Based upon the results of this national study, one-third of the 1961 college seniors were in graduate school in 1964—3 years later.[3] *This proportion, while high, understates graduate study for those whose career field was the biosciences where 55 percent of the 1961 college seniors of both sexes and two-thirds of the men were in graduate school in 1964.*[4]

A more recent nationwide survey of the June 1964 senior class confirms this rising propensity for graduate training, showing that two-fifths of this group intended to enroll for graduate or professional study in the Fall of 1964. *Roughly 60 percent of the bioscience majors and 70 percent of the men in this field were going on for graduate study immediately.*

For these reasons, the Office of Education projection of graduate enrollment has been increased by 10 percent a year, 1966–67 to 1975, a percentage increase somewhat lower than the difference between the Office of Education and Folger projections of bachelor's degrees conferred, 1971–75.

The modified Office of Education projection of graduate enrollment which terminated with 1975–76, has been extrapolated to 1980. This series is shown in table 22.

TABLE 22.—Trends in Graduate Enrollment, by Field, 1960–61 to 1965–66, and Projections, 1966–67 to 1979–80

[Thousands]

Year	Total all fields	Selected sciences		All other fields
		Total	Biosciences	
1960–61	314.4	102.6	14.8	211.8
1961–62	339.0	108.9	16.2	230.1
1962–63	373.9	119.4	17.8	254.4
1963–64	413.4	133.7	20.6	279.7
1964–65	477.5	148.9	23.7	328.6
1965–66	535.3	163.1	27.2	372.2
1966–67	712.0	216.2	36.3	495.8
1967–68	780.0	235.7	39.8	544.3
1968–69	838.0	252.1	42.7	585.9
1969–70	866.0	259.3	44.2	606.7
1970–71	909.0	270.8	46.4	638.2
1971–72	950.0	284.5	49.0	675.5
1972–73	1,021.0	301.2	52.1	719.8
1973–74	1,081.0	317.4	55.1	763.6
1974–75	1,142.0	333.7	58.2	808.3
1975–76	1,199.0	348.7	61.1	850.3
1976–77	1,260.0	364.6	64.3	895.4
1977–78	1,320.0	380.2	67.3	939.8
1978–79	1,386.0	397.2	70.7	988.8
1979–80	1,458.0	415.5	74.4	1,042.5

Source: *Data for 1960–61 to 1965–66*—Office of Education annual publications, enrollments for advanced degrees. *Data for 1966–67 to 1979–80*—total graduate enrollment—Office of Education projection of graduate opening fall degree credit enrollment, published in *Projections of Educational Statistics to 1975–76*, p. 17, increased 10 percent a year to make the series reflective of the factors delineated by the Commission on Human Resources for Advanced Education, which will affect the projected numbers of bachelor's degrees conferred, and therefore, substantially expand the base from which graduate enrollments is drawn. *Graduate enrollment by field*—National Institutes of Health.

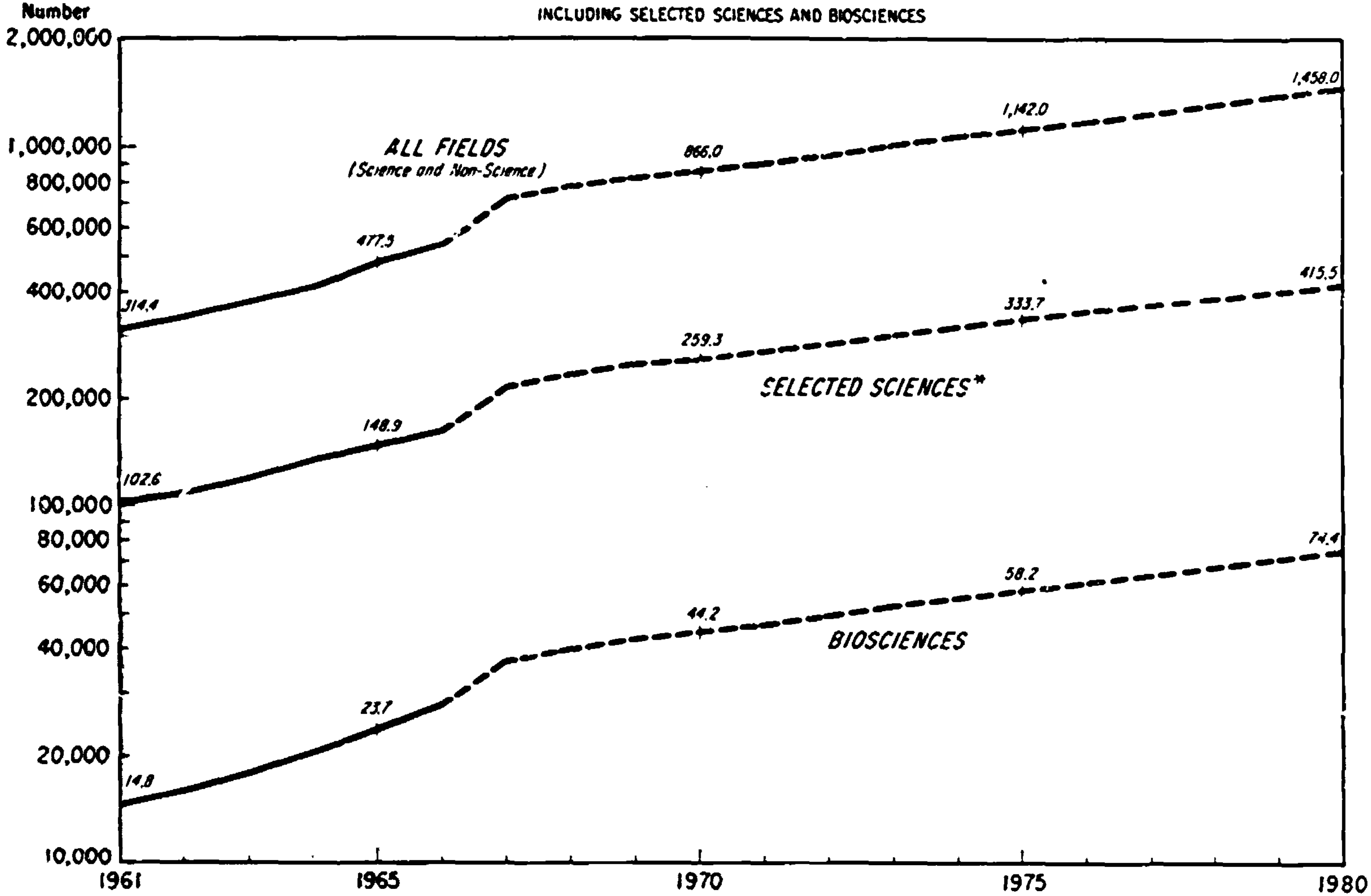
Future graduate enrollment by field.—The Office of Education projection of graduate enrollment provides no breakdown by field. Within the framework of the projection of total graduate enrollment, however, an illustrative projection, by selected science fields has been prepared by NIH. This breakdown is also sumarized in table 22. The 1965–66 actual distribution provides the basis for this illustrative projection, taking into account, however, a judgmental assessment of a slight decline in the proportion of the selected sciences enrollment to the total—from 30.5 percent in 1965–66 to 28.5 percent by 1980. Within the selected science fields, the 1966 pattern is expected to continue for all except engineering and the physical sciences; for each of these two fields, the distribution by 1980 is projected to decline by 1 percent from the 1966 level of 10.7 percent for engineering and by 1 percent from 6.8 percent in 1966 for the physical sciences.

[3] Special tabulation prepared for the National Institutes of Health by the National Opinion Research Center based upon 1961 College Senior Survey.

[4] Berger, Alan S., *Longitudinal Studies on the Class of 1961; the Graduate Science Students*, National Opinion Research Center, University of Chicago; January 1967.

CHART 12

Graduate Enrollment, 1961–65, and Projections, 1966–80



Sources. Actual data – Office of Education
Projections – National Institutes of Health

RAB-OPP-NIH
May 1968

* The selected science fields include the biosciences, mathematics and statistics, physical sciences, behavioral sciences (i.e. anthropology and sociology, and all psychology except clinical), and engineering.

The graduate enrollment projections are graphically illustrated in chart 12. In the biosciences, graduate enrollment is projected to increase from 44,000 in 1970 to more than 74,000 by 1980, an increase of 68 percent over the decade.

A note on quality.—What about the quality of the 1964 college seniors majoring in biology? Of those in the top fifth of their class, 93 percent were going on for graduate study. Of all in the top half, 88 percent were continuing on for graduate study.[8] Thus, the input of more than nine-tenths of the top group and 88 percent of the above average group augurs well for the quality of the future supply of Ph. D.'s 6 years hence.

Summary.—In short, considerable enlargement of the population base, a marked expansion in college and graduate enrollment, and increased educational and research opportunities for talented youth—will substantially broaden the base from which the Nation's future supply of M.D.'s and Ph. D.'s will be drawn. Taking these and other relevant factors into account, what is the outlook for output of M.D.'s and Ph. D.'s during this decade?

[8] Special tabulation prepared for the National Institutes of Health by the National Opinion Research Center based upon 1964 College Senior Survey.

C. Output of Ph. D.'s, 1961–67, and Projections to 1980

The number of newly trained Ph. D.'s awarded increased from less than 9,000 a year in 1958, to more than 20,000 by 1967, or about 10 percent a year for the decade. In the more recent period—1962–67, the annual rate of growth has been 12 percent a year.

For science fields of direct relevance to medical research and education, comparable growth rates have been experienced for both the 1958–67 period, and the more recent one of 1962–67, with Ph. D.'s in the selected sciences increasing from 4,700 in 1958 to 11,100 in 1967 (table 23).

TABLE 23.—Trends in Ph. D. Output, All Fields and Selected Sciences, 1958–67

Year	Total all fields	Total selected sciences	Biosciences			Mathematics and statistics	Physical sciences	Behavioral sciences[1]	Engineering
			Total	Basic medical sciences	Other biosciences				
1958	8,770	4,743	1,267	684	583	241	1,650	956	329
1959	9,212	6,029	1,212	636	576	292	1,801	1,025	699
1960	9,734	5,266	1,307	687	620	302	1,867	1,004	792
1961	10,411	5,622	1,208	723	585	339	1,993	1,042	940
1962	11,507	6,302	1,470	821	649	398	2,096	1,123	1,215
1963	12,720	7,050	1,582	860	722	498	2,428	1,185	1,357
1964	14,324	7,852	1,754	1,012	742	612	2,527	1,297	1,662
1965	16,302	8,941	2,030	1,184	846	708	2,859	1,276	2,068
1966	17,865	9,775	2,189	1,270	919	786	3,028	1,489	2,283
1967	20,295	11,127	2,398	1,473	925	913	3,478	1,757	2,581
	Percent increase[2]								
1958-62	7.0	7.3	3.8	4.7	2.7	13.4	6.2	4.1	17.9
1962-66	11.6	11.6	10.5	11.5	9.1	18.5	9.6	7.3	17.0
1958-67	9.8	9.9	7.3	8.9	5.2	15.9	8.6	7.0	17.0
1962-67	12.0	12.0	10.3	12.4	7.3	18.1	10.6	9.4	16.3

[1] Includes psychology, sociology, and anthropology.
[2] Annual compound rate of increase.

Note.—The data on Ph. D. output in the *selected sciences* represents a grouping of the subfields shown in the NAS publication. Specifically, subfields shown under the NAS category Biological Sciences have been classified in the following categories shown in this table: Basic medical sciences includes biochemistry, biophysics, physiology except plant physiology, anatomy, cytology, microbiology, embryology, pharmacology, and pathology; Other biosciences includes plant physiology, entomology, genetics, ecology, hydrobiology, botany, zoology, biological sciences general and all other, phytopathology, and nutrition.

Mathematics and statistics as shown in this table include all the subfields reported in the NAS mathematics category, plus biometrics and biostatistics reported in the Biological Sciences category in the NAS publication.

Behavioral sciences as shown in this table include psychology, sociology, and anthropology reported in the Social Sciences category in the NAS publication.

Physical sciences and engineering as shown in this table include all the subfields reported in the NAS categories for physics and astronomy, chemistry, earth sciences, and engineering.

Source: National Academy of Science, *Doctorate Recipients from United States Universities, 1958-1966*, NAS Pub. No. 1489; 1967 and unpublished data for 1967.

The most comprehensive and up-to-date data on the recipients of the Ph. D. degree are derived from the annual updating of the doctorate records file maintained since 1920 by the Office of Scientific Personnel of the National Research Council—National Academy of Sciences. These records provide more detailed and more current data than the statistics published by the Office of Education.

Projections of the likely availability of Ph. D. degree holders to meet the Nation's needs for principal research investigators in the biomedical sciences (see ch. III) have been developed by the National Institutes of Health, based upon extrapolations of recent trends of Ph. D.'s awarded, as shown by the National Academy of Sciences data. These projections by field are presented in table 24; chart 13 depicts the Ph. D. output in the basic medical and other biosciences.

Positing a continuation into the seventies and mideighties of the recent trends in doctorate production is based on the conviction that this is the most likely course, for the future, in view of the already documented--

- Significant increase in the 22-year-old age groups of the population—especially the sharp expansion between 1968 and 1969, and subsequently in the midseventies;
- Mounting college enrollment;
- Rising educational aspirations, resulting in a significant expansion of graduate enrollment in all fields.

TABLE 24.—Projection of Ph. D. Output, All Fields, and Selected Sciences, 1968–80

[Thousands]

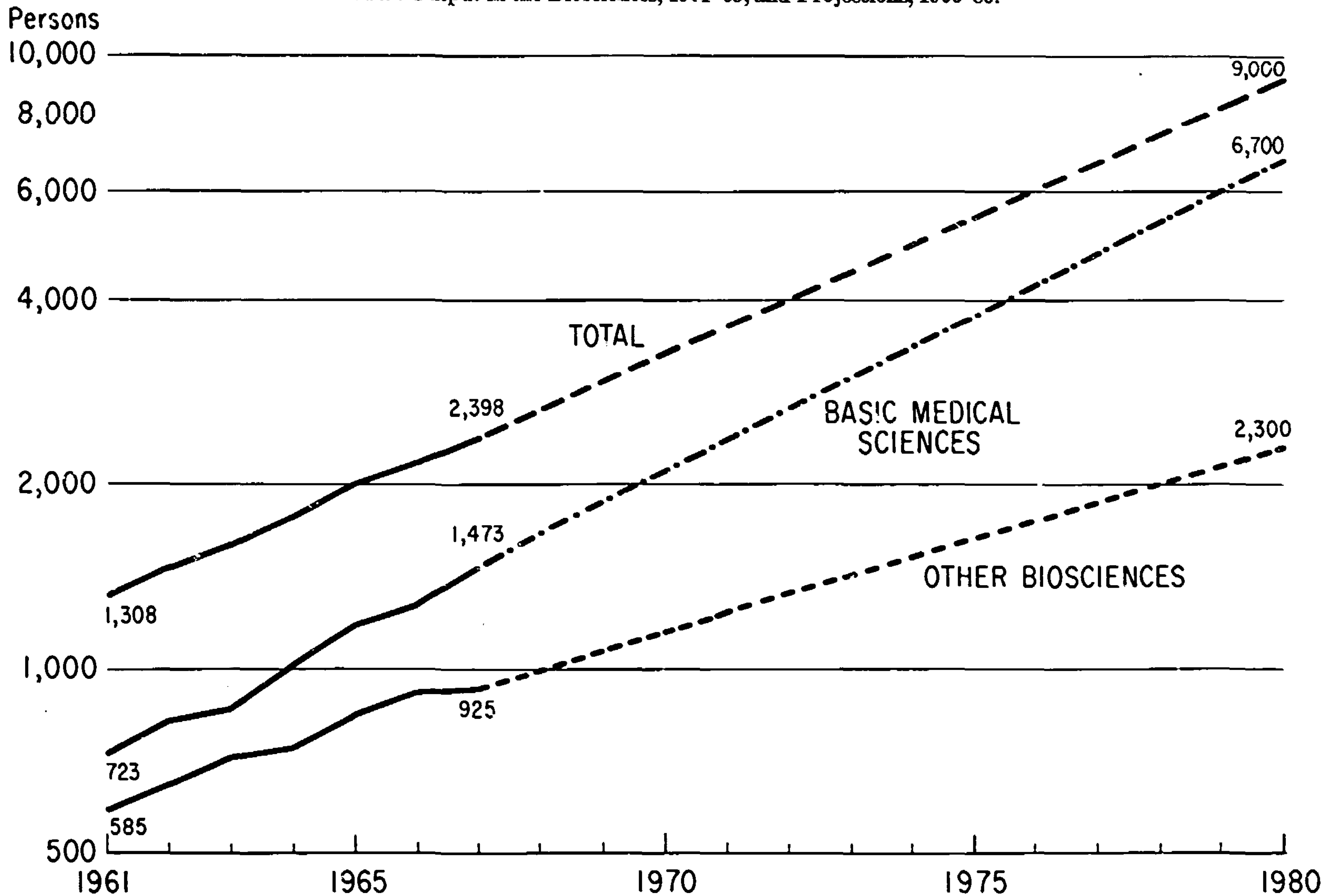
Year	Total all fields	Total selected sciences	Biosciences			Mathematics and statistics	Physical sciences	Behavioral sciences [1]	Engineering
			Total	Basic medical sciences	Other biosciences				
1967 actual	20.3	11.1	2.4	1.5	0.9	0.9	3.5	1.8	2.6
1968	22.7	12.5	2.6	1.7	1.0	1.1	3.8	1.9	3.0
1969	25.5	14.2	2.9	1.9	1.1	1.3	4.3	2.1	3.6
1970	28.5	16.0	3.2	2.1	1.1	1.5	4.7	2.3	4.2
1971	31.9	18.0	3.6	2.4	1.2	1.8	5.2	2.5	4.9
1972	35.8	20.5	4.0	2.6	1.3	2.2	5.8	2.8	5.7
1973	40.1	22.9	4.4	3.0	1.4	2.6	6.4	3.0	6.6
1974	44.9	25.8	4.9	3.5	1.5	3.0	7.0	3.3	7.6
1975	50.3	29.1	5.4	3.8	1.6	3.5	7.8	3.6	8.8
1976	56.3	32.9	6.0	4.2	1.7	4.1	8.6	3.9	10.2
1977	63.0	37.1	6.6	4.7	1.9	4.8	9.5	4.3	11.8
1978	70.6	41.8	7.3	5.3	2.0	5.7	10.5	4.7	13.5
1979	79.1	47.1	8.1	6.0	2.2	6.6	11.7	5.2	15.6
1980	88.8	53.1	9.0	6.7	2.3	7.7	12.9	5.7	17.8
	Growth rate [2]								
1967-80	12.0	12.8	10.7	12.4	7.3	17.8	10.6	[illegible]	16.0
	Percentage distribution								
1967	100.0	54.8	11.8	7.3	4.6	4.5	17.1	8.7	12.7
1970	100.0	56.0	11.3	7.3	4.0	5.4	16.5	8.1	14.7
1975	100.0	58.0	10.7	7.5	3.2	7.0	15.5	7.2	17.6
1980	100.0	60.0	10.2	7.6	2.6	8.7	14.6	6.4	20.2

[1] Includes psychology, sociology, and anthropology.
[2] Annual compound rate of increase computed from unrounded estimates.

Source: 1967—National Academy of Sciences. Projections—National Institutes of Health.

CHART 13

Ph. D. Output in the Biosciences, 1961–65, and Projections, 1966–80.



Sources: Actual data – Office of Education
Projections – National Institutes of Health

RAB-OPP-NIH
May 1968

Furthermore, it is also evident that (1) to an increasing extent the Ph. D. degree will be viewed by both student and prospective employer as the logical fullfillment of formal academic training, and (2) financial support in the post-Vietnam period will be available to a growing proportion of graduate students enabling them to continue to the doctorate level—probably at an accelerated pace because more students will be enrolled fulltime.

Assuming a continuation of the 12-percent growth (1962–67) in Ph. D. output by 1980, an estimated 88.6 thousand Ph. D.'s will be awarded, or about 4½ times the 1967 number. For the selected sciences, as a group, a slightly greater growth is anticipated, with the total numbers in these fields increasing almost five times from 11,000 in 1967 to 53,000 by 1980. Underlying this estimate is the assumption that the proportion of the selected science Ph. D.'s to the total will increase from 54.8 to 60 percent, 1967 to 1980.

For the individual fields within the selected science category, the projected number of Ph. D. degrees earned in the *biosciences* by 1980 will total 9,000, as compared with 2,400 in 1967. Comparable rates of growth are anticipated for the *physical sciences*, and the *behavioral sciences*. However, mirroring the increasing emphasis in recent years on the Ph. D. degree in *mathematics* and in *engineering*, the numbers of Ph. D. degrees earned in these two fields are projected to increase seven times, from less than 1,000 Ph. D.'s in mathematics to almost 8,000 by 1980, and for engineering from 2,600 in 1967 to 17,800.

How does this projection of total Ph. D.'s to be awarded compare with other available projections, namely, those prepared by the Office of Education and for the Commission on Human Resources and Advanced Education?

The NIH extrapolation results in Ph. D. levels that are substantially higher than either of the other projections; a comparison of the three series is shown in table 25. As already noted, the extrapolation by NIH of doctorate production using the growth trends of the late sixties was based on the conviction that this would more likely reflect the dynamics underlying the educational process in the seventies and eighties. On the other hand, the Office of Education projection is based essentially upon the past relationships of doctorate production to the population; while the Commission on Human Resources projection is based essentially upon past relationships of the doctorate to the baccalaureate degree. Neither of these methodologies, without some judgmental modification, can accommodate those factors emerging in the late

TABLE 25.—Comparison of Data on Ph. D. Output—Actual and Projections

[Thousands]

Year	Actual data Ph. D. output[1]		Projections of Ph. D. output		
	National Academy of Sciences	Office of Education	NIH[2]	Office of Education[3]	Commission on Human Resources[4]
1958	8.8	8.9			
1959	9.2	9.4			
1960	9.7	9.8			
1961	10.4	10.6			
1962	11.5	11.6			
1963	12.7	12.8			
1964	14.3	14.5			
1965	16.3	16.5			
1966	17.9			17.5	18.2
1967	20.3			18.8	20.2
1968			22.7	21.0	22.4
1969			25.5	23.6	24.7
1970			28.5	24.8	27.0
1971			31.9	24.9	29.3
1972			35.8	26.8	32.3
1973			40.1	32.0	35.8
1974			44.9	35.5	39.6
1975			50.3	35.8	43.5
1976			56.3	36.9	
	Percent increase[5]				
1958–65	9.2	9.2			
1958–67	9.8				
1962–65	12.3	12.4			
1962–67	12.0				
1966–76			12.1	7.7	
1966–75			12.2	8.3	10.2
1966–70			12.3	9.1	10.3
1970–76			12.0	6.3	
1970–75			12.0	7.6	10.0

[1] Actual data on Ph. D. output—minor differences in the total number of Ph. D. degrees awarded are shown in the series published by the Office of Education, in *Projections of Educational Statistics, to 1975-76*, p. 27, and the National Academy of Sciences, in *Doctorate Recipients from United States Universities 1958-1966*, and unpublished data, 1967. Data provided by the National Academy of Sciences, however, are more current and provide a more detailed and exact breakdown of the fields in which the Ph. D degree is earned. The Office of Education actual data were also used by the Commission on Human Resources in developing their projection.

[2] National Institutes of Health, projection based on extrapolation of National Academy of Sciences data, see table 24.

[3] Office of Education, *Projections of Educational Statistics to 1975-76*, p. 27.

[4] Commission on Human Resources and Advanced Education, presented by John K. Folger, "The Balance Between Supply and Demand for College Graduates", *Journal of Human Resources*, vol. 11, No. 2, spring 1967, p. 150.

[5] Annual compound rate of increase.

sixties which will have a greater impact on future Ph. D. output than the trends of the fifties and early sixties. Indeed, even though the assumptions underlying the Office of Education and the Commission on Human Resources projections are different, both result in levels of Ph. D. output which reflect rates of growth substantially lower than the actual recent experience of 12.4 percent for 1962–65; the OE projection growth rate being 7.7 percent, and the Commission on Human Resources projection 10.2 percent. When compared with the actual growth rate of 9.2 percent for the entire 1958–65 period, the Office of Education projection growth rate (1966–76) falls below, while the rate (1966–75) for the Commission on Human Resources is only slightly above.

It should also be noted that both the Office of Education and the Commission on Human Resources projections were developed prior to the availability of the actual data for 1967 which is the base year for the NIH extrapolation; the Office of Education projection carries to 1976, the Commission on Human Resources projection terminates in 1975.

How realistic is the assumption that the projection of Ph. D.'s in the selected science fields (i.e. those particularly germane for medical research) will increase from 54.8 percent of all Ph. D.'s awarded in 1967, to 60 percent by 1980? Stated differently, what would be the effect of holding this proportion constant at 54.8 percent to 1980?

It is true that for the past decade the proportion of Ph. D.'s awarded in the selected sciences to total Ph. D.'s has remained constant at about 54 percent of the total, on the basis of the National Academy of Sciences data. But the increasing emphasis on the Ph. D. degree in mathematics and in engineering, and the continued growth at the 1962–67 rates for the other selected sciences (table 24) results in a rising proportion of selected sciences as a group to total Ph. D.'s. Some corroboration of this trend is obtained from the Office of Education projection which does provide a breakdown by field. (In contrast, the Commission on Human Resources projection provides no field distribution.) This Office of Education breakdown shows the Ph. D.'s awarded in natural sciences increasing from 50 percent of all Ph. D.'s in 1966 to 55 percent by 1976.[6] The Office of Education natural sciences category, however, does not include all of the science fields covered in the selected sciences category, and includes some minor fields which are excluded from the selected sciences category. Unfortunately, detailed data by field are not available to permit a precise grouping of the Office of Education projection into the selected science category.

If the proportion of total Ph. D.'s in the selected sciences were held constant at 54.8 percent 1967–80, the result would be a reduction in the growth rate for total selected sciences from 12.8 percent, 1967 to 1980 assuming a rising proportion of Ph. D.'s in selected sciences to all Ph. D.'s awarded, to 12 percent. The effect of this alternative assumption is summarized below:

Ph. D.'s Awarded, 1967–80—Alternative Assumption

[Thousands]

Year	Total Ph. D.'s	Total selected sciences	Biosciences			Mathematics and statistics	Physical sciences	Behavioral sciences	Engineering
			Total	Basic medical	Other				
1967	20.3	11.1	2.4	1.5	0.9	0.9	3.5	1.8	2.6
1970	28.5	15.6	3.2	2.1	1.1	1.5	4.7	2.3	3.9
1975	50.3	27.5	5.4	3.8	1.6	3.1	7.8	3.6	7.7
1980	88.6	48.5	9.0	6.7	2.3	6.3	12.9	5.7	14.6
Growth rate: 1967–80	12.0	12.0	10.7	12.4	7.3	16.0	10.6	9.4	14.4

[6] Office of Education, *Projections of Educational Statistics to 1975–76*, p. 29.

TABLE 26.—Relationship of Ph. D. Output to Graduate Enrollment, by Field, 1961, 1965, and Projections, 1970, 1975, and 1980

Year	Percent of graduate enrollment							
	Total Ph. D. output	Total selected sciences	Biosciences		Mathematics and statistics	Physical sciences	Behavioral sciences	Engineering
			Basic medical sciences	Other biosciences				
Actual:								
1961	3	6	12	7	3	8	8	3
1965	3	6	13	6	4	8	7	4
Projection:								
1970	3	6	12	5	5	8	7	5
1975	4	9	15	5	8	11	8	8
1980	6	13	20	6	14	15	10	13

Note.—Based on graduate enrollment data presented in table 22 and Ph.D. output shown in tables 23 and 24.

Relationship of Ph. D. output to graduate enrollment.—About three out of every 100 students enrolled for graduate education in the 1961–65 period earned the doctorate degree. For the selected sciences as a group, however, where the Ph. D. degree is particularly important, the ratio was about double, or six out of 100. In the basic medical sciences, where training programs supported by the National Institutes of Health have been particularly significant, the ratio of doctorates to graduate enrollment has been 12 out of 100.

Throughout the 1961–65 period, these ratios, by field, have remained relatively stable, with the exception of mathematics and engineering, which have shown a rising trend.

The projection of Ph. D. output based upon the extrapolation of current trends, is based upon the assumption that an increasing proportion of graduate students will continue their formal academic education to the doctorate level. As a proportion of graduate enrollment, therefore, by 1980 about six out of every 100 graduate students in all fields and about 13 out of 100 students enrolled in the selected sciences will earn the doctorate degree.

These future trends and the past relationships by field are shown in table 26.

In addition to developing these year-by-year projections for Ph. D. output in the biosciences, a breakdown was estimated for the subfields comprising the basic medical sciences, and the other biosciences (table 27). These field breaks are in terms of aggregate output projections for the period 1968–80, as compared with the actual experience, 1961–67. These are the fields that provide the major share of Ph. D. trained scientists for medical research. It is estimated that Ph. D. output in the biosciences, 1968–80 will approximate 68,000.

TABLE 27.—Output of Ph. D.'s in the Biosciences, 1961–67, and Projections, 1968–80, by Field

Field	Output cumulative 1961–67	Projections cumulative 1968–80	Average annual numerical output	
			1961–67	1968–80
Total, biosciences	12, 727	68, 100	1, 818	5, 200
Basic medical sciences, total	7, 343	47, 700	1, 049	3, 700
Anatomy	744	5, 900	106	500
Biochemistry	2, 561	15, 100	366	1, 200
Biophysics	361	4, 800	52	400
Microbiology	1, 668	9, 300	238	700
Pathology	216	1, 800	31	100
Pharmacology	595	2, 700	85	200
Physiology	1, 198	8, 100	171	600
Other biosciences	5, 384	20, 400	769	1, 600
Botany	890	2, 400	127	200
Biology, general	64	500	9	(1)
Entomology	793	2, 900	113	200
Genetics	706	4, 100	101	300
Phytopathology	586	1, 100	84	100
Plant physiology	375	2, 900	54	200
Zoology	1, 469	3, 700	210	300
Biology, other	501	2, 700	72	200

[1] Less than 50.

Source: Actual data—National Academy of Sciences, *Doctorate Recipients from United States Universities, 1958–1966*, and unpublished data for 1967. Projections—National Institutes of Health.

For the basic medical sciences, the keystone in the arch of Ph. D.-trained biomedical manpower, output during the 1968–80 period will reach 48,000. *When the 1968–80 period is compared with the 1961–67 period, it means that 2,600 more Ph. D.'s will be awarded annually in the basic medical sciences if the projection is realized.*

In this connection, it should be noted that Ph. D. output in the basic medical sciences increased 12 percent between 1962 and 1967. This is more than double the 4.7 rate of increase between 1958 and 1962 (table 23). *The sharply rising growth rate follows, with the anticipated 5-year lag, behind the major expansion in NIH training programs beginning in 1957.*

In the broader terms of the "selected science fields" (see footnote, table 23) from which most scientists are drawn for biomedical research, it is estimated that Ph. D. output over the 1968–80 span will total 370,000. Moreover, Ph. D. output in the selected science fields for the 1976–80 period will *exceed* the 1961–65 output by 175,000—roughly, a fivefold increase over the 36,000 Ph. D.'s awarded in these fields, 1961–65.

It should be emphasized that the projection of Ph. D. output is predicated upon a rising proportion of full-time students. The key to increasing the proportion of full-time graduate students is Federal policy with respect to the support of graduate education.[7]

In a recent report, the National Science Foundation has stated that the importance of support for science and engineering education, particularly at the graduate level, at a continuing rate consistent with the growth in enrollments "cannot be overstated."[8] The report notes that the past growth has been accompanied by large increases in fellowships, research funds, equipment and facility outlays, etc., and probably could not have occurred without them. Consequently, according to the NSF report, extrapolation of past enrollment trends implies comparable increases in resources devoted to education in these fields.

[7] In this context, the current situation which reflects a decline in Federal support for graduate education is viewed as a perturbation of the long-term trend, 1950–65, of steadily rising Federal support.

[8] National Science Foundation, *Science and Engineering Staff in Universities and Colleges*, May 1967, p. 8.

It should be noted that the potential impact of the recently revised Selective Service law and regulations has not been considered in developing these projections of Ph. D. output. If, as predicted by many, graduate enrollment declines sharply in 1968–69, then we can anticipate a precipitous dip in Ph. D. output in 1973. In the light of rapidly changing events, it is not possible to predict the impact of short-term policy shifts upon long-term Ph. D. output projections. As a consequence, long-term projections have not been modified although it is recognized that actual experience is more apt to reflect peaks and valleys rather than smooth trends.

D. M.D. Output, 1956–67, and Projections to 1980

Historically, two diametrically opposite considerations have governed the output of M.D.'s and Ph. D.'s. In large measure, M.D. output has been fixed at a relatively inflexible proportion of total U.S. population. Ph. D. output, in contrast, has been responsive to the number of well-qualified students desiring and undertaking graduate study (chart 14). Note that this chart extends only to 1974 and depicts a continuation of present trends. In so doing, we are neglecting the fundamental fact that both entering medical students and first-time graduate students are drawn from a common pool of those awarded the bachelor's degree in the prior year.

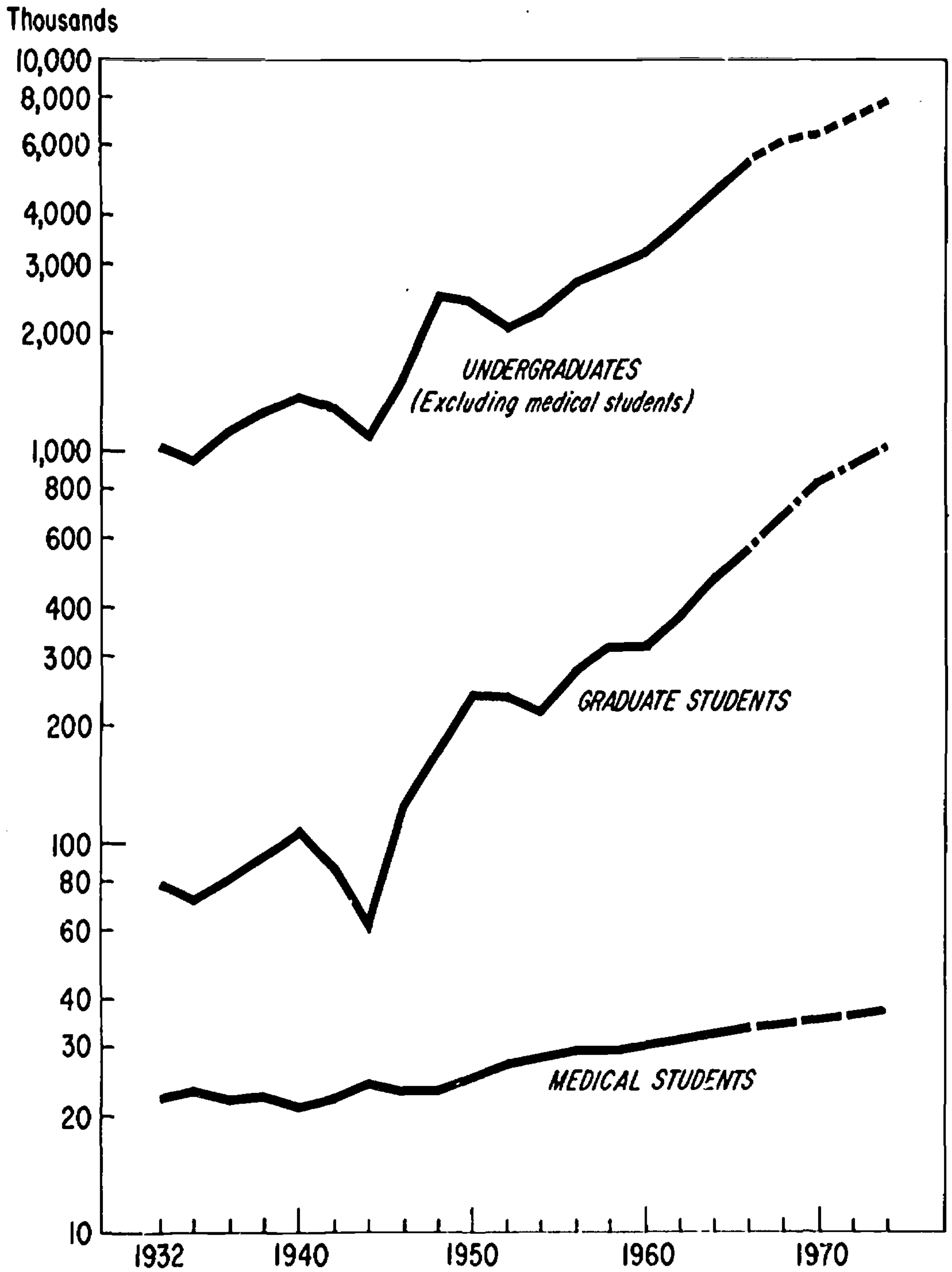
Assumptions underlying projections of M.D. student enrollment and output.—In developing projections of M.D. student enrollment and output, two alternatives have been prepared based on the evidence that both entering medical students and first-time graduate students are drawn from a common pool. In addition to these two, a third alternative has been projected, taking into account the probable developments over the next decade in medical education resources, short of a major change in national policy aimed at substantially enlarging the supply of physicians to meet the health needs of the American people.

The three alternatives are as follows: First, a continuation of past trends of the relationship of M.D. enrollment to the total population—4.6 per 100,000 U.S. population—this results in a low estimate.

Secondly, an alternative that reflects the post-World War II population dynamics and conse-

CHART 14

Enrollment at Institutions of Higher Education, 1932–66, and Projections, 1968–74



Sources: Office of Education, American Medical Association
National Institutes of Health

RAB-OPP-NIH
June 1967

quent increase in baccalaureates by suggesting that a relatively fixed proportion of graduating baccalaureates should enter medical school, and that public and private policy decisions could bring this ratio to 25 medical school students per 1,000 baccalaureates, a ratio approaching that of the early 1960's, but somewhat higher than recent experience. This results in a high estimate. The recent *Report of the National Advisory Commission on Health Manpower* supports the approach to relating expansion of entering classes in medical school to increases in bachelor's degrees.[9]

Thirdly, an intermediate projection that takes into consideration (1) the numbers of new schools expected to become operational before 1973, and (2) the incentives to expand slightly the size of entering classes responsive to statutory provisions governing the award of Federal basic improvement grants and Federal construction funds for medical school facilities (Health Professions Assistance Act). This results in an intermediate estimate which is in line with the more modest phasing suggested by the National Advisory Commission on Health Manpower.[10] The intermediate projection ignores the pressures to enlarge the supply of physicians to meet the health needs of the American people and assumes that there will not be a major change in national policy aimed at achieving this objective.

In developing these projections one further assumption has had to be made concerning the future attrition rate among medical students. Currently about 12 percent of medical students fail to graduate. The low projection assumes that this will continue through the graduating class of 1970–71, and will then decline to 10 percent. Both the intermediate and high projections assume that a change to the 10 percent rate will take place for the 1967–68 graduating class and continue to 1970–71, and then decline further to 8 percent thereafter. These declining attrition rates reflect the rising level of quality of first-year entrants made possible by the rapid enlargement in the pool of well-qualified applicants.[11]

Contrasting projections.—Based upon past trends, U.S. medical schools can be expected to award a *minimum* of about 110,000 M.D. degrees between 1968 and 1980 (table 28). This estimate of cumulative output over the decade has been developed by NIH, assuming that entering classes continue to represent 4.6 per 100,000 U.S. population, and that completions will increase from 88 percent of admissions to 90 percent.

If public and private forces adopt and implement a national policy goal of admitting 25 new students per 1,000 bachelor's degrees conferred,[12] *and if, in addition, the ratio of completions to admissions is increased from 88 percent to 92 percent, cumulative M.D. output from U.S. schools could approximate 190,000 between 1968 and 1980—an increment of more than 80,000 physicians above the low estimate.* If these high projections were to become a reality, M.D. output from U.S. schools would increase 150 percent from 8,000 in 1967–68 to more than 20,000 by 1980; under the low projection, the growth in M.D. output would be less than 20 percent.

The intermediate projection, however, which assumes no major change in national policy but takes account of the planned expansion of existing

[9] The report states: "The current increase in bachelor degrees indicates that by 1975 there will have to be spaces for 16,500 new medical students if the present inadequate ratio of medical school spaces to bachelor degrees is to be maintained. This figure is 50 percent above the projected 1975 capacities of medical schools. Education to the limit of an individual's capabilities is, like the right to health care, becoming an established national policy. It is likely that medical schools will be under heavy pressure to respond to demands for educational opportunity as well as demands for medical care." *Report of the National Advisory Commission on Health Manpower*, Vol. 1, November 1967, p. 17.

[10] With reference to total needs for M.D.'s the *Report of the National Advisory Commission on Health Manpower*, vol. 1, November 1967, states that "the current increase in bachelor degrees indicates that by 1975 there will have to be spaces for 16,500 new medical students if the present *inadequate* ratio of medical school spaces to bachelor degrees is to be maintained" and that this is "50 percent above the projected 1975 capacities of medical schools." (p. 17). The report also recommends: "The production of physicians should be increased beyond presently planned levels by a substantial expansion in the capacity of existing medical schools, and by continued development of new schools." (p. 19).

[11] Johnson, Davis G. and Hutchins, Edwin B., "Doctors or Dropouts," *Journal of American Medical Education*, vol. 41, December 1966.

[12] The policy goal is consistent with the goal suggested a decade ago by the report of the Surgeon General's Consultant Group on Medical Education.

TABLE 28. Medical School Admissions and Graduates, 1955–56 Through 1966–67, With Projections Through 1985

Year	Entering class U.S. medical schools			Graduates U.S. medical schools			M.D.'s from abroad (foreign input)			Total M.D.'s (United States and foreign)		
	[Thousands]											
	Actual											
1955–56	7.7			6.8			1.0			7.8		
1956–57	8.0			6.8			1.2			8.0		
1957–58	8.0			6.9			1.3			8.2		
1958–59	8.1			6.9			1.8			8.6		
1959–60	8.2			7.1			1.6			8.7		
1960–61	8.3			7.0			1.8			8.7		
1961–62	8.5			7.2			1.5			8.7		
1962–63	8.6			7.3			1.6			8.9		
1963–64	8.8			7.3			1.5			8.8		
1964–65	8.9			7.4			1.6			9.0		
1965–66	8.8			7.6			1.7			9.2		
1966–67	9.0			7.7			1.7			9.4		
1967–68	9.5											
Total	110.3			85.9			18.2			104.1		
	Projected											
	Low	Intermediate	High	Low	Intermediate	High	Low	Intermediate	High	Low	Intermediate	High
1967–68				7.8	8.0	8.0	1.7	1.7	1.7	9.5	9.7	9.7
1968–69	9.2	10.1	15.8	7.7	7.9	7.9	1.7	1.7	1.7	9.4	9.6	9.6
1969–70	9.3	10.8	18.1	7.9	8.1	8.1	1.7	1.7	1.7	9.6	9.8	9.8
1970–71	9.4	11.4	18.2	8.4	8.6	8.6	1.7	1.7	1.7	10.1	10.3	10.3
1971–72	9.6	12.3	18.3	8.3	9.3	14.5	2.1	1.9	2.9	10.4	11.2	17.4
1972–73	9.7	13.4	18.6	8.4	9.9	16.7	2.1	2.0	3.3	10.5	11.9	20.0
1973–74	9.8	14.3	19.2	8.5	10.5	16.7	2.1	2.1	3.3	10.6	12.6	20.1
1974–75	9.9	15.4	20.1	8.6	11.3	16.8	2.1	2.3	3.4	10.7	13.6	20.2
1975–76	10.0	16.5	21.2	8.7	12.3	17.1	2.2	2.5	3.4	10.9	14.8	20.5
1976–77	10.2	17.5	22.2	8.8	13.2	17.7	2.2	2.6	3.5	11.0	15.8	21.2
1977–78				8.9	14.2	18.[illegible]	2.2	2.8	3.7	11.1	17.0	22.2
1978–79				9.0	15.2	19.5	2.3	3.0	3.9	11.3	18.2	23.4
1979–80				9.2	16.1	20.4	2.3	3.2	4.1	11.5	19.3	24.5
Total	87.1	121.7	171.7	110.1	144.4	190.4	26.4	29.2	38.4	136.5	173.6	228.8
1977–78	10.3	18.5	22.9									
1978–79	10.5	19.5	23.7									
1979–80	10.6	20.5	24.4									
1980–81	10.8	21.5	24.8	9.3	17.0	21.1	2.3	3.4	4.2	11.6	20.4	25.3
1981–82	11.0	22.5	25.4	9.4	17.9	21.8	2.4	3.6	4.4	11.8	21.5	26.2
1982–83				9.6	18.9	22.4	2.4	3.8	4.5	12.0	22.6	26.9
1983–84				9.7	19.8	22.8	2.4	4.0	4.6	12.2	23.7	27.4
1984–85				9.9	20.7	23.4	2.5	4.1	4.7	12.3	24.8	28.0
Total	53.2	102.5	121.2	47.9	94.3	111.5	12.0	18.9	22.3	59.9	113.2	133.8

Note.—Actual data, 1956–67—Entering class and number of M.D.'s: "Medical Education in the United States, 1966–67," *Journal of the American Medical Association*, vol. 202, No. 8, Nov. 20, 1967, p. 756. Entering class, 1967–68, preliminary estimate of actual data, Association of American Medical Colleges. Foreign input: 1956–66, Medical Licensure Statistics Series by Council on Medical Education, "Additions to Medical Profession Representing Graduates of Foreign Medical Faculties," in *Journal of the American Medical Association*, vol. 200, No. 12, June 19, 1967, p. 1072, supplemented by passing candidates from approved schools in Canada, table 5, p. 1058, and comparable tables in preceding issues.

Projections—National Institutes of Health. Entering class: Low projection based upon ratio of 4.6 medical school admissions per 100,000 population. Intermediate projection based upon opening of schools already provisionally accredited, two to five additional new schools by 1973, and expansion of entering classes in existing schools required by (1) basic improvement grants, and (2) construction of teaching facilities under the Health Professions Assistance Act; the estimate for 1975–76, 16,500 admissions agrees with the figure cited by the National Advisory Commission on Health Manpower, see report of the Commission, vol. 1, November 1967, p. 17. High projection based upon ratio of 25 admissions per 1,000 bachelor's degrees.

Number of M.D.'s: Low projection for 1967–68 and 1969–70 based on 88 percent completion rate of the actual entering classes 3 years earlier; for 1970–71 based on 88 percent completion rate of the preliminary estimate of entering class, 1967–68; for 1971–72 to 1984–85, based on 90 percent completion rate of the low projection of entering classes 1968–69, to 1981–82. Intermediate projection for 1967–68 and 1969–70 based on 90 percent completion rate of the actual entering classes 3 years earlier; for 1970–71 based on 90 percent completion rate of the preliminary estimate of entering class 1967–68; for 1971–72 to 1984–85 based on 92 percent completion rate of the intermediate projection of entering classes 1968–69 to 1981–82. High projection for 1967–68 and 1969–70 based on 90 percent completion rate of the actual entering classes 3 years earlier; for 1970–71 based on 90 percent completion rate of the preliminary estimate of entering class 1967–68; for 1971–72 to 1984–85 based on 92 percent completion rate of the high projection of entering classes 1968–69 to 1981–82.

Foreign input: Low projection based on 25 percent of the low projection of M.D. output; intermediate projection based on 20 percent of the intermediate projection of M.D. output; high projection based on 20 percent of the high projection of M.D. output.

schools, and the creation of new or additional medical education facilities will provide for an output of M.D.'s totaling 145,000 for the 1968 to 1980 period, or roughly midway between the low and high estimates. Graduates from medical schools would double from 8,000 in 1967–68 to 16,000 by 1980.

When compared with the intermediate projection, it is apparent that the high projection would yield more than 22,000 additional M.D.'s—roughly a 30 percent increase—between 1976 and 1980.

The wide disparity between the different sets of assumptions and the consequences for entering classes and for M.D. output are graphically illustrated in charts 15A and 15B.

Feasibility of projections.—The possibility of the substantial increase in the size of entering classes is implicit in the burst of 22-year-olds between 1968 and 1969—a gain of more than 1 million in the cohort, rising from 2.8 million to 3.8 million in 1 year. This rise is reflected in baccalaureate projections,[13] increasing from 631,000 in 1968 to 769,000 in 1973, a jump of 138,000 baccalaureate degrees. At 25 per 1,000 baccalaureates, this would represent an entering class of more than 19,000 first-year medical students in the fall of 1973 as compared with an entering class of 14,000 assumed by the intermediate projection. Taking the NIH projected size of the entering M.D. class as given, it should be noted that the rate per 1,000 baccalaureates as projected by the Commission on Human Resources and Advanced Education would still be 25 per 1,000 through 1971, and would decline to 23 per 1,000 after 1971.

What evidence is available for testing whether such large numbers of college graduates will be seeking careers in medicine? The most recent data are based upon a national sample of 1966 college freshmen.[14] About 5 percent of the total sample expressed preferences for careers in medicine; about 8 percent of the men—primarily in private and public universities and 4-year colleges—expressed their intention to seek careers in medicine. When the sample is blown up, it would appear that a minimum of 60,000 entering freshmen indicated their desire to make medicine their life's work. The fact that a high proportion of the total was enrolled in private and public institutions with notably rigorous selection procedures suggests that perhaps one-half of the 60,000 may emerge in 1970 as college seniors applying for admission to whatever medical schools will offer them the opportunity to pursue their career objective.

Recent public statements of the American Medical Association and the Association of American Medical Colleges suggest that these organizations now support the acceptance of all well qualified applicants.

Between 1951 and 1967 the ratio of medical students per full-time faculty member has dropped sharply from 6.7 to 1.7 (chart 16). This expansion of full-time faculty in relation to the number of medical students provides a measure of elasticity for accommodating substantially larger numbers of medical students.[15] The implications are also clear with respect to the *more effective utilization* of existing basic science and clinical teaching facilities coupled with the rapid expansion of facilities to meet demonstrable need.

Additional Sources.—But the supply of new M.D.'s is by no means limited to the output of U.S. schools (table 28). Since 1950, the number of newly licensed physicians who received their degrees from foreign institutions rose steadily to a peak of 26 percent of U.S. graduates in 1959 and then leveled at about 22 percent.[16] Licenses

[13] The projection of bachelor's degrees conferred (on which the size of entering M.D. classes is based) has been developed by the National Institutes of Health; this projection is presented in app. E, table 10. This table also presents projections of the Office of Education, and the Commission on Human Resources and Advanced Education.

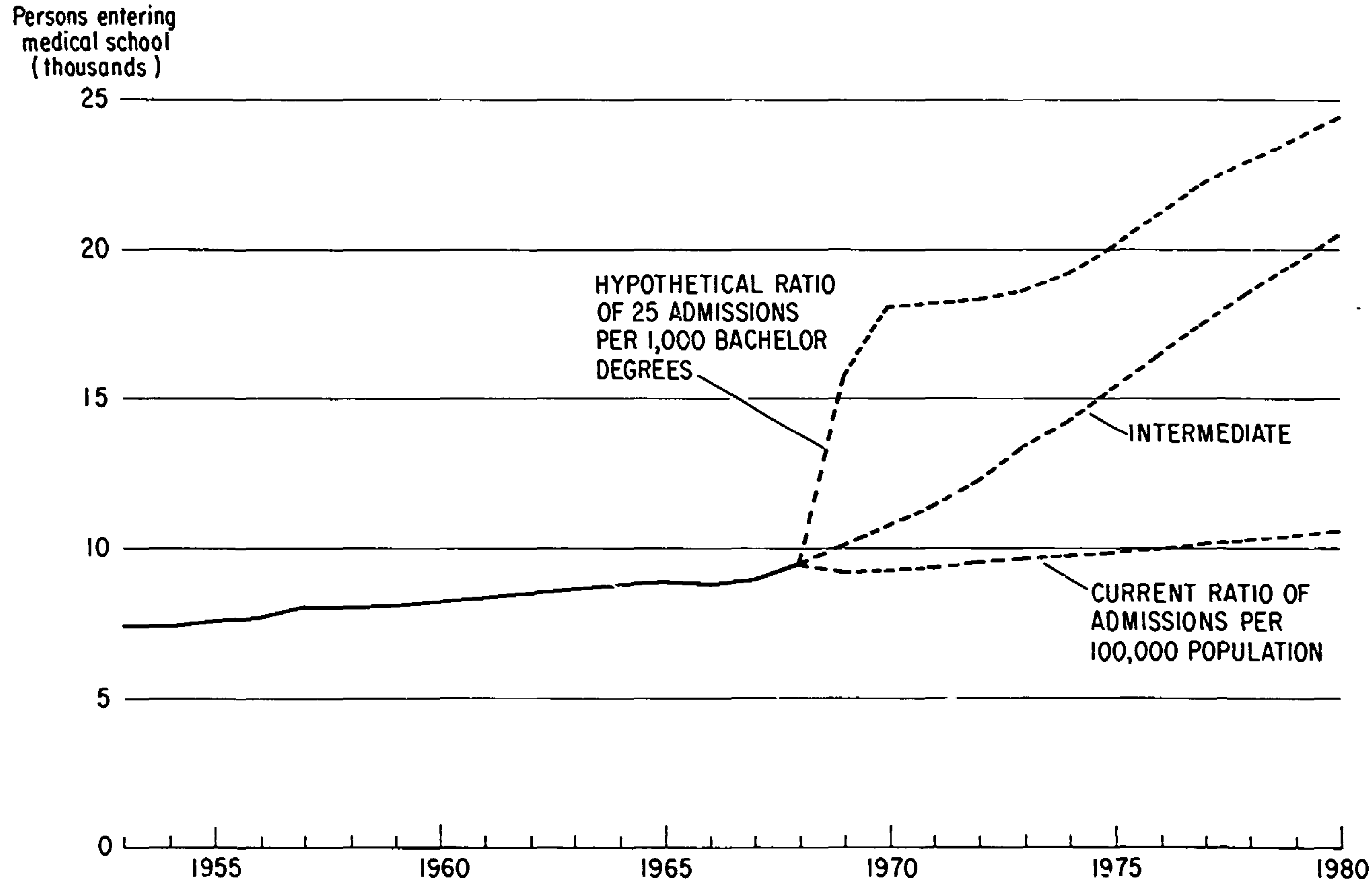
[14] Astin, Alexander W., *et al., National Norms for Entering College Freshman*, Fall 1966, American Council on Education, vol. 2, 1967.

[15] See Joe L. Spaeth, *American College Faculty Members*, 1963, National Opinion Research Center, Report No. 106, October 1966. This analysis based upon a national sample of teaching faculty in all fields, indicated that nearly 90 (88) percent of teaching faculty in the basic medical sciences (the preclinical disciplines) were also engaged in federally sponsored research.

[16] Foreign input includes three groups: (1) U.S. citizens who receive their medical education abroad, (2) M.D.'s who are not U.S. citizens at the time they receive their medical education in a foreign country but subsequently take up residence in the United States and (3) foreign citizens trained as M.D.'s outside the United States who engaged in research abroad supported by either public or private funds included in the Nation's total expenditures for medical research.

CHART 15a

Medical School Entering Classes, 1953–68, and Projections, 1969–80



Sources: American Medical Association
National Institutes of Health

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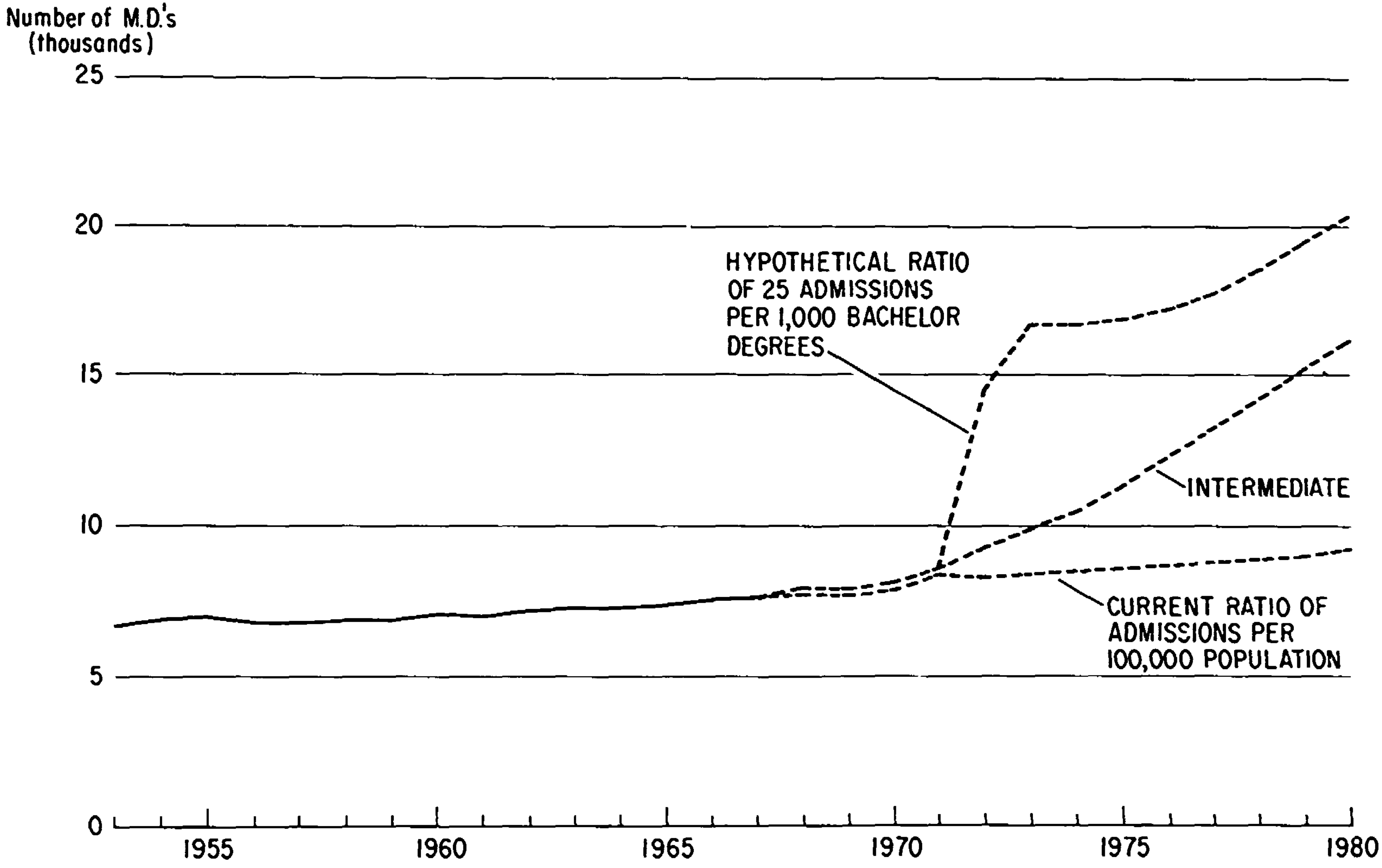
May 1968

CHART 15b

M.D. Output of U.S. Medical Schools, 1953–67, and Projections, 1968–80



Sources: American Medical Association
National Institutes of Health

RAB-OPP-NIH
May 1968

issued to U.S. citizens trained abroad approximated the output of three typical U.S. medical schools between 1960 and 1965.[17]

If the 1956–67 trend continues, it seems probable that the proportion of newly licensed, foreign-trained physicians may continue to approximate 20 to 25 percent of the annual supply of new M.D.'s trained in the U.S.[18] The use of this assumption suggests that the total addition to the U.S. supply of M.D.'s, 1968–80, from both domestic and foreign sources, might range from 136,000, using the low estimate based upon an inflexibly fixed ratio of 4.6 entering medical students per 100,000 population, to nearly 230,000 assuming that the size of entering medical classes is enlarged to 25 per 1,000 baccalaureates. The number of physicians under the intermediate projection would total 175,000 for the 12-year period.

[17] *Journal of the American Medical Association*, vol. 202, No. 8, Nov. 20, 1967, p. 754.

[18] The National Advisory Commission on Health Manpower recommends (see p. 18 of their report) that "the United States should produce a sufficient number of physicians to meet its needs" and that the influx of foreign medical graduates should be "phased out over a number of years." The report notes, however, that this phasing out of foreign medical graduates would necessitate an eventual expansion of 20 percent above present (and projected) enrollment in U.S. medical schools to replace this specific source of medical manpower.

As discussed later (p. 88) expanding the total supply of physicians would maintain the current proportion of M.D.'s in research, teaching, and related activities at 5.6 percent of the total in 1985 for the high projection; the intermediate projection would show a modest increase in this ratio to 6.3 percent (see table 29).

Additional sources of medical professionals are the Doctors of Osteopathy, Doctors of Dental Surgery, and Doctors of Veterinary Medicine. Comparable data on research participation are not available for these groups.[19] Nevertheless, members of each of these professions now engage in medical research; it is reasonable to assume that this number will grow in the decade ahead. Thus, it is necessary to estimate the probable input from these professions into medical research, 1966–85. Between 1951 and 1965, more than 65,000 degrees were awarded in these professions; the best available estimates suggest that approximately 110,000 will be awarded, 1966–85 (table 30). The annual average for this 20-year period is expected to approximate 5,500.

[19] Reliable estimates on current research participation of podiatrists, chiropodists, optometrists, and pharmacists are also not available. Consequently, the research manpower projections do not include these health professions.

TABLE 29.—Total Physician Population and Proportion of M.D.'s in Biomedical Research, Teaching, and Related Service Activities 1965, and Projections, 1970–1985

[Thousands]

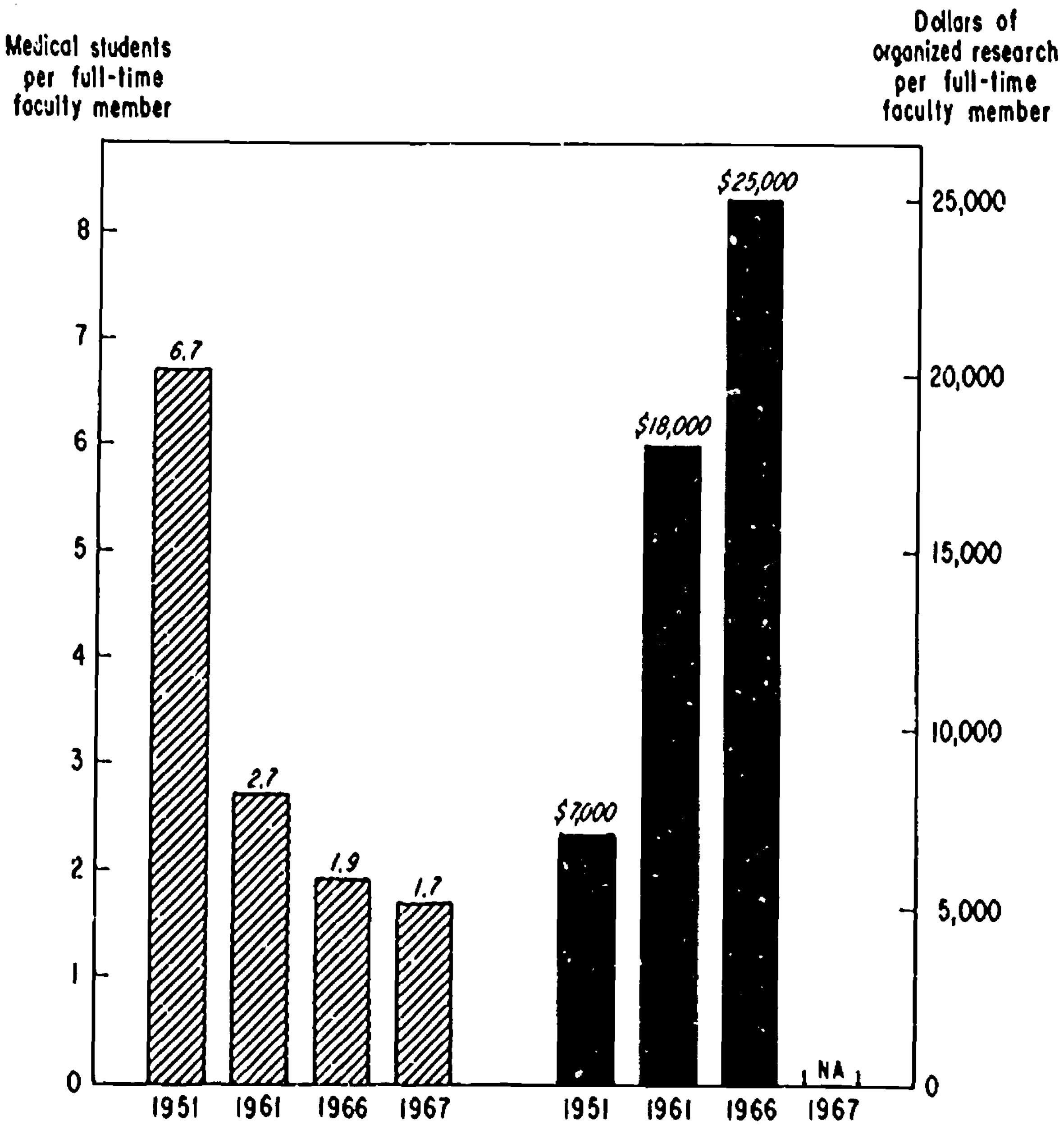
Year	Total number of physicians			M.D.'s in biomedical research, teaching, and related service activities			
	Low	Intermediate	High	Number[1]	Percent of total physicians		
					Low	Intermediate	High
1965 actual	305	305	305	17.0	5.6	5.6	5.6
Projected:							
1970	321	322	322	19.8	6.2	6.1	6.1
1975	340	348	375	23.7	7.0	6.8	6.3
1980	361	396	447	27.4	7.6	6.9	6.1
1985	384	467	533	29.6	7.7	6.3	5.6

[1] From table 13. It should be noted that these numbers include D.O.'s, D.D.S.'s, and D.V.M.'s as well as M.D.'s. However, because the former group comprises only a miniscule proportion of M.D.'s engaged in research, it is unlikely that their inclusion alters the ratio by as much as 1/10 of 1%.

Note.—Number of physicians—1965 actual: Ruhe, C. H. William, "Present Projections of Physician Production," *Journal of the American Medical Association*, vol. 198, No. 10, Dec. 5, 1966, p. 1100. Projections—National Institutes of Health, derived by adding to the 1965 base (305,000 physicians) the low, intermediate, and high projections of M.D.'s entering the physician pool from table 28; then subtracting 2 percent per annum for attrition due to death and retirement.

CHART 16

Number of Medical Students and Organized Research Expenditures in U.S. Medical Schools Per Full-Time Faculty Member: 1951, 1961, 1966, and 1967



Source: American Medical Association
National Institutes of Health

RAB-OPP-NIH
May 1968

TABLE 30.—Output of D.O.'s, D.D.S.'s and D.V.M.'s From U.S. Schools, 5-Year Intervals, 1946–65, and Projections to 1980

Year Group	Total	D.O.	D.D.S.	D.V.M.
Output 1946-65	77, 204	7, 602	57, 378	12, 224
1946-50	11, 893	1, 108	10, 785	N.A.
1951-55	21, 133	2, 224	14, 915	3, 994
1956-60	21, 953	2, 291	15, 554	4, 108
1961-65	22, 225	1, 979	16, 124	4, 122
Projections 1966–85	109, 900	10, 800	76, 600	22, 500
1966-70	24, 700	2, 600	17, 700	4, 400
1971-75	27, 200	2, 700	18, 900	5, 600
1976-80	28, 300	2, 700	19, 500	6, 100
1981-85	29, 700	2, 800	20, 500	6, 400

Sources: 1946-65—D.O.'s, D.D.S.'s, Public Health Service, *Health Manpower Source Book* and *Health Resources Statistics, 1965*; D.V.M.'s—American Veterinary Medical Association and *Health Resources Statistics 1965*; Projections 1965-85—National Institutes of Health.

TABLE 31.—Ratio of Output of M.D.'s to Ph. D.'s in the Selected Sciences, 1920–67, and Projections, 1970, 1975, and 1980

Year of degree	Output of M.D.'s	Output of Ph. D.'s in the selected sciences	Ratio M.D.'s/ Ph. D.'s
1920	3, 047	333	9. 15
1930	4, 565	1, 119	4. 08
1940	5, 097	1, 804	2. 83
1950	5, 553	3, 682	1. 51
1960	7, 081	5, 266	1. 34
1965	7, 409	8, 941	. 83
1966	7, 574	9, 775	. 77
1967	7, 743	11, 127	. 70
PROJECTED			
1970:			
Low	7, 900		. 49
Intermediate	8, 100	16, 000	. 51
High	8, 100		. 51
1975:			
Low	8, 600		. 30
Intermediate	11, 300	29, 100	. 39
High	16, 800		. 58
1980:			
Low	9, 200		. 17
Intermediate	16, 100	53, 100	. 30
High	20, 400		. 38

Source: Actual data—output of M.D.'s: 1920 and 1930, *Journal of the American Medical Association*, vol. 105, No. 9, August 1935, p. 686; 1940 to 1967, JAMA, vol. 202, No. 8, Nov. 20, 1967, p. 756. Ph. D. in the selected sciences: 1920 to 1950, National Academy of Sciences, *Doctorate Production in the United States, 1920–1951, 1963*, pp. 10, 11; 1965, 1966, NAS, *Doctorate Recipients from United States Universities, 1958–1966*, pp. 5–9; 1967, NAS unpublished data. Projections—M.D.'s and Ph. D.'s—National Institutes of Health.

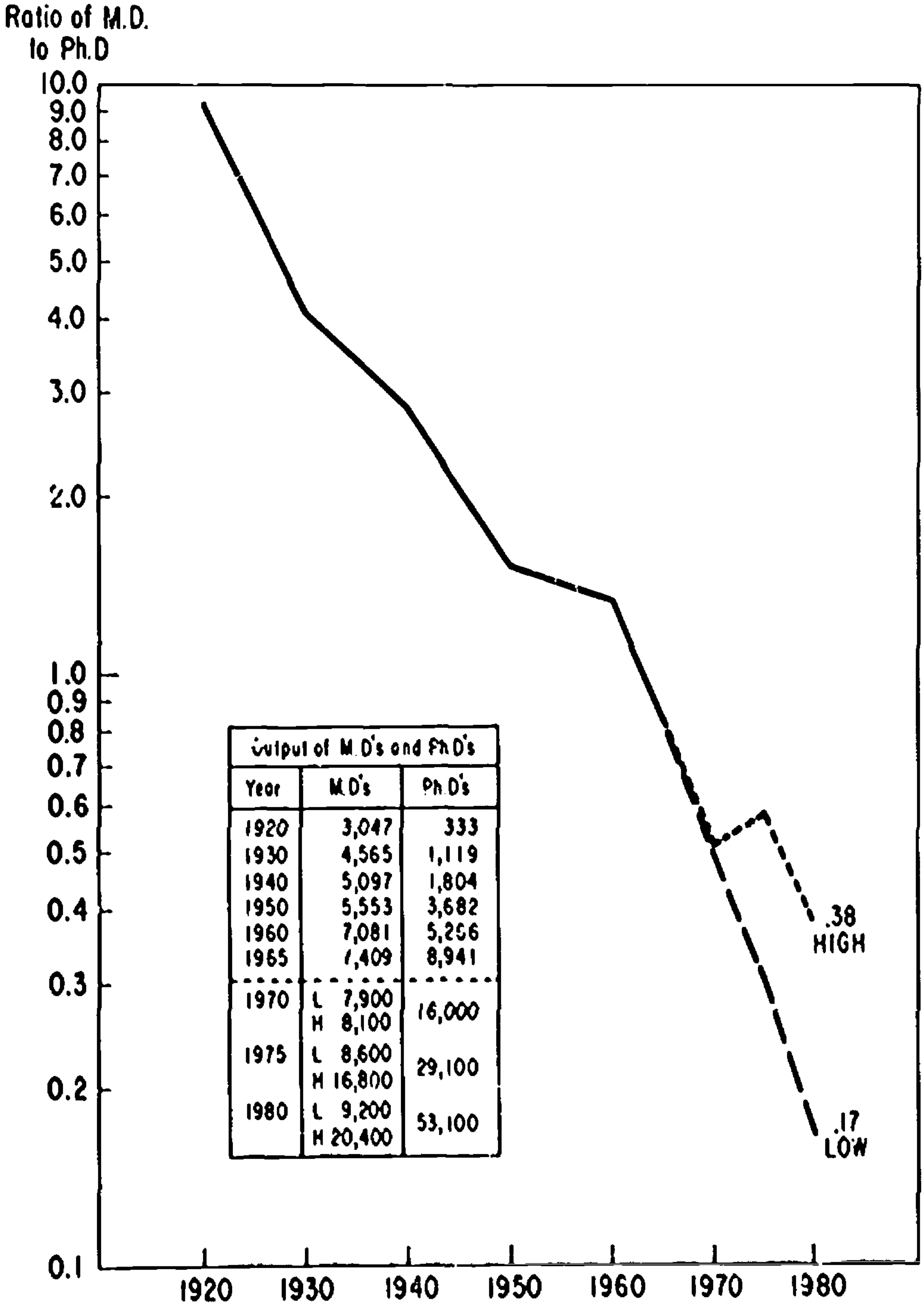
E. Output of M.D.'s and Ph. D.'s, 1920–65, and Projections to 1980

During the last 45 years, the ratio of the output of M.D.'s to Ph. D.'s in the selected sciences has declined sharply and steadily from 9 to 1 in 1920 down to 0.8 to 1 in 1965. It is likely that this long-term trend will continue through the eighties notwithstanding the probable increases in the size of medical school entering classes after 1969. These increases, discussed below, reflect the recommendations of the National Advisory Commission on Health Manpower and in addition, take account of the development of new medical schools and the expansion of existing institutions.

The ratio of M.D.'s to Ph. D.'s is presented in table 31 and illustrated graphically in chart 17. That is, assuming a continuation of gradually increasing output of M.D.'s to about 9,200 in 1980 (the low projections) and the estimated Ph. D. output of 53,100 in 1980, the ratio of M.D.'s to Ph. D.'s in the selected sciences would continue to decline to 0.17 by 1980. Assuming a major policy decision that the number of M.D.'s to be trained should be adequate to meet the health needs of the American people, then the number of medical school graduates would increase dramatically to 20,400 by 1980 (the high estimate) lifting the ratio to 0.38.

CHART 17

Ratio of Output of M.D.'s to Ph. D.'s in the Selected Sciences, 1920-65, Projected to 1980



Output of M.D's and Ph.D's

Year	M.D's	Ph.D's
1920	3,047	333
1930	4,565	1,119
1940	5,097	1,804
1950	5,553	3,682
1960	7,081	5,256
1965	7,409	8,941
1970	L 7,900 H 8,100	16,000
1975	L 8,600 H 16,800	29,100
1980	L 9,200 H 20,400	53,100

Sources: M.D's (Actual) - American Medical Association
Ph.D's (Actual) - National Research Council
Projections - National Institutes of Health

RAB-OPP-NIH
May 1968

V. THE FLOW OF PROFESSIONAL WORKERS INTO THE MEDICAL RESEARCH MANPOWER POOL, 1965–85

In the early years, research growth acted like a sponge, absorbing into research activity many M.D.'s and an even larger number of Ph. D.'s who had never dreamed of opportunities in biomedical fields on a scale made possible through the rapid and steady growth over the past 20 years. But the current and prospective supply of such investigators no longer meets the growing demand. The growth of financial support for medical research generates a demand for more trained researchers, which requires not only additional M.D.'s and Ph. D.'s but also postdoctoral research training for those who have already achieved the doctorate. *Thus, the education and development of large numbers of well-qualified investigators will be the primary strategic factor influencing the growth of medical research*

This factor is more critical for research than for other functions because:

1. The manpower pool is restricted to a highly specialized group.
2. Creative talent is scarce and only a portion of those adequately trained will be motivated toward research.
3. The possibility of improving utilization through job dilution or substitution of lesser skills is limited.
4. Extensive preparation is required to meet exacting standards.
5. The minimum training period is long—from 5 to 10 years beyond the bachelor's degree.
6. There is a considerable lag between completion of formal academic preparation for the M.D. or Ph. D. degree and entrance into the medical research manpower pool as an independent researcher.

This last consideration is crucial in examining the flow of well-qualified investigators into the medical research manpower pool because (1) doctoral-trained manpower (M.D. or Ph. D.) now comprises 77 percent of those actively engaged in medical research, and (2) it is estimated that this proportion may approach 85 percent by 1985,[1] taking into account the growing involvement of Ph. D.'s and M.D.'s in medical research.[2]

A. Time-Lag Influencing the Flow of Doctoral-Trained Scientists Into the Biomedical Manpower Pool

The supply of doctoral-level manpower serving as new principal investigators is drawn from those who have been serving as co-investigators and research associates; men from 3 to 15 years past their formal Ph. D. or M.D. training. As these new people move into the independent investigator supply, their numbers are replenished by postdoctoral fellows and trainees moving up the research career ladder. Their numbers in turn are replenished by younger postdoctoral fellows stepping into responsible research assistant slots. Consequently, for the short run, we must depend largely but not exclusively upon those who have already completed the formal requirements for their M.D. or Ph. D. degrees.

It is assumed that the vast majority of independent investigators with M.D.'s will flow into the pool within 5 to 15 years after receipt of the doctoral degree. If this seems unduly long, it must be recognized that the normal post-M.D. preparation involves a minimal period of 4 years, 1 year of internship and 3 years of residency training. Military service may add several additional years. Postdoctoral research training, while it further defers entrance into the research manpower pool as a fully-qualified independent investigator, provides the research experience and training requisite for more productive inquiry. Thus, the M.D. desiring to do medical research is likely to enter

[1] See ch. III, chart 5.

[2] This proportion may be influenced by recently enacted amendments to the Selective Service Act which would have the immediate impact of sharply curtailing male graduate enrollment in 1968 and 1969 and possibly subsequent years.

the manpower pool, with the capability of carrying out research at the level of an independent investigator, sometime between 5–15 years after completion of his medical school training. In the interim, of course, he will have participated as a research assistant or research associate before (1) seeking support in his own right in the arena of national competition, or (2) joining as a collaborator in a more highly organized research enterprise.

It is likewise assumed that the independent investigator with a Ph. D. will flow into the pool within 3 to 10 years after his doctorate. After his formal education in the sciences relevant to medical research, he can be expected to spend a minimum of 2 years in postdoctoral training, followed by additional experience and training as a research assistant or research associate before entering the medical research manpower pool as a fully-trained independent investigator.

Thus, for all practical purposes, M.D.'s who receive their degrees between 1956–1980 and Ph. D.'s who receive their degrees between 1957–1982 will constitute the pool from which additions to medical research manpower may be drawn between 1966 and 1985.

B. The Use of Models

The flow of professional workers into the medical research manpower pool can be simulated through the use of models that: (1) take into account the total number available; (2) estimate the proportion that will engage in medical research; (3) phase the entrance into the research manpower pool of each cohort or class over a 3–15 year period after receipt of the M.D. or Ph. D. degree; and (4) make assumptions about the additional number of scientists trained abroad and conducting medical research either in the United States or with U.S. support in a foreign country.

The crucial assumptions in developing such models are that (1) a relatively constant proportion of M.D.'s and a steadily rising number of Ph. D.'s already trained and those who will complete formal training will participate in biomedical research, teaching, and related service activities between now and 1985; (2) there will be a sustained expansion of research training opportunities both at predoctoral and postdoctoral levels; and (3) a continued enlargement of support will be available for research and for the construction of research and related facilities.

To illustrate the flow into the medical research manpower pool, models based on these assumptions have been prepared. These models simulate the year-by-year flow and set forth sources and assumptions in detail for two groups—M.D.'s and Ph. D.'s in the basic medical sciences—that now comprise nearly 80 percent of the doctoral-trained manpower pool for biomedical research.

The models show how new entrants flowing into the research manpower pool in any one year are drawn from Ph. D.'s and M.D.'s who have been trained from 3 to 15 years before (3–10 years for Ph. D.'s and 5–15 years for M.D.'s), and demonstrate that the long-term pay-off of today's training programs shows up in the enlarged supply and sharpened skills of tomorrow's researchers.

It should be emphasized that these models are artificial constructs and that the numbers in the year-by-year flow of new entrants into medical research depend heavily upon the validity of the assumptions used. In the present case, it is apparent that the assumptions with respect to Ph. D. output are not consonant with the realities of the current situation. But, as indicated in chapter II, the sharp contrast between assumptions and grim reality has blurred considerably as the outlook for peace in Vietnam has brightened. Consequently, the assumptions which apply to a long-term assessment based on two decades of experience rather than the current situation of unpredictable duration, have not been altered.

C. The Flow of M.D.'s Into Research, 1966–85

Table 32 traces the flow of M.D.'s from five classes (1960, 1965, 1970, 1975, and 1980) into the medical research manpower pool, 1965–94, using the *low* estimate of M.D. output; table 33 traces the flow, drawing upon the *high* estimate of M.D. output, and table 34 illustrates the flow under the intermediate projection. In illustrating the flow of these five classes, it has been assumed that:

1. The number of M.D.'s graduating each year will range between the low and high estimates described in chapter IV (table 28).
2. The proportion of M.D.'s entering research will remain constant at approximately 15 percent from each class, 1960 through 1980.
3. Input into medical research of foreign-trained M.D.'s will continue at approximately 20 percent of the total number of U.S.-

trained M.D.'s entering research, reflecting the continued need of those trained abroad to meet U.S. requirements for research, teaching, and service.

4. There is a minimum 5-year lag after graduation (for internship, residency. military service, and postdoctoral research training and experience) before entering into independent research.

5. All those entering into research will do so between the 6th and 15th year following graduation.

The class of 1965 entered medical school as freshmen in September 1961 and were awarded their M.D. degrees in 1965; they spent 1966 in internship; and most of those who ultimately might enter medical research will spend a minimum of 2 years, more likely 3-4 years, in

TABLE 32.—Model for Illustrating Flow of M.D.'s Entering Medical Research Manpower Pool, 1965-94, From Classes of 1960, 1965, 1970, 1975, and 1980 (*Low Estimates*)

Year of graduation	Number of M.D. degrees awarded	Total of M.D.'s entering medical research 1960-94 from classes of 1960, 1965, 1970, 1975 and 1980	Years					
			1960-64	1965-69	1970-74	1975-79	1980-84	1985 and after
Class of 1960	7,081	1,062	....	797	265	....	....	.....
Class of 1965	7,409	1,111	....	....	833	278	....	....
Class of 1970	7,888	1,183	....	....	....	885	298	....
Class of 1975	8,595	1,289	....	....	....	....	967	322
Class of 1980	9,171	1,376	....	....	....	....	....	1,376
Total entering research from above 5 classes	....	6,021	....	797	1,098	1,163	1,265	1,698
Plus foreign input	....	1,204	....	159	220	233	253	340
Grand total	....	7,225	....	956	1,318	1,396	1,518	2,038

Source: M.D. graduates of classes of 1960 and 1965 from *Journal of the American Medical Association*, vol. 202, No. 8, Nov. 20, 1967, p. 756. Projections for classes of 1970, 1975, and 1980, foreign input, and estimates of numbers entering medical research developed by the Resources Analysis Branch, OPPE, NIH. See app. E, table 1A, which gives year-by-year detail.

TABLE 33.—Model for Illustrating Flow of M.D.'s Entering Medical Research Manpower Pool, 1965-94, From Classes of 1960, 1965, 1970, 1975, and 1980 (*High Estimates*)

Year of graduation	Number of M.D. degrees awarded	Total of M.D.'s entering medical research 1965-94 from classes of 1960, 1965, 1970, and 1980	Years					
			1960-64	1965-69	1970-74	1975-79	1980-84	1985 and after
Class of 1960	7,081	1,062	....	797	265	....	....	....
Class of 1965	7,409	1,111	....	....	833	278	....	....
Class of 1970	8,068	1,210	....	....	....	907	303	....
Class of 1975	16,836	2,525					1,893	632
Class of 1980	20,424	3,064	....	....	....	....	....	3,064
Total entering research from above 5 classes	....	8,972	....	797	1,098	1,185	2,196	3,696
Plus foreign input	....	1,794	....	159	220	237	439	739
Grand total	....	10,766	....	956	1,318	1,422	2,634	4,435

Source: M.D. graduates of classes of 1960 and 1965 from *Journal of the American Medical Association*, vol. 202, No. 8, Nov. 20, 1967, p. 756. Projections for classes of 1970, 1975, and 1980, foreign input, and estimates of numbers entering medical research developed by Resources Analysis Branch, OPPE, NIH. See app. E, table 2A, which gives year-by-year detail.

TABLE 34.—Model for Illustrating Flow of M.D.'s Entering Medical Research Manpower Pool, 1965–94, From Classes of 1960, 1965, 1970, 1975, and 1980 (*Intermediate Estimates*)

Year of graduation	Number of M.D. degrees awarded	Total of M.D.'s entering medical research 1965–94 from classes of 1960, 1965, 1970, and 1980	Years					
			1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985 and after
Class of 1960	7,081	1,062	....	797	265	....	....	....
Class of 1965	7,409	1,111	....	....	833	278	....	....
Class of 1970	8,068	1,210	....	....	....	907	303	....
Class of 1975	11,316	1,697	....	....	....	....	1,275	422
Class of 1980	16,100	2,415	....	....	....	....	....	2,415
Total entering research from above 5 classes	....	7,495	....	797	1,098	1,185	1,578	2,837
Plus foreign input	....	1,499	....	159	220	237	316	567
Grand total	....	8,994	....	956	1,318	1,422	1,894	3,404

Source: M.D. graduates of classes of 1960 and 1965 from *Journal of the American Medical Association*, vol. 202, No. 8, Nov. 20, 1967, p. 756. Projections for classes of 1970, 1975, and 1980, foreign input, and estimates of numbers entering medical research developed by Resources Analysis Branch, OPPE, NIH. See app. E, table 3A, which gives year-by-year detail.

residency training followed by 1–2 years of postdoctoral research training. Thus, the first trickle from this class will not have entered the pool until 1970 at the earliest. Similarly, the class of 1966 which spent this year in internship and is now entering residency training will not conduct research as independent investigators before 1971 at the earliest. *By 1980, however, it is possible that all of those from 1965 or prior classes will have entered the pool; some will continue in this activity for the major portion of their careers; others will conduct research for a shorter period and then concentrate instead on medical care, administration, and other non-research activities.* Thus, the number from any given class making a career of research, either full-time or combined with teaching and related service activities, will be considerably below the 15-percent level which represents those who engage in research activities for some period of time within 15 years after receiving their M.D. degrees.

Nearly one out of every seven young men and women entering medical school as freshmen can look forward to productive experience in research, probably combined with teaching and related service activities. Their career aspirations and research interests are bound to be influenced by (1) the opportunities for research experience, (2) the nature of their medical education, and (3) the character of their postdoctoral training and experience.

Tables 32, 33, and 34 illustrate:

1. The long lag between attainment of the M.D. degree and entrance into research.
2. The effect of the projected increase in the number of new M.D.'s on the number entering research, beginning with roughly 1,100 for the class of 1960 and rising to approximately 1,200 for the class of 1970, then rising further to between 1,400 to 2,400 to 3,000 (low, intermediate, and high estimates) for the class of 1980.

This illustrative analysis has been carried through on a year-by-year basis to project the flow and total input from each medical school class that will influence the additional supply of M.D.'s in medical research, 1966–85 (app. E, tables 1A, 2A, and 3A). This projection, when *cumulated*, indicates that the total increment of M.D.'s (including those who receive their undergraduate training in foreign medical schools) entering the medical research manpower pool from 1966 through 1985 may approximate 27,000 (low projection) 30,000 (intermediate projection) and 36,000 (high projection). On an *annual* basis, an average of 1,380 per year (low projection), 1,620 (intermediate projection), and 1,820 (high projection) would enter the medical research manpower supply, 1966 to 1980 (app. E, tables 1B, 2B, and 3B).

As described in the preceding chapter (p. 80), comparable data are not available for an additional source of supply for the medical research manpower pool comprising Doctors of Osteopathy, Doctors of Dental Surgery, Doctors of Veterinary Medicine, podiatrists, chiropodists, optometrists, and pharmacists. However, projections of the output of D.O.'s, D.D.S.'s, and D.V.M.'s for 1966–85 are shown in table 30. The average annual output for this 20-year period is expected to approximate 5,500. If it is assumed that about 2.5 percent of each year's graduating classes of osteopathists, dentists, and veterinarians will participate in medical research at least on a part-time basis sometime during their careers, this would add approximately 140 doctoral-trained clinical investigators annualy, 1966–85.

D. Impact Upon the Total Supply of Physicians To Meet the Health Needs of the Nation

It is estimated that 27,000–36,000 additional M.D.'s will enter research, 1966–85, depending upon whether the low projections or the high projections are realized. The intermediate projection indicates a flow of 30,000 M.D.'s into medical research. What impact is this likely to have upon the proportion of M.D.'s in research to the total supply of physicians?

Over the long run it is evident that the Nation must expand the supply of physicians and other health personnel to meet the Nation's total health needs for medical care, teaching, and research.[3] The following observations, however, are pertinent to a serious consideration of short run implications.

1. In 1965, nearly four-fifths of the M.D.'s in research were located in universities and research institutes. Virtually all the M.D.'s in research in this sector were either full-time members of the clinical faculties of medical schools or in independent teaching and research hospitals. Of the remaining one-fifth, all but 5 percent were employed in Federal and State hospitals and health agencies.
2. Most of the M.D.'s engaged in research in medical schools and in non-Government and Government hospitals also teach medical students, instruct interns, and supervise the training of residents and postdoctoral fellows.
3. Most of these M.D.'s also render a wide range of health services in the inpatient and outpatient programs administered through the modern medical centers affiliated with medical schools or operated by Federal and State agencies.
4. M.D.'s engaged part time in research also perform teaching and service functions. As changes occur in the organization of health services, it is expected that increasing numbers of these physicians will participate in regional medical programs in research, in teaching, in service, and in continuing education both as teachers and as learners.

As pointed out in the preceding chapter, the total supply of physicians, to 1985 has been projected under three alternatives. The low projection indicates a 25-percent increase in the Nation's physicians from 305,000 in 1965 to 384,000 in 1985; the intermediate assumption projects a 50-percent increase to 467,000; the high projection results in a 75-percent increase to 533,000. Over this same period, the numbers of M.D.'s engaged in research, teaching and related activities are projected to increase 75 percent from 17,000, in 1965 to almost 30,000 in 1985. *Thus, by 1985, the proportion of M.D.'s in these activities in relation to the total supply of physicians for the high projection would remain at the 1965 level of 5.6 percent; for the intermediate projection this ratio would increase to 6.3 percent; and would increase more substantially to 7.7 percent under the low projection.*

Participation in biomedical research, therefore, will not materially diminish the supply of physicians available for service, providing that the substantial projected enlargement of total output of M.D.'s, 1970–85 occurs. To realize this assumption, prompt measures must be taken now to expand the size of entering classes, taking full advantage of the unprecedented numbers of well-qualified baccalaureates seeking careers in medicine, and thereby enlarging the supply of physicians to meet the many pressing health needs now postponed by the doctor shortage.

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[3] The National Advisory Commission on Health Manpower in volume I of its report of November 1967 recommends strongly that "The production of physicians should be increased beyond presently planned levels by a substantial expansion in the capacity of existing medical schools, and by continued development of new schools." (p. 19).

E. Participation of Ph. D.'s in the Biosciences in Medical and Health-Related Research

As of 1965, there were nearly 34,000 Ph. D.'s in the biosciences in the United States (table 35). The basic medical science group—anatomy, biochemistry, biophysics, microbiology, pathology, pharmacology, and physiology—comprise one-half of these bioscience Ph. D.'s.

What are the critical characteristics of this pool of Ph. D. trained scientists? [4]

1. *Youth and recency of training.*—Roughly half of the 34,000 bioscientists are under 40 years of age. Approximately 40 percent of the total received their degrees 1957–65; more than 70 percent of them have received their degrees since the close of World War II.
2. *High research orientation.*—Nearly 90 (89) percent of the basic medical scientists are engaged in research either as a primary or a secondary activity. The other bioscientists have almost as high a research participation (84 percent), but a smaller percentage report research as a primary activity.
3. About 70 percent of the bioscientists are employed in universities and research institutes, nearly 65 percent of them in colleges and universities.

TABLE 35.—Distribution of Ph. D.'s in Biosciences, by Discipline, 1965

Field and discipline	Number [1]	Percent
Biosciences	33, 501	100. 0
Basic medical sciences	16, 462	49. 1
Anatomy	1, 689	5. 0
Biochemistry	4, 722	14. 1
Biophysics	602	1. 8
Microbiology	4, 322	12. 9
Pathology	367	1. 1
Pharmacology	1, 737	5. 2
Physiology	3, 023	9. 0
Other biosciences	17, 039	50. 9
Botany	3, 177	9. 5
Ecology	598	1. 8
Entomology	2, 163	6. 5
Genetics	1, 873	5. 6
Hydrobiology	[2] 245	. 7
Nutrition	2, 177	6. 5
Plant pathology	1, 639	4. 9
Zoology	3, 496	10. 4
Biology, all other	1, 671	5. 0

[1] From the National Science Foundation *National Register of Scientific and Technical Personnel* as of 1966, supplemented by National Academy of Sciences data on Ph. D. output through 1960 and data from the Office of Education through 1965.
[2] This figure represents the national total for 1966.

Taken together, these three factors—youth, high research orientation, and high concentration in colleges and universities—characterize the current supply of Ph. D.'s in the biosciences.

This newly trained group has many productive years ahead; roughly half of all Ph. D.'s in these fields are under 40. Likewise, the fact that most of these Ph. D.'s are faculty members carrying on research as a part-time activity provides a highly elastic element in the manpower supply picture.[5] This element of elasticity is crucial because a slight increase in the proportion of faculty time devoted to research can substantially enlarge the effective medical research manpower pool.[6]

Between 1946 and 1967, nearly 210,000 Ph. D. degrees were awarded in all fields.[7] In the early years of this period, about two-fifths of all Ph. D.'s were awarded in the selected science fields; by 1967 this proportion had increased to 55 percent. While scientists from all fields and disciplines now participate in the Nation's medical research enterprise, about two-thirds of the Ph. D.'s are drawn from the biosciences. The basic medical sciences [8]

[4] Age, education, and employment data based upon the National Science Foundation *National Register of Scientific and Technical Personnel*, supplemented to provide complete coverage of Ph. D. output through 1965.

[5] Based upon a national sample survey, four-fifths of university teaching faculty in the basic medical sciences reported that they were also engaged in sponsored research. Spaeth, Joe L., *American College Faculty Members, 1963*, p. 45, National Opinion Research Center, October 1966.

[6] A recent study shows that university administrators anticipate such an increase in the proportion of faculty time devoted to research at new and developing institutions. *Preliminary Report on Expansion of Graduate and Professional Education*, Academy for Educational Development, Inc., December 1967.

[7] National Academy of Sciences, *Doctorate Production in United States Universities, 1920–1962*, and *Doctorate Recipients from United States Universities, 1958–1966*; 1967 data unpublished.

[8] The basic medical sciences are the component of total biosciences which includes anatomy, histology, bacteriology, virology, mycology, parasitology, microbiology, biochemistry, biophysics, cytology, embryology, pathology, pharmacology, and physiology.

represent the largest and most critical group of the Ph. D. scientists in medical research.

In the past, the great men in the basic medical sciences—Galen, Harvey, Bernard, Virchow, Koch, Ehrlich—were trained as physicians; they received extensive training in the natural sciences; they combined research with teaching and with service; they held university or independent institute faculty appointments; they were highly productive as researchers in their early years; they exercised a great influence upon their students throughout their lives.

These characteristics are almost equally descriptive of today's basic medical scientists—with the significant exception, occasioned by the growth of knowledge, the modern scientists are increasingly specialized. Today, the preponderance of basic medical scientists are Ph. D. trained; with a steadily decreasing proportion first seeking a medical education, the classical pattern that governed the output of basic medical scientists in the United States through the twenties.

F. The Flow of Ph. D.'s in the Basic Medical Sciences Into the Medical Research Manpower Pool, 1966–85

By applying the concept of the flow model as was done for M.D.'s we can estimate the probable number of Ph. D.'s who will enter the medical research manpower pool, 1965–85. Table 36 illustrates the flow of four cohorts (those receiving Ph. D.'s in the *basic medical sciences* in 1965, 1970, 1975, and 1980) into medical research, 1968–89. In developing this model, it has been assumed that:

1. The numbers of Ph. D.'s graduating each year are extrapolated from the National Academy of Sciences data on Ph. D. output described in chapter IV.
2. Ninety percent of Ph. D.'s in the basic medical sciences will enter research. This corresponds with current participation.
3. Foreign input equals 20 percent of the total U.S.-trained Ph. D.'s entering medical research, 1965–75,[9] this proportion will decline to 10 percent of the U.S. Ph. D. output, 1976–85.
4. There is a minimum 3-year lag for postdoctoral training and research experience between receipt of the Ph. D. and entrance into independent research.
5. Those entering research will do so between the 4th and 10th year after receipt of the Ph. D. This assumes that those who enter the pool as independent investigators prior to the 4th year after receipt of the Ph. D. probably are equal to the number who enter for the first time after their 10th year.

[9] National Institutes of Health First-Time Grantee Studies.

TABLE 36.—Model for Illustrating Flow of Ph. D.'s in the *Basic Medical Sciences* Entering Medical Research Manpower Pool, 1968–89, From Classes of 1965, 1970, 1975, and 1980

Year of graduation	Number of Ph. D. degrees awarded	Total of Ph. D.'s entering medical research 1968–89 from classes of 1965, 1970, 1975, and 1980	Years: 1968–69	1970–74	1975–79	1980–84	1985 and after
Class of 1965	1,184	1,066	426	640	....	....	....
Class of 1970	2,092	1,883	....	754	1,129	....	....
Class of 1975	3,753	3,378	....	....	1,352	2,026	....
Class of 1980	6,733	6,060	....	....	....	2,424	3,636
Total entering research from above four classes	....	12,387	426	1,394	2,481	4,450	3,636
Plus foreign input	....	1,421	85	279	248	445	364
Grand total	....	13,808	511	1,673	2,729	4,895	4,000

Source: Ph. D. graduates of class of 1965—National Academy of Sciences, *Doctorate Recipients from United States Universities, 1958–1966*. Projections for the classes of 1970, 1975, and 1980; foreign input, and estimates of numbers entering medical research developed by Resources Analysis Branch, OPPE, NIH. See app. E, table 4A, which gives year-by-year detail.

It is likely that 1,800 Ph. D.'s in the basic medical sciences will enter medical research by 1975 from the two cohorts of 1965 and 1970 (426 plus 640 plus 754=1,820) (see table 36).

Because Ph. D. output triples over a decade (2,092 in 1970 to 6,733 in 1980) enlarging the base correspondingly, the two later cohorts of 1975 and 1980 will add three times as many Ph. D.'s (5,800) in the basic medical sciences to the supply of medical researchers between 1975 and 1985.

Taking these four cohorts as illustrative, the total input including foreign trained Ph. D.'s into biomedical research 1968–80 will approximate 13,800. Moreover, Ph. D.'s entering medical research would mount steeply from about 1,100 from the 1965 cohort to 3,400 from the 1975 cohort and about 6,000 from the 1980 cohort.

This abbreviated analysis of four cohorts has been used to (1) illustrate the time lag between receipt of Ph. D. degree and entrance into the medical research manpower pool; (2) emphasize that the number of Ph. D.'s in the basic medical sciences entering research is likely to rise steeply in consonance with enlargement of Ph. D. output; and (3) show the number of Ph. D.'s in the basic medical sciences that will probably enter the supply of well-qualified independent investigators during each 5-year period depending upon the assumptions.

A more detailed, year-by-year analysis tracing the flow and total input from each Ph. D. cohort that will influence the additional supply of scientists trained in the basic medical sciences, and entering medical research, 1966–85 is presented in appendix E, table 4A. Drawing upon the data presented in this table and the matching cumulative table (app. E, table 4B), approximately 55,000 Ph. D.'s in the basic medical sciences may participate in the Nation's medical research effort, 1965–85.

G. Input of Ph. D.'s in Other Science Fields Into Medical Research Manpower Pool, 1966–85

Accepting the flow model as a projection technique, and the underlying assumptions, about 55,000 Ph. D.'s in the basic medical sciences may enter medical research, 1966–85. Comparable models have also been prepared [14] of the flow of Ph. D.'s trained in the other selected sciences of relevance for medical research. In total about 59,000 Ph. D.'s trained in fields other than the basic medical sciences may also enter the medical research manpower pool by 1985. The assumptions underlying the projected numbers for these fields are the same as those governing the flow into medical research of Ph. D.'s in the basic medical sciences, in terms of the numbers of Ph. D.'s graduating each year, the input into medical research of foreign trained Ph. D.'s, and the time lag between receipt of the Ph. D. degree and entrance into independent research. However, the proportion of persons trained in these fields who will participate in medical research will range downward from 90 percent for the basic medical sciences and about 50 percent for the other biosciences (the fields of greatest relevance to investigators in the health sciences) to 30 percent of those trained in selected areas in the behavioral sciences (psychology, sociology, and anthropology), 11 percent of the physical science Ph. D.'s, 7 percent for mathematicians and statisticians (including biometricians) and 6 percent of the engineers with formal advanced training.

Based on the projected number of Ph. D. graduates (table 24), the techniques used in the reproduced flow model for basic medical sciences, and the assumptions outlined above as to participation rates and foreign input, the following table summarizes by field, the likely flow of Ph. D.'s into medical research 1966–85:

Ph. D. input into medical research based on flow models—

Field:	1966–85 (thousands)
Total, selected sciences	113.3
Biosciences	68.9
Basic medical sciences	54.5
Other biosciences	14.4
All other fields	44.4
Behavioral fields	13.1
Physical sciences	14.2
Mathematics and statistics	8.9
Engineering	8.2

That medical research investigations will to a significant degree call upon those trained in the physical, engineering, and mathematics fields is a reflection of the directions envisioned for the

[14] See app. E, tables 5, 6, 7, 8, and 9.

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course of biomedical research, as outlined in chapter III, pages 26ff. Each year, on the average, a total of about 1,300 Ph. D.-trained scientists in these fields will become available for medical research. The preponderance, however, of new entrants into medical research will continue to be drawn from those trained in the biosciences, averaging about 3,500 a year. An average of 900 scientists a year, trained in the behavioral sciences (such as psychology, anthropology and sociology) will become an additional source of medical research manpower.

H. Assessment of Less Than Doctoral Manpower Requirements

The preceding analysis has concentrated upon doctoral-trained manpower. However, the supply of professional workers engaged in medical research is by no means limited to doctoral-trained manpower. In 1965, 15,000 professional workers in medical research—23 percent of the total—had not completed formal academic training through the doctoral level. This group includes biomedical researchers who have established their competence as independent researchers, larger but not exclusively in industry and government. It includes scientists in a number of fields such as public health, social work, and nursing where the master's degree is generally recognized as terminal preparation. While it is assumed that the proportion of professional workers with less than doctoral training will decline from 23 percent in 1965 to 16 percent in 1985 (chart 5), it is estimated that a total of some 18,000 such researchers will, nevertheless, be needed for replacement of attrition and for expansion (table 13). This would call for an average of 900 per year—a tiny fraction of the total output of master's degrees in these fields. Consequently, there can be no question that the required number of medical researchers with less than doctoral training will be available. The critical question is whether the caliber of their research training will be high enough to ensure their competence to function as independent researchers.

I. The Probable Balance Between Need and Supply of Doctoral Trained Manpower for Medical Research

The foregoing analyses of M.D. and Ph. D. supply flows, suggest that the aggregate potential supply of M.D.'s and Ph. D.'s for medical research for the 20-year period, 1966–85, will be sufficient to meet the manpower requirements delineated by the best judgment projection, and presented in table 13. In summary, about 116,200 doctoral trained professional investigators will be needed between 1966 and 1985, to (1) replace those lost because of death, retirement, and shifts to other occupations (11,900 M.D.'s, and 27,600 Ph. D.'s), and (2) expand the numbers of workers to bring the labor force to a total of 29,600 M.D.'s and 96,100 Ph. D.'s by 1985 (76,700 additional biomedical scientists i.e., 12,600 M.D.'s and 64,100 Ph. D.'s). This adds to a total of 24,500 additional M.D.'s, and 91,700 Ph. D.'s.

We have seen from the discussion of the projections of M.D.'s that the intermediate estimate would provide a flow of 30,800 M.D.'s into medical research (or 6,300 more than required) and the Ph. D. projection may provide a total of 113,300 Ph. D.'s (or 21,600 more than required) 1966–85. *While it appears that the aggregate input into medical research of doctoral trained investigators might exceed the aggregate requirements for the two decades, the inputs for successive 5-year periods during these decades will, however, not meet the requirements for Ph. D.'s during the seventies, but will exceed the needs for the 1980–85 quinquennium.* The shortfall of Ph. D.'s in the 1970's may approximate about 5,500 Ph. D.'s Conversely, in this decade there may be about 1,000 more M.D.'s engaged in research and related activities over and above the requirements for M.D.'s suggested by the best judgment projection. Thus, to some extent the shortfall of Ph. D. trained investigators could be met by more M.D.'s in research than the best judgment projection suggests. Additionally, the talents of some 2,000 Ph. D.'s may provide a source of manpower for the 1970 decade from those Ph. D.'s who are estimated to have completed their research training by 1970, but who will not have been drawn into the manpower pool because of the constraints upon expansion of biomedical research during the 1967–69 period.

Likewise, this temporary shortage of qualified Ph. D. investigators, for whom fiscal resources are available could be overcome through:

1. Higher participation rates, especially of Ph. D.'s trained in the behavioral, physical, mathematical, and engineering sciences.
2. Reduction of the time-lag between beginning of Ph. D. training and entrance into the biomedical research labor force.

3. Decrease in the attrition rate, especially for those moving into nonresearch activities.
4. Continued utilization of investigators with less than doctoral training although admittedly this may place strains upon the scientific capability and professionalism required.
5. More extensive use of specialized and costly equipment, thereby increasing the cost per man and reducing the total number of Ph. D. investigators needed.

(An alternative projection which is based on the employment in medical research, by 1985, of the total numbers of doctorally trained manpower that may become available for medical research by 1985 has been presented in chapter III. *This full utilization of the labor force would call for a total of 170,000 in medical research by 1985, 20,000 more than the 150,000 best judgment projection.*)

The flow models relating to doctoral trained-manpower and the availability of persons with less than doctoral training suggest that the best judgment projection is in reach. *But this is predicated upon meeting the urgent need for a substantial and continuing expansion of (1) NIH training activities, (2) institutional development programs, (3) construction of teaching, research, and related facilities in order to make possible the availability of 150,000 active research professionals by 1985, and (4) programs which encourage the early involvement of behavioral scientists, physical scientists, mathematicians, and engineers in biomedical research.*

J. Some Qualifying Obseravtions on the Estimate of M.D.'s and Ph. D.'s Entering Biomedical Research, 1965–85

The flow models used to analyze the potential supply of M.D.'s and Ph. D.'s in the biomedical sciences illustrate that:

1. The new doctoral-level entrants into the medical research manpower pool, 1966–85, will be drawn primarily, if not almost exclusively, from scientists who receive their M.D. or Ph. D. degrees after 1966:

   For M.D.'s, more than 70 percent of the new entrants will receive their M.D. degree, 1966 or later.

   For Ph. D.'s, more than 90 percent of the new entrants will have earned the doctoral degree, 1960 or later.
2. New entrants flowing into the research manpower pool in any one year are drawn from those who have been trained from 3 to 15 years before.
3. The long-term payoff in support for graduate education and postdoctoral training in the biomedical sciences shows up in the enlarged supply and sharpened skills of tomorrow's researchers.

Unfortunately, these models may also convey a misleading impression of an automatic or controlled flow of the desired numbers of researchers in quantities precisely sufficient to meet estimated needs. This, coupled with the fact that the analysis indicates that the potential supply may match future requirements, suggests that the problem of meeting the Nation's manpower needs for medical research has already been solved.

Consequently, some qualifying observations are warranted to (1) put the conclusions in proper perspective, and (2) reemphasize the critical assumptions and their influence upon the analysis of the flow of manpower into medical research.

1. It has been assumed that 53 percent of those currently engaged in medical research will need to be replaced by 1985. Death and retirement can be predicted with some degree of certainty. But movement out of medical research into other activities necessarily represents a judgmental estimate. Death, retirement, and movement out of medical research currently averages 2 percent per year. Consequently, if the actual movement of medical researchers into other activities exceeds the estimate, the additional number required by 1985 would increase correspondingly; and vice versa.
2. In estimating the input of doctoral-trained scientists into medical research, as shown in the flow models, it has been assumed that:
   a. Research combined with teaching and/or service will continue to be an attractive and productive career pattern for M.D.'s. The unstated premises implicit in this assumption are that (1) opportunities for such careers will continue to expand through increased support for research

and for research training essential to encourage and develop scientific capabilities of M.D.'s who seek careers in research and academic medicine; and (2) the organization of health service will be modified to fully utilize the facilities and expertise of the modern medical center.

b. The proportion of those trained as basic medical scientists who are engaged in research will continue at the prevailing 90 percent participation rate. Again, the the implicit premise underlying this assumption is that research and research training opportunities will continue to expand and attract this core group of basic scientists.

c. Research and research training opportunities will expand to attract larger numbers of scientists from the fields of the social and behavioral sciences and from the physical sciences, mathematics, and engineering. Whether this assumption holds true will depend largely upon (1) the exciting quality of opportunities available in medical research as compared with all other types of endeavor open to these Ph. D.'s from the behavioral sciences, the physical sciences, mathematics, and engineering; and (2) the character of NIH training activities deliberately designed to encourage participation of scientists drawn from these fields in biomedical research and teaching.

3. Thus, it is clear that meeting medical research manpower requirements, 1966-85, depends upon one fundamental assumption that support for research training, the conduct of research, and the construction of teaching, research, and related facilities will continue to expand, adapting whatever new mechanisms are best suited to the advancement of medical research in the national interest.

In short, there is nothing intrinsically "accurate" or "inaccurate" with respect to these assumptions. In each instance, however, it is believed that the assumptions constitute reasonable expectations, taking into account (1) experience, (2) long-term trends, and (3) the outlook for the future—except for the current uncertainties due to Vietnam budgetary constraints and Selective Service changes, discussed earlier.

Projections to the seemingly far-distant future of 1985 may seem unrealistic. Nevertheless, estimating biomedical manpower needs to 1985 provides a useful frame of reference for the development of a 10-year plan for NIH training programs; students entering medical school or graduate school after 1978 will not flow into the biomedical research manpower pool as independent investigators until the late Eighties.

VI. IMPLICATIONS FOR ACTION

The implications for action flow from (1) the best judgment projection of aggregate biomedical manpower needs, 1965–85, (2) the assessment of high priority staffing requirements in the nonprofit sector, 1967–75, and (3) the identification of critical shortage categories (see ch. III).

The National Institutes of Health serves as the primary instrument of the Federal Government for meeting national biomedical manpower needs for research, teaching, and related service activities through its training programs in all fields related to health. In this capacity, NIH bears a unique responsibility for insuring an adequate supply of well-qualified biomedical manpower for research, teaching, and related service activities for Government, for industry, for universities and medical schools, and for participation in the present and future medical research programs sponsored by a wide variety of Federal agencies and encompassing many major national purposes.

Other agencies such as the Office of Education and the National Science Foundation now provide support for predoctoral training of a small fraction of the total number of graduate students enrolled in the biosciences. Both agencies, however, will be faced with sharply mounting needs for graduate student support in fields other than the biosciences, and neither contributes significantly to biosciences postdoctoral support. Consequently, NIH must plan ahead on the assumption it will continue to bear primary responsibility for the training of biomedical scientists, both predoctoral and postdoctoral, to meet national manpower needs.

A. Meeting Immediate Needs

In order to meet the immediate needs (between now and 1975) for biomedical manpower for research, teaching, and related service activities, it is essential to:

1. Enlarge the supply of qualified biomedical research manpower in an increasingly diverse array of scientific disciplines.
2. Develop the faculty in the health sciences required to permit the predictable expansion of existing medical schools, other health professional schools, and graduate schools and the creation of *25 new* medical schools and *150 new* graduate schools in the 1965–75 decade.
3. Provide the scientific staff required for the initiation of major biomedical research efforts in the national interest, e.g., cardiovascular research institutes, centers for the study of aging, dental research institutes, mental retardation research centers, cancer research institutes, pharmacology-toxicology research centers, and eye research centers.
4. Ensure the availability of research-trained personnel for staffing medical centers and community hospitals participating in the rapidly expanding network of regional medical programs.
5. Take target-oriented action to expand, as rapidly as possible, the supply of biomedical manpower in critical shortage categories.

B. Relating Manpower Needs to the Development of Training Programs

In planning ahead to meet national biomedical manpower needs for research, teaching, and related service activities, the assessment of manpower requirements is only the first step. This assessment has yielded (1) a best judgment projection of long-range manpower requirements through 1985, as well as a range of projections based upon the probable effect of alternative assumptions; (2) an illustrative listing of high priority staffing requirements in the nonprofit sector; and (3) an identification of critical shortage categories. It points up the parameters and suggests the probable composition and timing of manpower needs.

The second and crucial step is to determine the roles which national programs should play in meeting these biomedical manpower requirements for the future.

Because of the very long lead time between (1) the initiation of training activities, (2) the output of well-qualified biomedical manpower, and (3) the entry into the manpower pool for biomedical research, teaching, and related service activities—from 5–10 years beyond the bachelor's degree for Ph. D.'s and from 8–15 years for M.D.'s, the following general considerations are crucial for meeting biomedical manpower needs for the future:

1. Provide strong incentives to attract new talent into the biomedical fields. This can best be done by: (1) Strengthening the capability of institutions to develop well-qualified biomedical manpower for research, teaching, and related service activities, and (2) providing qualified students with adequate support for graduate education and postdoctoral training.
2. Expand national programs in relation to (1) the trends in rising graduate enrollment and subsequent output of M.D.'s and Ph.D.'s in the sciences critical for the advancement of biomedical research, (2) the expansion of existing institutions and the creation of new centers for the training of biomedical scientists, and (3) the increasing need for participation of behavioral, mathematical, and physical scientists and bioengineers in biomedical research and related health activities.
3. Modify the ratio of predoctoral/postdoctoral support to relatively predictable fluctuations in the numbers available for training as graduate students and, subsequently, as postdoctoral fellows.
4. Stabilize support for the basic medical sciences, where NIH is the preponderant source of support for training, at a relatively constant proportion of graduate enrollment in these disciplines.
5. Expand support for fields becoming increasingly important for the progress of biomedical research. Illustrative of such fields are (1) behavioral sciences; (2) bioengineering; (3) genetics, ecology, and cell biology; and (4) the mathematical and physical sciences.
6. Reexamine mechanisms in the light of present and future needs to determine what changes are most appropriate for student support and for strengthening graduate and professional education in the health sciences.
7. Intensify deliberate efforts to (1) enhance the quality of training, (2) improve the nature of the training environment, and (3) assure that more stringent qualitative criteria are utilized by recipient institutions in the selection of individuals to receive NIH support for training.
8. Develop criteria and programs for the strategic phasing of institutional development with formal support for training activities.
9. Provide for systematic, continuing evaluation encompassing (1) the qualitative aspects of training activities and (2) the quantitative measures of effectiveness, relating output of training programs to meeting national biomedical manpower needs.

APPENDICES

APPENDIX A

DEFINITION OF BIOMEDICAL RESEARCH

Biomedical research comprises a broad area of scientific inquiry aimed ultimately at the improvement of human health and the conquest of disease. It draws upon all fields of science—life, physical, engineering, psychological, and social—and many disciplines with each field. Within this broader context *biomedical research* is defined as all systematic study directed toward the development and use of scientific knowledge through fundamental research in the laboratory, clinical investigations, clinical trials, epidemiological, engineering, and demographic studies, and controlled pilot projects in the following areas:

1. The causes, diagnosis, treatment, control, prevention of, and rehabilitation relating to, the physical and mental diseases and other killing and crippling impairments of mankind;
2. The origin, nature, and solution of health problems not identifiable in terms of disease entities, such as—research in problems of mental health and human development; alcoholism; drug addiction; sexual deviancy; accident prevention; air and water pollution.
3. Broad fields of science where the research is undertaken to obtain an understanding of processes affecting disease and human well-being;
4. Research in nutritional and population problems impairing, contributing to, or otherwise affecting optimum health;
5. Development of improved methods, techniques, and equipment for research, diagnosis, therapy, rehabilitation, the delivery of health services, and the promotion of public health;
6. Research concerning all aspects of the organization and delivery of health services.

APPENDIX B

BIOMEDICAL RESEARCH MANPOWER ESTIMATES, 1965

The estimate of 64,000 professional workers engaged in biomedical research in 1965 is based on the bench-mark estimate for 1960, established by the National Institutes of Health, and detailed in "Manpower for Medical Research, 1965–1970",[1] updated to 1965 for the purposes of this Report, using the methodology outlined below.

The 1960 estimate.—The estimates of professional workers in biomedical research in 1960, by sector and level of training, were derived primarily from surveys conducted or stimulated by the Resources Analysis Branch, Office of Program Planning, NIH, and related surveys. The sources and methodology underlying these estimates were discussed in the extensive notes to appendix tables 7 and 8 of "Manpower for Medical Research, 1965–1970." In summary, the 1960 estimates were as follows:

Sector:	*Thousands*
Government	7.8
Industry	7.2
Nonprofit institutions	24.7
Total	39.7

Level of training:	*Thousands*
M.D.	11.4
Ph. D.	18.0
Less than doctoral	10.3
Total	39.7

It was recognized, at the time these estimates were prepared, that the coverage of the industry sector did not accurately reflect the total biomedical research performed by industry (see p. 1 of "Manpower for Medical Research, 1965–1970"). Specifically, the figures for professional manpower and expenditures for medical research were limited to the then available data on the research activities of manufacturers of ethical pharmaceuticals. Estimates prepared by the Resources Analysis Branch are now available of expenditures for biomedical research of companies in the medical supply, electronics, chemicals, and biomedical engineering fields. The industry estimate of 7,200 professional workers in 1960 has, therefore, been increased to 9,200 and the total to 41,700, for 1960.

The 1965 estimate.—In the absence of comprehensive surveys relating to 1965, similar to those underlying the estimates of biomedical research manpower for 1960, the following procedure was followed in deriving the 1965 estimate of 64,000 professional workers in biomedical research.

1. The manpower estimates for 1960, adjusted to reflect complete coverage for the industry sector, were accepted as bench-mark estimates.
2. An expenditure per professional worker in biomedical research was derived for each sector by relating the numbers of professional workers to the dollar totals for biomedical research (in 1967 dollars), as follows:

Sector	Biomedical research, 1960		
	Expenditures (millions) 1967 dollars	Professional manpower (thousands)	Expenditures per professional
Government	$151	7,800	$19,400
Industry	312	9,200	33,900
Nonprofit institutions	483	24,700	19,600
Total	946	41,700	22,700

[1] *Resources for Medical Research, Report No. 3*, PHS Pub. No. 1001.

3. The expenditures per professional worker, by sector, were increased at the rate of 6 percent per annum for the Government and nonprofit sectors, and 7 percent for the industry sector, 1960–65. The 1965 expenditures per professional worker were related to the dollar totals (in 1967 dollars) for biomedical research, to derive estimates of the numbers of professional workers in 1965 by sector, as follows:

Sector	Biomedical research, 1965		
	Expenditures (millions) 1967 dollars	Professional manpower (thousands)	Expenditures per professional
Government	$307	11, 800	$25, 900
Industry	557	11, 900	46, 800
Nonprofit institutions	1, 056	40, 300	26, 100
Total	1, 920	64, 000	30, 000

As a final step, the estimates for 1965, derived above, were compared for reasonableness with the available data relating to professional workers in biomedical research.

1. *Government sector.*—The 11,800 total estimate of professional manpower in biomedical research in both Federal and State and local government agencies was corroborated by the result of blowing up the numbers of the professional and scientific staff at the National Institutes of Health by the proportion the NIH intramural research dollar total represents of the total biomedical research activities in the Government sector. In 1965, the National Institutes of Health professional and scientific staff (excluding administration) numbered 3,600, and the NIH intramural research dollar total was equal to 30 percent of the combined intramural total for Federal and State and local government agencies ($340 million in 1967 dollars). Applying this 30 percent factor yields a total of 12,000, comparable with the 11,800 estimate derived above.

2. *Industry sector.*—The 11,900 total estimate of professional manpower in biomedical research in industry was substantiated by the available data on the size of the 1965 scientific and professional staff engaged in research and development in the pharmaceutical industry. A survey, conducted by the Pharmaceutical Manufacturers Association, indicated that member firms of that Association employed 9,000 scientists in R. & D. in 1965. The pharmaceutical industry accounts (on a dollar basis) for about 75 percent of all industrially performed biomedical research. Consequently, a blowup factor to take account of all professional research workers engaged in industrially performed biomedical research was applied to the 9,000 figure, yielding 12,000—corroborating the 11,900 estimate.

3. *Nonprofit sector.*—Definitive head-counts of the numbers of persons serving as principal investigators and their collaborators in biomedical research in the nonprofit sector are not available. This sector comprises institutions of higher education (both public and private), hospitals (including those affiliated with medical schools), research institutes, and other nonprofit research organizations. The arrangements under which research is conducted at these institutions are complex; i.e., faculty members of educational institutions engage in research in combination with their teaching function, and in the case of physicians, in combination with the practice of medicine. Furthermore, biomedical research is conducted at institutions where medical research is not the sole or predominant research objective. Recent surveys of the manpower in R. & D., by the National Science Foundation focus upon the total R. & D. activity of the organization, and not specifically upon the medical and health-related portion. Where, however, all the R. & D. activity of the organization is biomedical, indications of the scientific manpower engaged in biomedical research can be ascertained. Thus, the recent NSF survey of the scientific activities in institutions of higher education requested information separately for the Nation's medical schools—where all the research is medical and health-related. The definitions and guidelines established for the NSF survey requested that professional personnel be reported in the function (teaching, R. & D., other activities) in which they were primarily employed. Thus, in accordance with NSF guidelines, persons primarily engaged in teaching but also engaged in research were not reported in the R. & D. category.

Nonetheless, the results of the NSF study as it relates to the Nation's medical schools provides the basis for checking the reasonableness of the estimate of biomedical research manpower derived for the nonprofit sector.

Medical schools are the single-largest performer of biomedical research. As of January 1965 the date for which NSF collected information, medical schools accounted for almost 40 percent of the total biomedical research performed in the nonprofit sector.

The NSF study shows a total of 14,500[2] full- and part-time scientists engaged in R. & D. in medical schools, with research as their primary function. On the assumption that since medical schools perform, in dollar terms, 40 percent of the total biomedical research in the nonprofit sector, 40 percent of the estimated biomedical research manpower in this sector would also be associated with medical schools. Applying this factor to the estimated 40,300 total biomedical research professionals in 1965 yields 16,100 for the medical schools. The difference between the 16,100 and the 14,500 reported in the survey is easily accounted for: A minimum of 10 percent of the 23,000 full- and part-time scientists and clinicians in medical schools who reported teaching as their primary activity are also engaged (as a secondary function) in research.

Level of training.—The bench-mark estimates for 1960 provided a distribution by level of training, of the professional manpower engaged in biomedical research. The studies, upon which these estimates were based, showed a change in the composition of the manpower, by level of training, from 1958. In 1960, a higher proportion of investigators had doctoral degrees and a lower proportion had less than doctoral training; within the doctoral group, persons with the Ph. D. or Sc. D. degree increased as a proportion of the total; the proportion for those with M.D. or related degrees remained unchanged.

The bench-mark estimates are as follows:

	Manpower in biomedical research			
	1960		1958	
	Number (thousands)	Percent	Number (thousands)	Percent
M.D.	11.4	29	10.0	29
Ph. D.	18.0	45	14.7	42
Less than doctoral	10.3	26	9.9	29
Total	39.7	100	34.6	100

Studies of the level of training of the scientific staff in R. & D. at pharmaceutical companies, indicate that in the 5 years since 1960, there has been a decline in the proportion of research workers with less than doctoral training; the group with Ph. D. or Sc. D. degrees increasing correspondingly.

From this, and other indications of the increasing participation in biomedical research of persons with the Ph. D. degree, the following distribution of the 1965 professional manpower in biomedical research has been used as the base for the projections detailed in this report:

	1965 Number (thousands)	Percent
M.D.	17.0	27
Ph. D.	32.0	50
Less than doctoral	15.0	23
Total	64.0	100

[2] Unpublished detail provided to the National Institutes of Health by the National Science Foundation. The NSF preliminary report has been released as "Resources for Scientific Activities at Universities and Colleges, 1964"; *Reviews of Data on Science Resources*, No. 9, August 1966.

APPENDIX C

MEDICAL SCHOOLS IN DEVELOPMENT [1]

School (location)	Expected starting date	Year first class will graduate	First year enrollment	
			Planned	Actual 1968
Brown University Program in Medical Science (Providence)	[2] 1963	[3] 1969	50	13
University of New Mexico School of Medicine (Albuquerque) [4]	1964	1968	48	26
Rutgers Medical School (New Brunswick)	1966	1970	64	16
Michigan State University College of Human Medicine (East Lansing)	[5] 1966	1970	64	27
University of Arizona College of Medicine (Tucson)	1967	1971	64	32
University of Hawaii School of Medicine (Honolulu)	1967	1971	50	28
Pennsylvania State University—M.S. Hershey Medical Center (Hershey)	1967	1971	64	40
University of California School of Medicine (Davis)	1968	1972	128	48
University of California School of Medicine (San Diego)	1968	1972	96	47
University of Connecticut School of Medicine (Hartford)	[illegible]	1972	64	31
Mount Sinai School of Medicine (New York) [6]	19[illegible]8	[7] 1970	100	[7] 36
University of Texas—South Texas Medical School (San Antonio)	[8] 1968	[8] 1970	100	56
Louisiana State University School of Medicine (Shreveport)	19[illegible]	1973	100	--------
University of Massachusetts School of Medicine (Worcester)	1970	1974	112	--------
Medical College of Ohio at Toledo	1969	1974	100	--------
State University of New York School of Medicine (Stony Brook)	1971	1975	150	--------
University of South Florida College of Medicine (Tampa)	1971	1975	110	--------

[1] *Journal of the American Medical Association*, vol. 206, No. 9, Nov. 25, 1968, pp. 1994, 1995, 1998-2006.

[2] The Brown University program is a 6-year program that begins in the freshmen class in the undergraduate school. Hence, the starting date shown is that for first-year undergraduates.

[3] This date is for the completion of the Brown program, but graduates will have to continue elsewhere for clinical training or for Ph. D. training in the sciences.

[4] Originally a 2-year school but never operated as such; now a 4-year school.

[5] Michigan State has a 5-year program which begins with the fourth year of undergraduate training. Thus, fall 1966 is the time at which the first undergraduates in the program began their senior year.

[6] The Mount Sinai School of Medicine is affiliated with the City University of New York.

[7] First class at Mount Sinai consists of 36 first-year students and 23 third-year students; consequently, the first class (third-year students admitted in 1968) will graduate in 1970.

[8] Enrollment actually began in September 1966 (15 students) and 1[illegible] (seven students), but these students were assigned to University of Texas medical schools at Dallas and Galveston; in 1968, the first year of operations at San Antonio these second- and third-year students (and other transfers) continued their studies at San Antonio, which will, therefore, graduate its first class in 1970.

MEDICAL SCHOOLS LIKELY TO BE DEVELOPED IN THE FUTURE

Medical schools likely to be developed in the future have been grouped into three categories: (1) those which are likely to receive accreditation in the next 5 years; (2) those which stand a reasonable chance of emerging within the next 10 years; and (3) other possibilities where it is not feasible to assess the time factor.

It is difficult to make a precise assessment of which of the other new medical schools will emerge first because plans are buffeted by feasibility studies, political influences, and financial opportunities and constraints.

However, as shown below, it appears likely that a minimum of five new medical schools may receive provisional accreditation within the next 5 years. The SUNY (State University of New York) master plan calls for two more SUNY medical centers; the first one is likely to be based in Nassau County. The Florida legislature has authorized a new medical school at the University of South Florida, Tampa-St. Petersburg. The Indiana legislature has authorized a new medical school at Ball State University in Muncie but there are pressures from the South Bend area for a medical school as a branch of Indiana University, possibly located on the Notre Dame campus. The Howard Hughes offer to the University of Nevada has triggered a new medical school in that State; the feasibility study has already been completed by AMA–AAMC. There are pressures for a new medical school on the main campus of the University of Tennessee at Knoxville, although no action has yet been taken by the legislature or by the university.

There is a reasonable possibility that an additional eight to 12 new medical schools will be established by 1977: SUNY at Westchester or at Binghamton, the University of South Alabama, Mobile, the University of Texas at Houston; the University of Illinois, Chicago, either doubling class size or establishing a new school; the University of Missouri at Kansas City, and two new State medical schools in the Nation's most populous State—California—in the two major metropolitan areas, Los Angeles and San Francisco.

Additional but indefinite possibilities are offered in North Carolina and by the University of Delaware, the University of Maine, the University of South Carolina, and Southern Illinois University. While plans have blown hot and then cold for the Boise Medical Foundation, the Norfolk area and the St. Paul area, there is a reasonable possibility that new medical schools may be established in one or more of these areas within the next decade. New Jersey, which now sends out of State enough students for three medical schools, is pressing for a third State medical school. Thus, the pace at which the State moves will be influenced by the steps taken by New York and Pennsylvania schools to give priority to their own residents. The University of Wisconsin at Milwaukee is just beginning to build its graduate programs; however, there is a reasonable possibility that the State may establish a second medical school in Milwaukee rather than doubling class size at Madison.

By 1972 (5)	*By 1977 (8–12)*	*Indefinite (7)*
SUNY (Nassau)	SUNY (Westchester or Binghamton)*	University of Delaware (Wilmington)
University of South Florida (Tampa)	University of South Alabama (Mobile)*	East Carolina College (Greenville)
Ball State University (Muncie) or Indiana University (South Bend)	University of Texas (Houston)*	University of Maine (2-year school in Portland)
University of Nevada (Reno or Las Vegas)	Boise Medical Foundation (Boise)	University of South Carolina (Columbia)
University of Tennessee (Knoxville)	University of Virginia (Norfolk)	M.I.T. (Cambridge)
	University of Minnesota or Northern Association of Medical Education (St. Paul or Duluth)	Brandeis (Waltham)
	University of Illinois (Chicago)*	Southern Illinois University (Carbondale)
	New Jersey (Trenton)*	
	University of Wisconsin (Milwaukee)*	
	University of Missouri (Kansas City)*	
	University of California (new schools in Los Angeles and San Francisco areas)*	

*More likely.

Source: 1. Files of Resources Analysis Branch, OPPE, NIH.

2. Progress report on *Future of Higher Education, 1965–1985* prepared for the National Institutes of Health by the Academy for Educational Development, Inc., March 1967 (unpublished).

3. Discussions with C. H. William Ruhe, M.D., Associate Secretary, Council on Medical Education, AMA, assessing the probability of institutional plans, political decisions, and State commitments becoming reality, school by school.

APPENDIX D

LOCATIONS OF PROBABLE MAJOR EXPANSIONS IN GRADUATE EDUCATION, 1965-80

Region	*State*	*Institution*
New England	Maine	University of Maine
	New Hampshire	University of New Hampshire
	Vermont	
	Massachusetts	Boston University Brandeis University Northeastern University University of Massachusetts—Amherst University of Massachusetts—Boston
	Rhode Island	Brown University University of Rhode Island
	Connecticut	University of Connecticut—Hartford University of Connecticut—Storrs
Middle Atlantic	New York	City University of New York New York University SUNY—Albany SUNY—Binghamton SUNY—Buffalo SUNY—Nassau SUNY—Stony Brook SUNY—Westchester University of Rochester
	New Jersey	Rutgers—Newark Rutgers—New Brunswick
	Pennsylvania	Carnegie University Lehigh University Pennsylvania State University—Hershey Pennsylvania State University—University Park Temple University University of Pittsburgh

Region	State	Institution
East North Central	Ohio	Akron State University Bowling Green State University Case Western Reserve University Cleveland State University Kent State University Miami University Ohio University Toledo State University Wright State University
	Michigan	Eastern Michigan University Michigan State University University of Michigan Wayne State University Western Michigan University
	Indiana	Indiana University—Bloomington Indiana University—Indianapolis Purdue University
	Illinois	Northern Illinois University Northwestern University Southern Illinois University—Carbondale Southern Illinois University—Edwardsville University of Illinois—Urbana University of Illinois—Chicago
	Wisconsin	University of Wisconsin—Madison University of Wisconsin—Milwaukee
West North Central	Minnesota	University of Minnesota—Minneapolis
	Iowa	
	Missouri	University of Missouri—Kansas City University of Missouri—St. Louis Washington University
	North Dakota	
	South Dakota	
	Nebraska	
	Kansas	Kansas State University University of Kansas Wichita State University
South Atlantic	Delaware	University of Delaware
	Maryland	Johns Hopkins University University of Maryland—Catonsville University of Maryland—College Park

South Atlantic—Continued

Region	*State*	*Institution*
	West Virginia	West Virginia University
	District of Columbia	
	Virginia	Old Dominion College
		University of Virginia—Charlottesville
		University of Virginia—Fairfax
		Virginia Polytechnic Institute
	North Carolina	Duke University
		East Carolina College
		University of North Carolina—Chapel Hill
		University of North Carolina—Charlotte
		University of North Carolina—Greensboro
		University of North Carolina—Raleigh
	South Carolina	
	Georgia	Atlanta University
		Emory University
		Georgia Institute of Technology
		University of Georgia
	Florida	Florida Atlantic University
		Florida State University
		Florida Technological University
		University of Florida
		University of Miami
		University of South Florida
		University of West Florida
East South Central	Alabama	University of Alabama—Birmingham
		University of Alabama—Huntsville
		University of South Alabama
	Mississippi	
	Tennessee	Memphis State University
		University of Tennessee—Oak Ridge
		University of Tennessee—Knoxville
		Vanderbilt University
	Kentucky	University of Kentucky
West South Central	Louisiana	Louisiana St. University—Baton Rouge
		Louisiana St. University—New Orleans
		Tulane University
	Arkansas	University of Arkansas
	Oklahoma	Oklahoma State University
		University of Oklahoma

West South Central—Continued

Region	*State*	*Institution*
	Texas	Arlington State Col. North Texas State University Rice University Texas A&M University Texas Technological College University of Houston University of Texas—Dallas University of Texas—El Paso University of Texas—San Antonio
Mountain	New Mexico	University of New Mexico
	Arizona	Arizona State University University of Arizona
	Nevada	
	Utah	Brigham Young University University of Utah
	Colorado	University of Colorado University of Denver
	Wyoming	
	Montana	
	Idaho	
Pacific	Alaska	University of Alaska
	Hawaii	University of Hawaii
	Washington	University of Washington Washington State University
	Oregon	Oregon State University University of Oregon
	California	California State College—Long Beach Fresno State College Sacramento State College San Francisco State College San Jose State College University of California—Berkeley University of California—Davis University of California—Irvine University of California—Los Angeles University of California—Riverside University of California—San Diego University of California—Santa Barbara University of California—Santa Cruz

APPENDIX E

Table 1A

Model for Estimating Annual Flow of M.D.'s Entering into the Medical Research Manpower Supply from Those Awarded M.D. Degrees, (Low Estimates) 1/, 1952-80
(Shows Research Input in the Years 1961-1985)

M.D. degrees awarded: Year	M.D. degrees awarded: Number	Entering medical research: Percent	Entering medical research: Number	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Net increment 1966-85: Total	Net increment 1966-85: Average
1952-1955...	26,586	13	3,456	519	439	353	264	173	172	132	89	45	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	438	22
1956...	6,845	13	890	133	134	133	134	134	44	45	44	45	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	222	11
1957...	6,796	13	883	...	132	133	132	133	132	44	44	44	45	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	353	18
1958...	6,861	14	961	...	...	144	144	145	144	144	48	48	48	48	48	...	...	...	...	...	...	...	...	...	...	...	...	...	528	26
1959...	6,860	14	960	...	...	...	144	144	144	144	144	48	48	48	48	48	...	...	...	...	...	...	...	...	...	...	...	...	672	34
1960...	7,081	15	1,062	...	...	...	...	159	160	159	160	159	53	53	53	53	53	...	...	...	...	...	...	...	...	...	...	...	903	45
1961...	6,994	15	1,049	...	...	...	...	...	157	158	157	158	157	52	53	52	53	52	...	...	...	...	...	...	...	...	...	...	1,049	52
1962...	7,168	15	1,075	...	...	...	...	...	...	161	162	161	162	161	53	54	53	54	54	...	...	...	...	...	...	...	...	...	1,075	54
1963...	7,264	15	1,090	...	...	...	...	...	...	...	163	164	163	164	164	54	54	54	55	54	...	...	...	...	...	...	...	...	1,090	54
1964...	7,336	15	1,100	...	...	...	...	...	...	...	...	165	165	165	165	165	55	55	55	55	55	...	...	...	...	...	...	...	1,100	55
1965...	7,409	15	1,111	...	...	...	...	...	...	...	...	...	166	167	166	167	167	55	56	55	56	56	...	...	...	...	...	...	1,111	56
1966...	7,574	15	1,136	...	...	...	...	...	...	...	...	...	...	170	171	170	171	170	57	57	56	57	57	...	...	...	...	...	1,136	57
1967...	7,743	15	1,161	...	...	...	...	...	...	...	...	...	...	...	175	174	174	174	174	58	58	58	58	58	...	...	...	...	1,161	58
1968...	7,793	15	1,169	...	...	...	...	...	...	...	...	...	...	...	...	175	176	175	176	175	58	59	58	59	58	...	...	...	1,169	58
1969...	7,708	15	1,156	...	...	...	...	...	...	...	...	...	...	...	...	...	173	174	173	174	173	58	58	58	58	57	...	...	1,156	58
1970...	7,888	15	1,183	...	...	...	...	...	...	...	...	...	...	...	...	...	...	177	177	177	177	177	60	60	60	59	59	...	1,183	59
1971...	8,360	15	1,254	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	188	188	188	188	188	63	63	63	63	62	1,254	63
1972...	8,299	15	1,245	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	187	186	187	186	187	62	63	62	63	1,183	59
1973...	8,392	15	1,259	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	189	188	189	189	189	63	63	63	1,135	57
1974...	8,490	15	1,274	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	191	191	191	191	192	64	64	1,084	54
1975...	8,595	15	1,289	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	193	194	193	194	193	64	1,031	52
1976...	8,686	15	1,303	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	195	196	195	196	195	977	49
1977...	8,800	15	1,320	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	198	198	198	198	792	40
1978...	8,919	15	1,338	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	201	200	201	602	30
1979...	9,043	15	1,356	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	203	204	407	20
1980...	9,171	15	1,376	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	206	206	10
U.S. total................				652	705	763	818	888	953	987	1,011	1,037	1,051	1,072	1,096	1,112	1,130	1,140	1,165	1,180	1,196	1,219	1,238	1,254	1,268	1,285	1,301	1,320	23,015	1,151
Foreign input..............				130	141	153	164	178	191	197	202	207	210	214	219	222	226	228	233	236	239	244	248	251	254	257	260	264	4,602	230
Total, new entrants into medical research manpower supply..............				782	846	916	982	1,066	1,144	1,184	1,213	1,244	1,261	1,286	1,315	1,334	1,356	1,368	1,398	1,416	1,435	1,463	1,486	1,505	1,522	1,542	1,561	1,584	27,617	1,381

1/ For method of derivation of Low, High, and Intermediate estimates, see Chapter IV.

SOURCE: M.D. output 1952-67 from JAMA, 202:756, 1967, Table 25. Projections for 1968-80 developed by the Resources Analysis Branch, OPPE, NIH.

NOTES ON METHOD

1. A rising percentage of M.D.'s (from 13 percent of the Class of 1956 to 15 percent of the Class of 1960) will enter into medical research as independent investigators at some time during their career.

2. There is a minimal 5-year lag between graduation and entering into independent research: 1-year internship, 3-year residency, plus 1-year postdoctoral training.

3. In developing this model, it has been assumed that 75 percent of M.D.'s entering medical research as independent investigators will do so in the 5 years following postdoctoral training (15 percent per annum); the other 25 percent will enter between the 6th and 10th year following postdoctoral training (5 percent per annum). It is further assumed that a substantial proportion will have had experience as research assistants and research associates prior to entering the independent investigator pool. It is also recognized that some will enter the pool for the first time 20-25-30 years after receipt of the M.D. degree.

4. Foreign input (M.D.'s trained in foreign medical schools) equals 20 percent of the total number of U.S.-trained M.D.'s entering the research manpower pool each year. Foreign input consists of the following components:

a. U.S. citizens who went abroad for their medical education.
b. M.D.'s who received their degree abroad who may or may not be U.S. citizens and are now engaged in research in the U.S.
c. M.D.'s trained abroad who are conducting research, whose research expenditures are included in the total national expenditures for medical research either in the government or the industry component.

5. The model begins with a cumulative total of the graduating classes, 1952-1955; some of these graduates will enter medical research in 1961 and later years. From 1966 on, totals are complete except for those M.D.'s from classes prior to 1952 who enter research subsequent to 15 years after graduation.

6. Foreign inputs into research are also incomplete prior to 1966--the first year showing a complete flow for U.S. supply. In order to demonstrate method in the model, foreign inputs are computed at 20 percent of the total U.S.-trained input for each year.

APPENDIX E

Table 1B

Model for Estimating Cumulative Flow of M.D.'s Entering into the Medical Research Manpower Supply from Those Awarded M.D. Degrees, (Low Estimates) [1], 1952-80
(Shows Research Input in the Years 1961-1985)

Year	M.D. degrees awarded Number	Entering medical research Percent	Entering medical research Number	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Difference between 1965 and 1985
1952-1955...	26,580	13	3,456	319	950	1,311	1,575	1,748	1,920	2,052	2,141	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	438
1956...	6,845	13	890	133	267	400	534	668	712	757	801	846	890	890	890	890	890	890	890	890	890	890	890	890	890	890	890	890	222
1957...	6,796	13	883	...	132	265	397	530	662	706	750	794	839	883	883	883	883	883	883	883	883	883	883	883	883	883	883	883	353
1958...	6,861	14	961	...	...	144	288	433	577	721	769	817	865	913	961	961	961	961	961	961	961	961	961	961	961	961	961	961	528
1959...	6,860	14	960	...	...	...	144	288	432	576	720	768	816	864	912	960	960	960	960	960	960	960	960	960	960	960	960	960	672
1960...	7,081	15	1,062	...	...	...	...	159	319	478	638	797	850	903	956	1,009	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	903
1961...	6,994	15	1,049	...	...	...	...	...	157	315	472	630	787	839	892	944	997	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049
1962...	7,168	15	1,075	...	...	...	...	...	...	161	323	484	646	807	860	914	967	1,021	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075
1963...	7,264	15	1,090	...	...	...	...	...	...	...	163	327	490	654	818	872	927	981	1,036	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090
1964...	7,330	15	1,100	...	...	...	...	...	...	...	...	165	330	495	660	825	880	935	990	1,045	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
1965...	7,409	15	1,111	...	...	...	...	...	...	...	...	...	166	333	499	666	833	888	944	999	1,055	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111
1966...	7,574	15	1,136	...	...	...	...	...	...	...	...	...	...	170	341	511	682	852	909	966	1,022	1,079	1,136	1,136	1,136	1,136	1,136	1,136	1,136
1967...	7,743	15	1,161	...	...	...	...	...	...	...	...	...	...	...	175	349	523	697	871	929	987	1,045	1,103	1,161	1,161	1,161	1,161	1,161	1,161
1968...	7,795	15	1,169	...	...	...	...	...	...	...	...	...	...	...	...	175	351	526	702	877	935	994	1,052	1,111	1,169	1,169	1,169	1,169	1,169
1969...	7,708	15	1,156	...	...	...	...	...	...	...	...	...	...	...	...	...	173	347	520	694	867	925	983	1,041	1,099	1,156	1,156	1,156	1,156
1970...	7,888	15	1,183	...	...	...	...	...	...	...	...	...	...	...	...	...	...	177	354	531	708	885	945	1,005	1,065	1,124	1,183	1,183	1,183
1971...	8,360	15	1,254	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	188	376	564	752	940	1,003	1,066	1,129	1,192	1,254	1,254
1972...	8,299	15	1,245	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	187	373	560	746	933	995	1,058	1,120	1,183	1,183
1973...	8,392	15	1,259	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	189	377	566	755	944	1,007	1,070	1,133	1,133
1974...	8,490	15	1,274	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	191	382	573	764	956	1,020	1,084	1,084
1975...	8,595	15	1,289	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	193	387	580	774	967	1,031	1,031
1976...	8,686	15	1,303	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	195	391	586	782	977	977
1977...	8,800	15	1,320	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	198	396	594	792	792
1978...	8,919	15	1,338	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	201	401	602	602
1979...	9,043	15	1,356	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	203	407	407
1980...	9,171	15	1,376	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	206	206
U.S. total....................				852	1,357	2,120	2,950	3,826	4,779	5,766	6,777	7,814	8,865	9,937	11,033	12,145	13,275	14,415	15,580	16,760	17,956	19,175	20,413	21,667	22,935	24,220	25,321	26,841	23,015
Foreign input.................				130	271	424	580	766	757	1,134	1,356	1,563	1,773	1,987	2,206	2,428	2,654	2,885	3,116	3,352	3,591	3,835	4,083	4,333	4,587	4,844	5,104	5,368	4,607
Total, new entrants into medical research manpower supply.......				782	1,628	2,544	3,526	4,592	5,736	6,920	8,133	9,377	10,638	11,924	13,239	14,573	15,929	17,298	18,696	20,112	21,547	23,010	24,496	26,000	27,522	29,064	30,625	32,209	27,617

[1] For method of derivation of Low, High, and Intermediate estimates, see Chapter IV.

For SOURCE and NOTES ON METHOD, see footnotes to Table 1A.

APPENDIX E

Table 2A

Model for Estimating Annual Flow of M.D.'s Entering into the Medical Research Manpower Supply from Those Awarded M.D. Degrees, (High Estimates) 1/, 1952-80
(Shows Research Input in the Years 1961-1985)

M.D. degrees awarded: Year	M.D. degrees awarded: Number	Entering medical research: Percent	Entering medical research: Number	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Net increment 1966-85: Total	Net increment 1966-85: Average
1952-1955...	26,586	13	3,456	319	439	353	264	173	172	132	89	45	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	438	22
1956...	6,843	13	890	130	134	133	134	134	44	45	44	45	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	222	11
1957...	6,796	13	883	...	132	130	132	133	132	44	44	44	45	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	353	18
1958...	6,861	14	961	...	...	144	144	149	144	144	48	48	48	48	48	...	...	...	...	...	...	...	...	...	...	...	...	...	528	26
1959...	6,860	14	960	...	...	...	144	144	144	144	144	48	48	48	48	48	...	...	...	...	...	...	...	...	...	...	...	...	672	34
1960...	7,081	15	1,062	...	...	...	...	159	160	159	160	159	53	53	53	53	53	...	...	...	...	...	...	...	...	...	...	...	903	45
1961...	6,994	15	1,049	...	...	...	...	...	157	158	157	158	157	52	53	52	53	52	...	...	...	...	...	...	...	...	...	...	1,049	52
1962...	7,168	15	1,075	...	...	...	...	...	...	161	162	161	162	161	53	54	53	54	54	...	...	...	...	...	...	...	...	...	1,075	54
1963...	7,264	15	1,090	...	...	...	...	...	...	...	163	164	163	164	164	54	55	54	55	54	...	...	...	...	...	...	...	...	1,090	55
1964...	7,336	15	1,100	...	...	...	...	...	...	...	...	165	165	165	165	165	55	55	55	55	55	...	...	...	...	...	...	...	1,100	55
1965...	7,409	15	1,111	...	...	...	...	...	...	...	...	...	166	167	166	167	167	55	56	55	56	56	...	...	...	...	...	...	1,111	56
1966...	7,574	15	1,136	...	...	...	...	...	...	...	...	...	...	170	171	170	171	170	57	57	56	57	57	...	...	...	...	...	1,136	57
1967...	7,743	15	1,161	...	...	...	...	...	...	...	...	...	...	...	175	174	174	174	174	58	58	58	58	58	...	...	...	...	1,161	58
1968...	7,970	15	1,196	...	...	...	...	...	...	...	...	...	...	...	...	179	180	179	180	179	59	60	60	60	60	...	...	...	1,196	60
1969...	7,883	15	1,182	...	...	...	...	...	...	...	...	...	...	...	...	...	177	178	177	177	177	59	59	59	59	60	...	...	1,182	59
1970...	8,066	15	1,210	...	...	...	...	...	...	...	...	...	...	...	...	...	...	182	182	181	181	181	61	61	61	60	60	...	1,210	61
1971...	8,550	15	1,283	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	192	192	192	192	192	65	65	65	64	64	1,283	64
1972...	14,536	15	2,180	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	327	327	327	327	327	109	109	109	109	2,071	104
1973...	16,452	15	2,468	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	374	375	374	375	375	125	125	125	2,248	112
1974...	16,744	15	2,512	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	377	378	377	378	378	126	126	2,140	107
1975...	16,836	15	2,525	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	379	379	378	379	378	126	2,019	101
1976...	17,112	15	2,567	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	385	385	385	385	385	1,925	96
1977...	17,664	15	2,650	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	397	398	397	398	1,590	79
1978...	18,492	15	2,774	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	416	416	416	1,248	62
1979...	19,504	15	2,926	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	439	439	878	44
1980...	20,424	15	3,064	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	460	460	23
U.S. total...				652	705	763	818	888	953	987	1,011	1,037	1,051	1,072	1,096	1,116	1,138	1,153	1,182	1,335	1,535	1,742	1,945	2,146	2,267	2,375	2,499	2,648	30,288	1,514
Foreign input...				130	141	153	164	178	191	197	202	207	210	214	219	223	228	231	236	267	307	348	389	429	453	475	500	530	6,056	303
Total, new entrants into medical research manpower supply...				782	846	916	982	1,066	1,144	1,184	1,213	1,244	1,261	1,286	1,315	1,339	1,366	1,384	1,418	1,602	1,842	2,090	2,334	2,575	2,720	2,850	2,999	3,178	36,344	1,817

1/ For method of derivation of Low, High, and Intermediate estimates, see Chapter IV.

For SOURCE and NOTES ON METHOD, see footnotes to Table 1A.

APPENDIX E

Table 2B

Model for Estimating Cumulative Flow of M.D.'s Entering into the Medical Research Manpower Supply from Those Awarded M.D. Degrees (High Estimates) 1/, 1952-80
(Shows Research Input in the Years 1961-1985)

M.D. degrees awarded: Year	M.D. degrees awarded: Number	Entering medical research: Percent	Entering medical research: Number	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Difference between 1965 and 1985
1952... 1955	26,388	13	3,456	319	958	1,311	1,575	1,748	1,920	2,052	2,141	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	438
1956...	6,865	13	890	139	267	400	534	668	712	757	801	846	890	890	890	890	890	890	890	890	890	890	890	890	890	890	890	890	222
1957...	6,796	13	883	...	132	265	397	530	662	706	750	794	839	883	883	883	883	883	883	883	883	883	883	883	883	883	883	883	353
1958...	6,861	14	961	...	...	144	288	433	577	721	769	817	865	913	961	961	961	961	961	961	961	961	961	961	961	961	961	961	528
1959...	6,860	14	960	...	...	...	144	288	432	576	720	768	816	864	912	960	960	960	960	960	960	960	960	960	960	960	960	960	672
1960...	7,081	15	1,062	...	...	...	...	159	319	478	638	797	850	903	956	1,009	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	903
1961...	6,994	15	1,049	...	...	...	...	...	157	315	472	630	787	839	892	944	997	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049
1962...	7,168	15	1,075	...	...	...	...	...	...	161	323	484	646	807	860	914	967	1,021	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075
1963...	7,266	15	1,090	...	...	...	...	...	...	...	163	327	490	654	818	872	927	981	1,036	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090
1964...	7,336	15	1,100	...	...	...	...	...	...	...	...	165	330	495	660	825	880	935	990	1,045	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
1965...	7,409	15	1,111	...	...	...	...	...	...	...	...	...	166	333	499	666	833	888	944	999	1,055	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111
1966...	7,574	15	1,136	...	...	...	...	...	...	...	...	...	...	170	341	511	682	852	909	966	1,022	1,079	1,136	1,136	1,136	1,136	1,136	1,136	1,136
1967...	7,743	15	1,161	...	...	...	...	...	...	...	...	...	...	...	175	349	523	697	871	929	987	1,045	1,103	1,161	1,161	1,161	1,161	1,161	1,161
1968...	7,970	15	1,196	...	...	...	...	...	...	...	...	...	...	...	...	179	359	538	718	897	956	1,016	1,076	1,136	1,196	1,196	1,196	1,196	1,136
1969...	7,883	15	1,182	...	...	...	...	...	...	...	...	...	...	...	...	...	177	355	532	709	886	945	1,004	1,063	1,122	1,182	1,182	1,182	1,182
1970...	8,068	15	1,210	...	...	...	...	...	...	...	...	...	...	...	...	...	...	182	364	545	726	907	968	1,029	1,090	1,150	1,210	1,210	1,210
1971...	8,550	15	1,283	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	192	384	576	770	960	1,025	1,090	1,155	1,219	1,283	1,283
1972...	14,536	15	2,180	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	327	654	981	1,308	1,635	1,744	1,853	1,962	2,071	2,071
1973...	16,652	15	2,498	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	374	749	1,123	1,498	1,873	1,998	2,123	2,248	2,248
1974...	16,746	15	2,512	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	377	755	1,132	1,510	1,888	2,014	2,140	2,140
1975...	16,836	15	2,525	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	379	758	1,136	1,515	1,893	2,019	2,019
1976...	17,112	15	2,567	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	385	770	1,155	1,540	1,925	1,925
1977...	17,666	15	2,650	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	397	795	1,192	1,590	1,590
1978...	18,492	15	2,774	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	416	832	1,248	1,248
1979...	19,506	15	2,926	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	439	878	878
1980...	20,474	15	3,066	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	460	460
U.S. total........................				652	1,357	2,120	2,938	3,826	4,779	5,786	6,777	7,814	8,865	9,937	11,035	12,149	13,287	14,440	15,622	16,957	18,492	20,242	22,179	24,325	26,592	28,967	31,466	34,114	30,288
Foreign input....................				130	271	424	588	766	957	1,134	1,356	1,563	1,773	1,987	2,204	2,429	2,657	2,888	3,124	3,391	3,698	4,046	4,435	4,864	5,317	5,792	6,292	6,822	6,056
Total, new entrants into medical research manpower supply..............				782	1,628	2,544	3,526	4,592	5,736	6,920	8,133	9,377	10,638	11,924	13,239	14,578	15,944	17,328	18,746	20,348	22,190	24,288	26,614	29,189	31,909	34,759	37,758	40,936	36,344

1/ For method of derivation of Low, High, and Intermediate estimates, see Chapter IV.

For SOURCE and NOTES ON METHOD, see footnotes to Table 1A.

APPENDIX E

Table 3A

Model for Estimating Annual Flow of M.D.'s Entering into the Medical Research Manpower Supply From Those Awarded M.D. Degrees, (Intermediate Estimates) 1/, 1952-80
(Shows Research Input in the Years 1961-1985)

Year	M.D. degrees awarded: Number	Entering medical research: Percent	Entering medical research: Number	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
1952... 1955	26,856	13	3,456	519	439	353	264	173	172	132	89	43	...	...	...
1956...	6,845	13	890	133	134	133	134	134	44	43	44	43	44	...	...
1957...	6,796	13	883	...	132	133	132	133	132	44	44	44	45	44	...
1958...	6,861	14	961	...	...	144	144	145	144	144	48	48	48	48	48
1959...	6,860	14	960	...	...	...	144	144	144	144	144	48	48	48	48
1960...	7,081	15	1,062	...	...	...	...	159	160	159	160	159	53	53	53
1961...	6,994	15	1,049	...	...	...	...	...	157	158	157	158	157	52	53
1962...	7,168	15	1,075	...	...	...	...	...	...	161	162	161	162	161	53
1963...	7,264	15	1,090	...	...	...	...	...	...	...	163	164	163	164	164
1964...	7,336	15	1,100	...	...	...	...	...	...	...	...	165	165	165	165
1965...	7,409	15	1,111	...	...	...	...	...	...	...	...	...	164	167	166
1966...	7,574	15	1,136	...	...	...	...	...	...	...	...	...	...	170	171
1967...	7,743	15	1,161	...	...	...	...	...	...	...	...	...	...	...	175
1968...	7,970	15	1,196	...	...	...	...	...	...	...	...	...	...	...	...
1969...	7,883	15	1,182	...	...	...	...	...	...	...	...	...	...	...	...
1970...	8,068	15	1,210	...	...	...	...	...	...	...	...	...	...	...	...
1971...	8,550	15	1,283	...	...	...	...	...	...	...	...		...	...	...
1972...	9,292	15	1,394	...	...	...	...	...	...	...	...	...	...	...	...
1973...	9,936	15	1,490	...	...	...	...	...	...	...	...	...	...	...	...
1974...	10,488	15	1,573	...	...	...	...	...	...	...	...	...	...	...	...
1975...	11,316	15	1,697	...	...	...	...	...	...	...	...	...	...	...	...
1976...	12,328	15	1,849	...	...	...	...	...	...	...	...	...	...	...	...
1977...	13,156	15	1,973	...	...	...	...	...	...	...	...	...	...	...	...
1978...	14,168	15	2,125	...	...	...	...	...	...	...	...	...	...	...	...
1979...	15,180	15	2,277	...	...	...	...	...	...	...	...	...	...	...	...
1980...	16,100	15	2,415	...	...	...	...	...	...	...	...	...	...	...	...
U.S. total...				652	705	763	818	888	953	987	1,011	1,037	1,051	1,072	1,096
Foreign input...				130	141	153	164	175	191	197	202	207	210	214	219
Total, new entrants into medical research manpower supply...				782	846	916	982	1,066	1,144	1,184	1,213	1,244	1,261	1,286	1,315

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Net increment 1966-85: Total	Net increment 1966-85: Average
1952... 1955	...	...	...	...	...	...	...	...	...	...	...	...	...	438	23
1956...	...	...	...	...	...	...	...	...	...	...	...	...	...	222	11
1957...	...	...	...	...	...	...	...	...	...	...	...	...	...	353	18
1958...	...	...	...	...	...	...	...	...	...	...	...	...	...	528	28
1959...	48	...	...	...	...	...	...	...	...	...	...	...	...	672	35
1960...	53	53	...	...	...	...	...	...	...	...	...	...	...	905	47
1961...	52	53	52	...	...	...	...	...	...	...	...	...	...	1,049	55
1962...	54	53	54	54	...	...	...	...	...	...	...	...	...	1,075	57
1963...	54	55	54	55	54	...	...	...	...	...	...	...	...	1,090	57
1964...	165	55	55	55	55	55	...	...	...	...	...	...	...	1,100	58
1965...	167	167	55	56	55	56	56	...	...	...	...	...	...	1,111	58
1966...	170	171	170	57	57	56	57	57	...	...	...	...	...	1,136	60
1967...	174	174	174	174	58	58	58	58	58	...	...	...	...	1,161	61
1968...	179	180	179	180	179	59	60	60	60	60	...	...	...	1,196	63
1969...	...	177	178	177	177	177	59	59	59	59	60	...	...	1,182	62
1970...	...	...	182	182	181	181	181	61	61	61	60	60	...	1,210	64
1971...	...	...	...	192	192	192	192	192	65	65	65	64	64	1,283	68
1972...	...	...	...	...	209	209	209	209	209	70	70	70	70	1,325	70
1973...	...	...	...	...	...	224	224	224	224	224	74	74	74	1,342	71
1974...	...	...	...	...	...	...	236	236	236	236	236	79	79	1,338	70
1975...	...	...	...	...	...	...	...	255	255	255	255	255	85	1,360	72
1976...	...	...	...	...	...	...	...	...	277	277	277	277	277	1,385	73
1977...	...	...	...	...	...	...	...	...	...	296	296	296	296	1,184	62
1978...	...	...	...	...	...	...	...	...	...	...	318	318	318	954	50
1979...	...	...	...	...	...	...	...	...	...	...	...	342	342	684	36
1980...	...	...	...	...	...	...	...	...	...	...	...	...	362	362	19
U.S. total...	1,116	1,138	1,153	1,182	1,217	1,267	1,332	1,411	1,504	1,603	1,711	1,835	1,967	25,643	1,350
Foreign input...	223	228	231	236	243	253	266	282	301	321	342	367	393	5,129	270
Total, new entrants into medical research manpower supply...	1,339	1,366	1,384	1,418	1,460	1,520	1,598	1,693	1,805	1,924	2,053	2,202	2,360	30,772	1,620

1/ For method of derivation of Low, High, and Intermediate estimates, see Chapter IV.

For SOURCE and NOTES ON METHOD, see footnotes to Table 1A.

APPENDIX E

Table 3B

Model for Estimating Cumulative Flow of M.D.'s Entering into the Medical Research Manpower Supply from Those Awarded M.D. Degrees (Intermediate Estimates) 1/, 1952-80
(Shows Research Input in the Years 1961-1985)

M.D. degrees awarded: Year	M.D. degrees awarded: Number	Entering medical research: Percent	Entering medical research: Number	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
1952-1955...	26,586	13	3,456	319	958	1,311	1,575	1,748	1,920	2,052	2,141	2,186	2,186	2,186	2,186
1956...	6,845	13	890	133	267	400	534	668	712	757	801	846	890	890	890
1957...	6,796	13	883	...	132	265	397	530	662	706	750	794	839	883	883
1958...	6,861	14	961	...	...	144	288	433	577	721	769	817	865	913	961
1959...	6,860	14	960	...	...	...	144	288	432	576	720	768	816	864	912
1960...	7,081	15	1,062	...	...	...	...	159	319	478	638	797	850	903	956
1961...	6,996	15	1,049	...	...	...	...	...	157	315	472	630	787	839	892
1962...	7,168	15	1,075	...	...	...	...	...	...	161	323	484	646	807	860
1963...	7,266	15	1,090	...	...	...	...	...	...	...	163	327	490	654	818
1964...	7,336	15	1,100	...	...	...	...	...	...	...	...	165	330	495	660
1965...	7,409	15	1,111	...	...	...	...	...	...	...	...	...	166	333	499
1966...	7,574	15	1,136	...	...	...	...	...	...	...	...	...	...	170	341
1967...	7,743	15	1,161	...	...	...	...	...	...	...	...	...	...	...	175
1968...	7,970	15	1,196	...	...	...	...	...	...	...	...	...	...	...	...
1969...	7,885	15	1,182	...	...	...	...	...	...	...	...	...	...	...	...
1970...	8,068	15	1,210	...	...	...	...	...	...	...	..	...	...	...	...
1971...	8,550	15	1,283	...	...	...	...	...	...	...	...	...	...	...	...
1972...	9,297	15	1,396	...	...	...	...	...	...	...	...	...	...	...	...
1973...	9,776	15	1,400	...	...	...	...	...	...	...	...	...	...	...	...
1974...	10,488	15	1,573	...	...	...	...	...	...	...	...	...	...	...	...
1975...	11,316	15	1,697	...	...	...	...	...	...	...	...	...	...	...	...
1976...	12,328	15	1,849	...	...	...	...	...	...	...	...	...	...	...	...
1977...	13,136	15	1,973	...	...	...	...	...	...	...	...	...	...	...	...
1978...	14,168	15	2,125	...	...	...	...	...	...	...	...	...	...	...	...
1979...	15,180	15	2,277	...	...	...	...	...	...	...	...	...	...	...	...
1980...	16,100	15	2,415	...	...	...	...	...	...	...	...	...	...	...	...
U.S. total				652	1,357	2,120	2,930	3,826	4,779	5,766	6,777	7,814	8,865	9,937	11,033
Foreign input				130	271	424	588	765	956	1,153	1,355	1,563	1,773	1,987	2,207
Total, new entrants into medical research manpower supply				782	1,628	2,544	3,526	4,591	5,735	6,919	8,132	9,377	10,638	11,926	13,240

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Difference between 1965 and 1985
1952-1955...	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	2,186	438
1956...	890	890	890	890	890	890	890	890	890	890	890	890	890	222
1957...	883	883	883	883	883	883	883	883	883	883	883	883	883	353
1958...	961	961	961	961	961	961	961	961	961	961	961	961	961	528
1959...	960	960	960	960	960	960	960	960	960	960	960	960	960	672
1960...	1,009	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	903
1961...	944	997	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	7,049	1,049
1962...	914	967	1,021	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075
1963...	872	927	981	1,036	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090
1964...	825	880	935	990	1,045	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
1965...	666	833	888	944	999	1,055	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111
1966...	511	682	852	909	966	1,022	1,079	1,136	1,136	1,136	1,136	1,136	1,136	1,136
1967...	349	523	697	871	929	987	1,045	1,103	1,161	1,161	1,161	1,161	1,161	1,161
1968...	179	359	538	718	897	956	1,016	1,076	1,136	1,196	1,196	1,196	1,196	1,196
1969...	...	177	355	532	709	886	945	1,004	1,063	1,122	1,182	1,182	1,182	1,182
1970...	...	...	182	364	545	726	907	968	1,029	1,090	1,150	1,210	1,210	1,210
1971...	...	...	...	192	384	576	768	960	1,025	1,090	1,155	1,219	1,283	1,283
1972...	...	...	...	...	209	418	627	836	1,045	1,115	1,185	1,255	1,325	1,325
1973...	...	...	...	...	...	224	448	672	896	1,120	1,194	1,268	1,342	1,342
1974...	...	...	...	...	...	...	236	472	708	944	1,180	1,259	1,338	1,338
1975...	...	...	...	...	...	...	...	255	510	765	1,020	1,275	1,360	1,360
1976...	...	...	...	...	...	...	...	...	277	554	831	1,108	1,385	1,385
1977...	...	...	...	...	...	...	...	...	...	296	592	888	1,184	1,184
1978...	...	...	...	...	...	...	...	...	...	...	318	636	954	954
1979...	...	...	...	...	...	...	...	...	...	...	...	347	684	684
1980...	...	...	...	...	...	...	...	...	...	...	...	...	362	362
U.S. total	12,149	13,287	14,440	15,622	16,839	18,106	19,438	20,849	22,353	23,956	25,667	27,502	29,469	25,643
Foreign input	2,430	2,657	2,888	3,124	3,368	3,621	3,888	4,170	4,471	4,791	5,133	5,500	5,894	5,129
Total, new entrants into medical research manpower supply	14,579	15,944	17,328	18,746	20,207	21,727	23,326	25,019	26,824	28,747	30,800	33,002	35,363	30,772

1/ For method of derivation of Low, High, and Intermediate estimates, see Chapter IV.

For SOURCE and NOTES ON METHOD, see footnotes to Table 1A.

APPENDIX E

Table 4A

Model for Estimating Annual Flow of Ph.D.'s in the Basic Medical Sciences[1] into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1956-82
(Shows Research Input in the Years 1964-85)

Ph.D. degrees awarded: Year	Ph.D. degrees awarded: Number	Entering Medical Research: Number	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Net increment 1966-85: Total	Net increment 1966-85: Average
1956-1960...	3,157	2,841	406	347	235	180	118	61	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	594	30
1961...	723	651	130	130	[illegible]	66	65	65	65	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	391	20
1962...	821	739	...	148	148	148	74	74	74	73	...	...	...	...	...	...	...	...	...	...	...	...	...	...	591	30
1963...	860	776	...	...	155	155	155	78	77	77	77	...	...	...	...	...	...	...	...	...	...	...	...	...	774	39
1964...	1,012	911	...	...	...	182	182	182	92	91	91	91	...	...	...	...	...	..	...	...	...	...	...	...	911	46
1965...	1,184	1,066	...	...	...	...	213	213	213	107	107	107	106	...	...	...	...	...	...	...	...	...	...	...	1,066	53
1966...	1,270	1,143	...	...	...	...	...	229	229	229	114	114	114	114	...	...	...	...	...	...	...	...	...	...	1,143	57
1967...	1,473	1,326	...	...	...	...	...	...	265	265	265	133	133	133	132	...	...	...	...	...	...	...	...	...	1,326	66
1968...	1,656	1,490	...	...	...	...	...	...	...	298	298	298	149	149	149	149	...	...	...	...	...	...	...	...	1,490	75
1969...	1,861	1,675	...	...	...	...	...	...	...	...	335	335	335	168	168	167	167	...	...	...	...	...	...	...	1,675	84
1970...	2,092	1,883	...	...	...	...	...	...	...	...	...	377	377	377	188	188	188	188	...	...	...	...	...	...	1,883	94
1971...	2,351	2,116	...	...	...	...	...	...	...	...	...	...	423	423	423	212	212	212	211	...	...	...	...	...	2,116	106
1972...	2,643	2,379	...	...	...	...	...	...	...	...	...	...	...	476	476	476	238	238	238	237	...	...	...	...	2,379	119
1973...	2,971	2,674	...	...	...	...	...	...	...	...	...	...	...	...	535	535	535	268	267	267	267	...	...	...	2,674	134
1974...	3,339	3,005	...	...	...	...	...	...	...	...	...	...	...	...	...	601	601	601	301	301	300	300	...	...	3,005	150
1975...	3,753	3,378	...	...	...	...	...	...	...	...	...	...	...	...	...	...	676	676	676	338	338	337	337	...	3,378	169
1976...	4,218	3,796	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	759	759	759	380	380	380	379	3,796	190
1977...	4,741	4,267	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	853	853	853	427	427	427	3,840	192
1978...	5,329	4,796	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	959	959	959	480	480	3,837	192
1979...	5,990	5,391	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,078	1,078	1,078	540	3,774	189
1980...	6,733	6,080	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,212	1,212	1,212	3,636	182
1981...	7,368	6,811	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,362	1,362	2,724	136
1982...	8,306	7,655	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,531	1,531	77
U.S. total			534	625	668	731	807	902	1,015	1,140	1,287	1,455	1,637	1,840	2,071	2,328	2,617	2,942	3,305	3,714	4,175	4,693	5,276	5,931	48,534	2,427
Foreign input			107	125	134	146	162	180	203	228	258	291	327	368	207	233	262	294	330	371	418	469	528	593	6,002	300
Total, new entrants into medical research manpower supply			641	750	802	877	969	1,082	1,218	1,368	1,545	1,746	1,964	2,208	2,278	2,561	2,879	3,236	3,635	4,085	4,593	5,162	5,804	6,524	54,536	2,727

[1] Includes anatomy, histology, bacteriology, virology, mycology, parasitology, microbiology, biochemistry, biophysics, cytology, embryology, pathology, pharmacology, and physiology.

SOURCE: Ph.D. output 1956, 1957, Office of Education; 1958-67, National Academy of Sciences, Doctorate Recipients from United States Universities, 1958-66; 1967, unpublished data. Projections 1968-82, developed by Resources Analysis Branch, OPPE, NIH.

NOTES ON METHOD

1. Ninety percent of the Ph.D.'s in the basic medical sciences will enter into medical research as independent investigators at some time during their career.

2. There is a minimal 3-year lag between receipt of the Ph.D., subsequent postdoctoral training, and entrance into independent research.

3. In developing this model, it has been assumed that 60 percent of the Ph.D.'s in the basic medical sciences entering medical research as independent investigators will do so in the 3 years following postdoctoral training (20 percent per annum); the other 40 percent will enter between the 7th and 10th year following award of the Ph.D. degree (10 percent per annum). It is further assumed that a substantial proportion will have had experience as research assistants and research associates prior to entering the independent investigator pool. It is also recognized that some enter the pool for the first time 20-25-30 years after receipt of Ph.D. degree.

4. Foreign input (Ph.D.'s trained in foreign universities) equals approximately 20 percent (1966-75), and 10 percent (1976-85) of the total number of U.S.-trained Ph.D.'s in the basic medical sciences entering the medical research manpower pool each year. Foreign input consists of the following components:

a. U.S citizens who went abroad to complete their science training for the Ph.D., Sc.D., or equivalent degree.
b. Ph.D.'s who received their degree abroad who may or may not be U.S. citizens and are now engaged in research in the U.S.
c. Ph.D.'s trained abroad who are conducting research, whose research expenditures are included in the total national expenditures for medical research either in the government or in the industry component.

5. The model begins with a cumulative total of Ph.D.'s awarded 1956-60. Some of these Ph.D.'s will enter medical research in 1964 and later years. From 1965 on totals are complete except for those Ph.D.'s from classes prior to 1956 who enter research subsequent to 10 years or more after earning the Ph.D. degree.

6. Foreign inputs into research are also incomplete prior to 1965. In order to demonstrate method in the model, foreign entrants are computed at 20 percent of the total U.S.-trained input each year.

APPENDIX E

Table 4B

Model for Estimating Cumulative Flow of Ph.D.'s in the Basic Medical Sciences into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1956-82
(Shows Research Input in the Years 1964-85)

Ph.D. degrees awarded: Year	Ph.D. degrees awarded: Number	Entering medical research: Number	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1956-1960...	3,157	2,841	404	751	986	1,166	1,284	1,345	1,345	1,345	1,345	1,345	1,345
1961...	723	651	130	260	390	456	521	586	651	651	651	651	651
1962...	821	739	...	148	296	444	518	592	666	739	739	739	739
1963...	860	774	...	...	155	310	465	543	620	697	774	774	774
1964...	1,012	911	...	...	...	182	364	546	638	729	820	911	911
1965...	1,184	1,066	...	...	...	...	213	426	639	746	853	960	1,066
1966...	1,270	1,143	...	...	...	...	...	229	458	687	801	915	1,029
1967...	1,473	1,326	...	...	...	...	...	...	265	530	795	928	1,061
1968...	1,656	1,490	...	...	...	...	...	...	...	298	596	894	1,043
1969...	1,861	1,675	...	...	...	...	...	...	...	...	335	670	1,005
1970...	2,092	1,883	...	...	...	...	...	...	...	...	...	377	754
1971...	2,351	2,116	...	...	...	...	...	...	...	...	...	...	423
1972...	2,643	2,379	...	...	...	...	...	...	...	...	...	...	...
1973...	2,971	2,674	...	...	...	...	...	...	...	...	...	...	...
1974...	3,339	3,005	...	...	...	...	...	...	...	...	...	...	...
1975...	3,753	3,378	...	...	...	...	...	...	...	...	...	...	...
1976...	4,218	3,796	...	...	...	...	...	...	...	...	...	...	...
1977...	4,741	4,267	...	...	...	...	...	...	...	...	...	...	...
1978...	5,329	4,796	...	...	...	...	...	...	...	...	...	...	...
1979...	5,990	5,391	...	...	...	...	...	...	...	...	...	...	...
1980...	6,733	6,060	...	...	...	...	...	...	...	...	...	...	...
1981...	7,568	6,811	...	...	...	...	...	...	...	...	...	...	...
1982...	8,506	7,659	...	...	...	...	...	...	...	...	...	...	...
U.S. total..			534	1,159	1,827	2,558	3,365	4,267	5,282	6,422	7,709	9,164	10,801
Foreign input			107	232	366	512	674	854	1,057	1,285	1,543	1,834	2,161
Total, new entrants into medical research manpower supply			641	1,391	2,193	3,070	4,039	5,121	6,339	7,707	9,252	10,998	12,962

Ph.D. degrees awarded: Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Difference between 1965 and 1985
1956-1960...	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	1,345	594
1961...	651	651	651	651	651	651	651	651	651	651	651	391
1962...	739	739	739	739	739	739	739	739	739	739	739	591
1963...	774	774	774	774	774	774	774	774	774	774	774	774
1964...	911	911	911	911	911	911	911	911	911	911	911	911
1965...	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
1966...	1,143	1,143	1,143	1,143	1,143	1,143	1,143	1,143	1,143	1,143	1,143	1,143
1967...	1,194	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326
1968...	1,192	1,341	1,490	1,490	1,490	1,490	1,490	1,490	1,490	1,490	1,490	1,490
1969...	1,173	1,341	1,508	1,673	1,675	1,675	1,675	1,675	1,675	1,675	1,675	1,675
1970...	1,131	1,319	1,507	1,695	1,883	1,883	1,883	1,883	1,883	1,883	1,883	1,883
1971...	846	1,269	1,481	1,693	1,905	2,116	2,116	2,116	2,116	2,116	2,116	2,116
1972...	476	952	1,428	1,666	1,904	2,142	2,379	2,379	2,379	2,379	2,379	2,379
1973...	...	535	1,070	1,605	1,873	2,140	2,407	2,674	2,674	2,674	2,674	2,674
1974...	...	...	601	1,202	1,803	2,104	2,405	2,705	3,005	3,005	3,005	3,005
1975...	...	...	...	676	1,352	2,028	2,366	2,704	3,041	3,378	3,378	3,378
1976...	...	...	...	...	759	1,518	2,277	2,657	3,037	3,417	3,796	3,796
1977...	...	...	...	...	...	853	1,706	2,559	2,986	3,413	3,840	3,840
1978...	...	...	...	...	...	...	959	1,918	2,877	3,357	3,837	3,837
1979...	...	...	...	...	...	...	...	1,078	2,156	3,234	3,774	3,774
1980...	...	...	...	...	...	...	...	...	1,212	2,424	3,636	3,636
1981...	...	...	...	...	...	...	...	...	...	1,362	2,724	2,724
1982...	...	...	...	...	...	...	...	...	...	...	1,531	1,531
U.S. total..	12,641	14,712	17,040	19,657	22,599	25,904	29,618	33,793	38,486	43,762	49,693	48,534
Foreign input	2,529	2,736	2,969	3,231	3,525	3,855	4,226	4,644	5,113	5,641	6,234	6,002
Total, new entrants into medical research manpower supply	15,170	17,448	20,009	22,888	26,124	29,759	33,844	38,437	43,599	49,403	55,927	54,536

For SOURCE and NOTES ON METHOD, see footnotes to Table 4A.

APPENDIX E

TABLE 5.—Summary of Illustrative Annual Flow Model of Ph. D.'s in the *Other Biosciences*[1] Into the Medical Research Manpower Supply, 1966–85, From Those Awarded Ph. D. Degrees, 1957–82

Ph. D. Degrees awarded		Entering medical research				
Year	Number	Total 1966–85	1966–70	1971–75	1976–80	1981–85
1957–60	2,286	292	292			
1961–65	3,544	1,590	1,207	383		
1966–70	5,045	2,525	277	1,713	535	
1971–75	7,091	3,547		378	2,411	758
1976–80	10,090	3,968			535	3,433
1981, 1982	5,141	762				762
U.S. total		12,684	1,776	2,474	3,481	4,953
Foreign input		1,693	355	495	348	495
Total, new entrants into medical research manpower supply		14,377	2,131	2,969	3,829	5,448

[1] Includes biology general, botany general, zoology general, ecology, entomology, genetics, nutrition, plant pathology, plant physiology, and biological sciences.

Source: Ph. D. output 1957, Office of Education; 1958–67, National Academy of Sciences, *Doctorate Recipients from United States Universities, 1958–66*; 1967 unpublished data.

Projections 1968–82, developed by Resources Analysis Branch, OPPE, NIH.

NOTES ON METHOD

1. Fifty percent of the Ph. D.'s in the other biosciences will enter into medical research as independent investigators at some time during their career.

2. There is a minimal 3-year lag between receipt of the Ph. D., subsequent postdoctoral training, and entrance into independent research.

3. In developing this model, it has been assumed that 60 percent of the Ph. D.'s in these fields entering medical research as independent investigators will do so in the 3 years following postdoctoral training (20 percent per annum); the other 40 percent will enter between the 7th and 10th year following award of the Ph. D. degree (10 percent per annum). It is further assumed that a substantial proportion will have had experience as research assistants and research associates prior to entering the independent investigator pool. It is also recognized that some enter the pool for the first time 20–25–30 years after receipt of the Ph. D. degree.

4. Foreign input (Ph. D.'s trained in foreign universities) equals approximately 20 percent (1966–75), and 10 percent (1976–85) of the total number of U.S. trained Ph.D.'s entering the medical research manpower pool each year in these fields. Foreign input consists of the following components:

   a. U.S. citizens who went abroad to complete their science training for the Ph. D., Sc. D., or equivalent degree.

   b. Ph. D.'s who received their degree abroad who may or may not be U.S. citizens and are now engaged in research in the United States.

   c. Ph. D.'s trained abroad who are conducting research, whose research expenditures are included in the total national expenditures for medical research either in the government or in the industry component.

5. The model begins with a cumulative total of Ph. D.'s awarded, 1957–60. Some of these Ph. D.'s will enter medical research in 1966 and later years. From 1965 on, totals are complete except for those Ph.D.'s from classes prior to 1957 who enter research subsequent to 10 years after earning the Ph. D. degree.

APPENDIX E

TABLE 6.—Summary of Illustrative Annual Flow Model of Ph. D.'s in the *Behavioral Sciences*[1] Into the Medical Research Manpower Supply, 1966–85, From Those Awarded Ph. D. Degrees, 1957–82

Ph. D. degrees awarded		Entering medical research				
Year	Number	Total 1966–85	1966–70	1971–75	1976–80	1981–85
1957–60	3, 718	292	292	----------	----------	----------
1961–65	5, 923	1, 585	1, 212	373	----------	----------
1966–70	9, 572	2, 872	283	1, 055	634	----------
1971–75	15, 186	4, 556	----------	467	3, 097	992
1976–80	23, 801	5, 585	----------	----------	733	4, 852
1981, 1982	12, 950	1, 148	----------	----------	----------	1, 148
U.S. total		16, 038	1, 787	2, 795	4, 464	6, 992
Foreign input		2, 061	357	559	446	699
Total, new entrants into medical research manpower supply		18, 099	2, 144	3, 354	4, 910	7, 691

[1] Includes anthropology sociology, and psychology. It is expected, however, that the scope of the behavioral sciences will, in the future, also include medical economics.

Source: See table 5, app. E.

NOTES ON METHOD

1. 30 percent of the Ph. D.'s in the behavioral sciences will enter into medical research as independent investigators at some time during their career.

2-5. See table 5, app. E.

TABLE 7.—Summary of Illustrative Annual Flow Model of Ph. D.'s in the *Physical Sciences*[1] Into the Medical Research Manpower Supply, 1966–85, From Those Awarded Ph. D. Degrees, 1957–82

Ph. D. degrees awarded		Entering medical research				
Year	Number	Total 1966–85	1966–70	1971–75	1976–80	1981–85
1957–60	6, 886	194	194	----------	----------	----------
1961–65	11, 903	1, 175	891	284	----------	----------
1966–70	19, 314	2, 125	211	1, 447	467	----------
1971–75	32, 149	3, 537	----------	357	2, 402	778
1976–80	53, 221	4, 569	----------	----------	590	3, 979
1981, 1982	30, 021	975	----------	----------	----------	975
U.S. total		12, 575	1, 296	2, 088	3, 459	5, 732
Foreign input		1, 596	259	418	346	573
Total, new entrants into medical research manpower supply		14, 171	1, 555	2, 506	3, 805	6, 305

[1] Includes physical sciences general, astronomy, chemistry, metallurgy, meteorology, pharmaceutical chemistry, physics, and earth sciences.

Source: See table 5, app. E.

NOTES ON METHOD

1. Eleven percent of the Ph. D.'s in the physical sciences will enter into medical research as independent investigators at some time during their career.

2-5. See table 5, app. E.

APPENDIX E

TABLE 8.—Summary of Illustrative Annual Flow Model of Ph. D.'s in *Mathematics and Statistics* Into the Medical Research Manpower Supply, 1966–85, From Those Awarded Ph. D. Degrees, 1957–82

Ph. D. degrees awarded		Entering medical research				
Year	Number	Total 1966-85	1966-70	1971-75	1976-80	1981-85
1957–60	1,084	20	20			
1961–65	2,555	164	124	40		
1966–70	5,639	394	35	269	90	
1971–75	13,101	917		82	622	213
1976–80	28,963	1,562			184	1,378
1981, 1982	19,436	398				398
U.S. total		3,455	179	391	898	1,989
Foreign input		403	36	78	90	199
Total, new entrants into medical research manpower supply		3,858	215	469	988	2,188

Source: See table 5, app. E.

NOTES ON METHOD

1. Seven percent of the Ph. D.'s in mathematics and statistics will enter into medical research as independent investigators at some time during their career.

2-5. See table 5, app. E.

TABLE 9.—Summary of Illustrative Annual Flow Model of Ph. D.'s in *Engineering* Into the Medical Research Manpower Supply, 1966–85, From Those Awarded Ph. D. Degrees, 1957–82

Ph. D. degrees awarded		Entering medical research				
Year	Number	Total 1966-85	1966-70	1971-75	1976-80	1981-85
1957–60	2,716	42	42			
1961–65	7,242	397	295	102		
1966–70	15,649	939	85	639	215	
1971–75	33,645	2,020		186	1,371	463
1976–80	68,901	3,194			385	2,809
1981, 1982	43,984	774				774
U.S. total		7,366	422	927	1,971	4,046
Foreign input		871	84	185	197	405
Total, new entrants into medical research manpower supply		8,237	506	1,112	2,168	4,451

Source: See table 5, app. E.

NOTES ON METHOD

1. Six percent of the Ph. D.'s in engineering will enter into medical research as independent investigators at sometime during their career.

2-5. See table 5, app. E.

APPENDIX E

TABLE 10.—Projections of Bachelor's Degrees Conferred, 1968–75

[Thousands]

Year	Office of Education [1]	NIH [2]	Folger	
1967–68	616	631	[3] 651	[4] (635)
1968–69	676	726	713	(695)
1969–70	673	730	742	(723)
1970–71	686	732	753	(734)
1971–72	713	745	816	(796)
1972–73	747	769	844	(823)
1973–74	783	805	888	(866)
1974–75	818	850	927	(904)

[1] Office of Education, *Projections of Educational Statistics to 1975–76, 1966*. Projections shown on table 17, p. 27, of bachelor's and first-professional degrees have been reduced by 8.5 percent to exclude first-professional degrees.

[2] Projections prepared by Resources Analysis Branch, Office of Program Planning and Evaluation, National Institutes of Health. Based upon long-term trends and experience, represents a composite of 21-, 22-, and 23-year-olds receiving bachelor's degree. The NIH projections are approximately 2.5 percent above those prepared by the Office of Education; for all years, except 1969, 1970 and 1971. They are appreciably lower than the projections prepared by Dr. John K. Folger, formerly the Director of the Commission on Human Resources and Advanced Education. By 1975, Folger's projection overall is about 6 percent above the NIH projection.

[3] Projections prepared by John K. Folger, formerly the Director of the Commission on Human Resources and Advanced Education. See, "The Balance Between Supply and Demand for College Graduates," *The Journal of Human Resources*, vol. II, No. 2, Spring 1967, pp. 143–175, particularly table 1, p. 146.

[4] Op. cit. Figures in parentheses ( ) reflect reduction of projections shown on table 1, p. 146 (Folger) by 2.5 percent to exclude first-professional degrees.

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