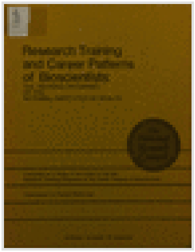

Research Training and Career Patterns of Bioscientists: The Training Programs of the National Institutes of Health (1976)

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RESEARCH TRAINING AND CAREER PATTERNS OF BIOSCIENTISTS: THE TRAINING PROGRAMS OF THE NATIONAL INSTITUTES OF HEALTH

Report
of the

Committee on a Study of the Impact of the NIH
Research Training Programs on the Career Patterns of Bioscientists

COMMISSION ON HUMAN RESOURCES
NATIONAL RESEARCH COUNCIL

National Academy of Sciences
Washington, D. C.
July 25, 1975

NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
2101 CONSTITUTION AVENUE
WASHINGTON, D.C. 20418

September 11, 1975

Dr. Donald S. Fredrickson
Director
National Institutes of Health
9000 Rockville Pike
Bethesda, Maryland 20014

Dear Dr. Fredrickson:

I am pleased to present to the National Institutes of Health the report of the Committee on a Study of the Impact of NIH Training Programs on the Career Patterns of Bioscientists. The study was requested in a letter of May 10, 1971 to me from Dr. Thomas J. Kennedy, Jr., Associate Director for Program Planning and Evaluation, and was supported under Contract PH 43-64-44, Task Order 60 with the National Institutes of Health.

Two principal tasks were undertaken in this study: the assembling of relevant career data about individual NIH trainees and fellows from the inception of the training activities in 1938 to the present and the analysis of these data to determine outcomes of training. In regard to the first, the NIH request urged that existing data sources be used rather than special questionnaire surveys. A great deal of effort was devoted to this task by the Committee and its staff. Thanks to their work a computerized Roster of NIH Trainees and Fellows, containing some 94,000 individual records, was created to be used during the study and later for administrative purposes, by the NIH. The analysis included collation of this roster with such other sources as the Doctorate Records File, the National Registers of Scientific and Technical Personnel, and the Science Citation Index. Whenever possible, comparisons were made with other groups of predoctoral or postdoctoral trainees or fellows not supported by NIH, but in a retrospective study of this kind it was not possible to develop completely comparable control groups. Nevertheless, the Committee has examined a number of important outcomes of the training activities, as quantitatively as possible, and compared them with the training goals.

Dr. Donald S. Fredrickson
September 11, 1975
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We hope that the data and analyses presented here will be helpful to the National Institutes of Health in its evaluation of the training programs.

Sincerely yours,

Philip Handler
President

Enclosures (30)

NOTICE: The project which is the subject of this report was approved by the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Board's judgment that the project is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the committee selected to undertake this project and prepare this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. Responsibility for the detailed aspects of this report rests with that committee.

Each report issuing from a study committee of the National Research Council is reviewed by an independent group of qualified individuals according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved, by the President of the Academy, upon satisfactory completion of the review process.

The work on which this publication is based was performed pursuant to Contract No. PH43-64-44 with the National Institutes of Health of the Department of Health, Education and Welfare.

PREFACE

The launching of the study reported here, concerning the research training programs of the National Institutes of Health, occurred just one month prior to the announcement of phasing out of training-grant support. However, there was a sense among members of the study committee that it was imperative to continue this study and to use this opportunity to ascertain not only what had happened as a result of the training grants, but to make an assessment of the training programs that might provide useful guidance for future policy. Recent legislation has restored training programs. The findings of this report may suggest ways for more effective utilization of such programs.

There was a constant concern among the members of the Committee just exactly what our "task" was to be. We took seriously the charge to determine "the effect of NIH traineeship and fellowship programs on the careers of bioscientists." We tried to make maximum use of the imperfect measures available to determine the role of training grants and fellowships in preparing and encouraging M.D.'s, graduate students, and post-Ph.D.'s to enter into and continue with biomedical research. But, at the same time, several other broad policy issues had to be answered as a foundation of our understanding of why the federal government should in any way be involved in the training-grant program.

There seems to be a general acceptance, both by the bioscience community and by the citizenry of these United States, that support for biomedical research is a necessary and appropriate federal function. Such support certainly falls within the Constitutional powers delegated to the federal government. It is one of the most important ways in which we can develop the human, scientific, and technological resources to improve the health of our citizens.

Once it is recognized that biomedical research is necessary and appropriate, then it is clear that provision must be made to insure the availability of a sufficient number of well-trained researchers. This involves formal and informal graduate and postdoctoral training and education to provide a high quality of research manpower to engage in these efforts. It is not universally accepted, however, that the federal government has a role to play in such training.

The education and training required by a person who seeks to carry out clinical investigations and basic scientific research on the frontiers of medical knowledge is formidable. The researcher must complete not only an undergraduate degree in one of the basic sciences, but also a graduate program leading to the M.D. or Ph.D. as well. Many of our professors on medical school faculties have earned both degrees. Beyond the M.D. and Ph.D., the young medical scientist must master the ever-increasing complexity of the equipment and instrumentation of the modern laboratory and keep up with the rapidly advancing frontiers of knowledge. Further postdoctoral training, under the supervision of teams of senior scientists or physicians in the specialized areas of interest, is desirable and often mandatory. These years of graduate and postdoctoral education are spent at considerable personal cost in loss of income, yet great benefit accrues to society in the resultant research and teaching.

Biomedical research must be responsive to the health needs of the society. It must constantly be aware of the "state of the art" of delivering health care. The ultimate goal of biomedical research is to alleviate disease and improve the health of the people. Without research in the basic sciences, there will be little improvement in the state of the art. We are nowhere near understanding the fundamental basis of cancer, stroke, and heart disease, not to mention many other widespread killers and cripplers of our society. Effective treatment or prevention of these health problems is hampered by this lack of fundamental knowledge.

If we accept these assumptions, many issues follow. The report we present seeks to address the immediate question of the impact of training programs on career patterns, but at the same time tries to provide some insight into the impact of these programs on departments, institutions, and national efforts in the education of biomedical scientists.

The Committee received help from many persons and organizations. Solomon Schneyer, Director, Division of Program Analysis in the Office of the Director, NIH, provided data and interpretation of NIH administrative policies in the training programs. Many members of the staff of the Commission on Human Resources of the National Research Council were helpful. Our special thanks go to Allen M. Singer who served as the principal staff officer for the study. His contributions were indispensable. Ingrid M. Wharton performed the difficult task of developing and integrating the data bank. In addition, George Boyce, Mary Campanucci, Porter Coggeshall, Joseph Finan, Corazon Francisco, Lindsey Harmon, and Norma Melendez provided excellent support in the development and analysis of data. To them, to such organizations as the Association of American Medical Colleges, and to the representatives of many universities and medical schools who provided needed data go our sincere thanks.

July 14, 1975

Paul D. Saltman
Chairman

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LIST OF ABBREVIATIONS

AAMC	Association of American Medical Colleges
ADAMHA	Alcohol, Drug Abuse, and Mental Health Administration
AEC	Atomic Energy Commission
AMA	American Medical Association
D.V.M.	Doctor of Veterinary Medicine
GRE	Graduate Record Examination
HEW	Department of Health, Education, and Welfare
NASA	National Aeronautics & Space Administration
NCI	National Cancer Institute
NDEA	National Defense Education Act
NEI	National Eye Institute
NHLI	National Heart and Lung Institute
NIAID	National Institute of Allergy and Infectious Diseases
NIAMDD	National Institute of Arthritis, Metabolism, and Digestive Diseases
NICHD	National Institute of Child Health and Human Development
NIDR	National Institute of Dental Research
NIEHS	National Institute of Environmental Health Science
NIGMS	National Institute of General Medical Sciences
NIH	National Institutes of Health
NINCDS	National Institute of Neurological and Communicative Disorders and Stroke
NRC	National Research Council
NSF	National Science Foundation
PHS Act	Public Health Service Act
USOE	United States Office of Education
WW	Woodrow Wilson Foundation

Symbols Used in the Equations of Chapter 5

BA/P	Baccalaureate/Population Ratio
PD	Probability of Deferment
SA	Student Aid, higher education
SAGE	Student Aid, Graduate Education
$B	BA salaries
$C/HS	College/High school salary ratio
$F/TL	Relative faculty salaries
$PHDCH/$PHDTL	Relative salaries of PhD chemists
$B/BA	Salaries of bioscience PhD's relative to bioscience BA's
R^2	The coefficient of determination
R_{1p}/R_t	Relative funds for research in the life and physical sciences
R_1/R_t	Relative federal funds for research in life sciences

R_{pe}/R_t	Relative federal funds for research in physical science and engineering
ENPE/ENTL	Relative graduate enrollments in physical science and engineering
EN1FBI/EN1FTL	Relative first-year bioscience enrollments
$EN1FTL_1/B_{i-1}$	Ratio of graduate enrollment to Baccalaureate degrees
$ENLTBI/B_{i-1}$	Bioscience Enrollment—BA ratio
MEDAPP	Number of applications for medical school
MDENR	Total enrollments in medical schools
NIHTF/SAGE	Relative NIH student aid funds
PHDBI/PHDTL	Relative bioscience PhD production
PHDPE/PHDTL	Relative physical science and engineering PhD production
$PhDTL_i/\overline{EN}_i$	PhD/Enrollment ratio
TFBI/TFTL	Relative federal expenditures for bioscience traineeships and fellowships
TFPE/TFTL	Relative federal expenditures for traineeships and fellowships in physical science and engineering

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INTRODUCTION

A. ORIGINS OF THE STUDY

This report was prepared by a committee of the National Research Council (NRC), administratively housed within the Commission on Human Resources (formerly the Office of Scientific Personnel), in response to a request from the National Institutes of Health (NIH) for assistance in determining the effect of its traineeship and fellowship programs on the careers of bioscientists. The request was accepted by the NRC on June 6, 1971. Included in the study were two principal tasks: (1) the preparation of a computerized roster containing relevant program information on essentially all former trainees and fellows supported by the Institutes of NIH back to the inception of the training programs in 1938 and (2) the analysis of these data and related data to determine the outcomes of the training programs observable in the career patterns of bioscientists.

Although the study committee was appointed late in 1971 and guided the project throughout its existence, it and its staff were fully occupied at the beginning of the project by the requirements of the first task. It was successfully completed and a comprehensive record concerning over 94,000 trainees and fellows now exists, providing the basis not only for the analyses reported here, but for administrative studies undertaken by the NIH.

The study questions addressed by the Committee then guided the further activities. They include:

- What have been the training support patterns for NIH trainees and fellows? How many students have been supported in each biomedical field? For how long? At what point in their graduate careers?

- What percentage of the NIH pre-Ph.D. trainees and fellows ultimately attained the doctorate? How does the Ph.D. attainment rate for NIH trainees and fellows compare with that of other graduate students?

- What is the baccalaureate-to-doctorate time lapse of NIH appointees? How does it compare with the time lapse of doctorate recipients in the same fields without NIH support?

- What are the post-training careers of NIH trainees and fellows? How productive are they?

- Is the mechanism of support of graduate students (traineeships, fellowships, research assistantships under research contracts, etc.) a significant factor in academic performance or post-training careers?

These questions are truly formidable, and some of them—in a retrospective study of this kind—were unanswerable. In addition, the Committee saw the necessity of obtaining a clear understanding of the institutional setting within which those supported in these programs were trained and made arrangements to visit or in other ways consult with the directors of training programs. This was done through a series of site visit and conference calls.

The present report contains the results that the Committee regards as well-founded on the available data and the experience of training directors and trainees. Many other aspects of this problem of evaluation arose during the Committee's deliberations, were discussed, and—in some instances—explored in staff studies. Not all of the analyses undertaken are reported here, however, because some proved inconclusive, and others, while holding promise of future utility, could not be completed within the present study. Moreover, throughout the report and especially in Chapter 5, we have set forth some of the difficulties which inevitably beset a statistical analysis of data such as those available here.

B. THE TRAINING PROGRAMS

The National Cancer Act of August 5, 1937, established the National Cancer Institute within the Public Health Service and authorized it to establish training facilities and award fellowships to the "most brilliant and promising research fellows from the U. S. or abroad" for the purpose of conducting studies relating to the cause, prevention, and methods of diagnosis and treatment of cancer. In 1938, the first NCI fellowships were awarded to 17 individuals in such fields as biochemistry, physiology, and genetics. During the 1940's and halfway through the 1950's, these fellowship programs grew slowly but steadily, adding a few hundred new trainees each year and spreading out into most of the basic biological sciences and many of the clinical sciences. In 1948, the first NIH training grants were awarded directly to institutions for the purpose of strengthening their teaching capabilities. Two years later, in 1950, stipends were first paid to the trainees by the institutions holding the training grants. In 1956, the spurt of general scientific activity in this country led to a decade of rapid growth in the NIH and its training programs such that in 1965, 7,922 individuals entered these programs. Since then, the number of entrants has declined each year except for 1969, which had a slight increase over 1968. As of 1975 the programs are continuing at funding levels considerably reduced from previous years.

Late in 1972, a decision was made within the administration to phase out the NIH training programs. No funds for new starts under the programs were included in the administration's budget request to Congress for fiscal year 1974. In 1973, the Department of Health, Education and Welfare (HEW) inaugurated a postdoctoral fellowship program to be funded at about $30 million annually. Then in 1974 Congress passed the National Research Service Award Act[1] amending previous training authorities and establishing National Research Service Awards which require that trainees or fellows must meet a payback provision if they fail to pursue research or teaching activities for a period equal to the number of months of federal support received. Physicians, dentists, nurses, or other health care providers can satisfy their obligation under this Act by practicing in designated shortage areas for 20 months for each year of support received.

Toward the end of the 1960's, the Executive Branch of the government began to re-examine all federal programs for support for training. The National Institutes of Health were asked to perform extensive analyses of their training programs and undertook a comprehensive program of data collection and analysis. The study reported on herein is part of that analysis. (Since the National Institute of Mental Health was not a component of NIH in 1971, its training programs were excluded from the study.)[2]

C. RESEARCH PLAN

The Committee devised a research plan for the study which contained basically three elements, who, what, and how, defined as follows:

Who: The first kind of information needed was a description of the trainee population including their identification, academic background, and field of interest at the time of training. This basic task

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[1]The Act also provided for the National Academy of Sciences to conduct a continuing study and report annually to the Secretary of HEW on the need for biomedical and behavioral research manpower. The first such report was issued on June 11, 1975. See Personnel Needs and Training for Biomedical and Behavioral Research, National Academy of Sciences, Washington, D. C., 1975.

[2]The NIMH was established as part of NIH in 1949. In 1967 it was separated from NIH and made an independent bureau within the Public Health Service. In 1973 it was combined with other units of the PHS to form the Alcohol, Drug Abuse and Mental Health Administration (ADAMHA).

was accomplished by the establishment of the roster of former NIH trainees and fellows referred to above. The raw data were obtained from the automated files of NIH, augmented by data from the records of the various Institutes. When completed, this roster contained comprehensive information about the population of trainees at the time they were in training. Comparison groups of non-supported individuals and those supported by other federal and private fellowship programs were obtained from the National Science Foundation, the Office of Education, the Woodrow Wilson Foundation, the American Medical Association, and the Doctorate Records File maintained by the Commission on Human Resources.

What: Information about the subsequent careers of the people in the study was obtained primarily by utilizing existing data files such as the National Register of Scientific and Technical Personnel and similar files providing career data. The principal mode of operation was to match the NIH Roster and the files of comparison groups against the career outcome files to develop aggregate statistics on career patterns and achievements. Only statistical results were sought. Individuals were not identified in the resulting tables.

Although difficult problems are encountered in using this methodology, they are counterbalanced by the fact that a much larger group of people can be studied in this way at less cost and difficulty than by means of a questionnaire survey of comparable size. Over 500,000 individuals from all files, including about 94,000 from NIH, were involved in this study.

For purposes of this study, a "match" occurred when an individual in one of the study groups was found in one of the outcome files. This "matching rate" varied depending on what facet of a career was being analyzed. For those who attained the Ph.D., the rate was almost 100% because the Doctorate Records File maintained by the Commission on Human Resources contains rather complete information on virtually all Ph.D.'s granted by U. S. universities since 1920. For other facets of a career, the rate was limited by the amount of information available from other files. Career information was obtained on about 200,000 out of the 500,000 individuals in the study for an overall "matching rate" of about 40% in this case. However many of the individuals in the study were recent graduates who had not had time to establish a career pattern or to be included in the surveys of professional bioscientists from which the career pattern information was derived. For the older cohorts—those whose B.A. was prior to 1960—the "matching rate" was about 60%.

It was not possible to obtain complete longitudinal data in this study (i.e., information on the same individuals at different time periods). What was done instead was to take a snapshot of the primary work activity of a large group of individuals during the 1968-70 time period, group them by cohort, and then try to infer what their career patterns were. Although some longitudinal data were available for the NIH-supported group from the NIH File of Trainees and Fellows which provided such information on this group during the time they were in training, no career pattern information was available in longitudinal form and so the snapshot technique was used. This snapshot technique provides at least information on what the members of the study group were doing during 1968-70. At most it gives a rough idea of their career patterns.

How: The third kind of information needed was how the training programs have affected the career patterns of trainees, and consequently how effective the programs have been in accomplishing their goals. This called for some method of analyzing the impact or the outcomes of the programs. One way in which one might imagine this could be done would be to compare the career patterns of the NIH-supported group with those of a group of non-supported individuals similar to the supported group except in the fact of non-support. In an ideal experimental situation, the individuals in the study would have been assigned at random to the supported and non-supported groups. Then the Committee would have been more confident that any observed differences in career outcomes between the two groups were not due to differences in ability or other extraneous factors. However, the Committee had no opportunity to construct such an experiment since it was faced with the task of assessing a program that had been operating for over 30 years. Available data had to be used, and it was necessary to recognize that the selectivity factor present in the supported group could account for at least a portion of any observed differences in achievements between the groups.

D. OTHER STUDIES

Site visits were conducted by the advisory committee at several medical schools and universities with varying degrees of involvement with NIH-supported training programs. The purpose of these visits and conferences was to elicit the views of the faculty on the impact that the programs had had on the trainees, the departments, and the total educational environment.

A macroeconomic approach to the task of evaluation was also undertaken. This consisted of the construction of regression equations which related aggregate economic and demographic variables to graduate enrollments and Ph.D. degrees in the biosciences and other fields. The equations were developed empirically from an extensive set of data gathered for the 1956-70 time period in an attempt to show how the flow of students through the educational and training process has been affected by government programs, the market mechanism, and demographic trends.

E. ORGANIZATION OF THE REPORT

After a brief summary in Chapter 1, the various mechanisms of support are discussed in Chapter 2. Chapter 3 describes that portion of the individual's career dealing with training and education.

Chapter 4 deals with career outcomes and achievements. This part provides the primary follow-up data and analysis of career patterns. Included in the analysis are Ph.D. attainment rates, place of employment of former trainees, work activities, earnings profiles and estimates of contributions made to research.

The final chapter describes the study of economic and demographic aggregates that resulted in the empirical model of the major factors affecting enrollments and degrees in graduate education. The methodological details of this modeling procedure are described in Appendix B along with the data used in the analysis.

The report—as seems fitting in a study of this kind—does not contain recommendations for policy. The reader will find extensive analyses here and—to the extent the data justify them—interpretations of significance, but not recommendations. The Committee hopes, however, that policymakers will find the results of the study helpful in determining what the programs studied have accomplished and thereby be aided in setting national policies in this area.

1. SUMMARY AND PRINCIPAL FINDINGS

A. CHARACTERISTICS OF THE NIH TRAINING PROGRAM

The first task in this study was to collect data on all the trainees and fellows who had been supported by the research training program of the National Institutes of Health since the training program began in 1938. Out of this task was developed the NIH Roster of Trainees and Fellows which provided the basic information necessary to conduct the follow-up study of these individuals. Among other things, this file enabled some details of the complete NIH-wide training programs to emerge for the first time.

- About 94,000 people were supported under these research training programs between 1938 and 1972. Many of these received their first award as pre-Ph.D.'s on training grants during the period of rapid growth in the 1960's. Beginning in 1958, the programs underwent a sharp expansion which lasted for about 10 years before leveling off. During this time the training grant became the primary support mechanism.

- Just about half of all trainees and fellows began their training in the basic biomedical sciences, the most heavily supported ones being biochemistry, microbiology, and physiology. The clinical sciences were next largest with about 30% of the trainees, and the balance was distributed among other health-related fields, the physical sciences, and psychology.

- Although NIH through its various components, such as the Bureau of Health Resources Development (now part of the Health Resources Administration), has supported the education of medical, dental, and other students in the health professions, the NIH training and fellowship programs have generally been directed to the support of training of researchers. It is important to make this distinction because the goals in each case are very different. Yet it is sometimes difficult to do so—clinical research requires clinical knowledge and experience. Support of the health professionals generally is designed to encourage practitioners in that area; the research training programs, to which this study is confined, are designed primarily to support those interested in research and teaching careers.

• These research training programs have provided support to pre-M.D.'s and post-M.D.'s as well as pre- and post-Ph.D.'s. About 40% of the full-time trainees were pre- or post-M.D.'s and 47% were pre- or post-Ph.D.'s, with 13% unknown. Most of the pre-M.D.'s were part-time trainees (less than eight consecutive months of support) who took their training in the summer between semesters in medical school. The pre-M.D. support was for training supplemental to their medical education.

• Almost three-fourths of the people supported by NIH have started on training grants, one-fourth on fellowships.

• The proportion of graduate students in the biosciences supported by NIH reached a peak of 28% in 1964 and has gradually declined since then to about 18% in 1971. In the health professions, the 1967 peak of 16% has declined to about 10% in 1971. These proportions are estimated from data compiled by different sources using different definitions of fields and hence might be somewhat distorted by this lack of uniformity.

• The length of support provided by NIH depends heavily on the academic level of the trainee. Those who were seeking a Ph.D. received more support than others because of the long period of study required to attain the Ph.D. The average length of NIH pre-Ph.D. support was 22 months while for the post-Ph.D.'s it was about 16 months. Some students have received both pre- and postdoctoral support, so that the average length of support <u>per individual</u> in full-time training has been a little more than two years. About 7% of the appointees have received four or more years of support.

• The total cost to NIH for a typical fellow whose first award occurred during 1966-70 was about $8,200 for a pre-Ph.D. and about $11,000 for a post-Ph.D. These figures include the stipend and dependency allowances, which go to the fellow, and allowances for tuition and supplies, which go to the institution. Increases in the amount of support have just about kept up with increases in the cost of university education.

• Pre-Ph.D. trainees began to receive support an average of 2½ years after the B.A. Post-Ph.D. support typically began between one and two years after the Ph.D. Post-M.D.'s received their first support generally after the residency, about 4½ years beyond the M.D.

B. CAREER OUTCOMES

• In the biological sciences, those individuals with predoctoral traineeships or fellowships attained the Ph.D. more frequently and in less time than those without such support. Differences in ability, however, may account for some of the differences in Ph.D. attainment rates and in the shorter time lapse from B.A. to Ph.D.

• The pre-Ph.D. trainees supported by NIH in the biosciences between 1956 and 1965 had a Ph.D. attainment rate of 66% compared to 73% for the NSF trainees, 63% for the NDEA trainees, and 42% for the non-supported group during the same period. NIH pre-Ph.D. fellows had an attainment rate of 91% in the biosciences compared to 89% for the NSF fellows and 69% for the Woodrow Wilson fellows.

• The attainment of the Ph.D. or M.D. degree is almost always a requirement for a research career in the biosciences. A commitment to research, as manifested in the willingness to undertake a long period of training, even beyond the Ph.D. in some cases, is also a characteristic exhibited by many bioscientists. The data in this study show that the more education and training scientists have received, the more likely they are to be engaged primarily in research activities, to be employed by a university or professional school, and to have higher research productivity as measured by the number of publications and citations in the world's scientific literature. These observations seem to result from the interaction that takes place between the commitment to research and the training received, the one perhaps complementing the other. The association between the level of education and training on the one hand and the level of research activity on the other is a consistent one which holds for M.D.'s as well as Ph.D.'s, and persists throughout most stages of a career.

• In general, the M.D.'s who have received NIH support do not list research as a primary work activity as often as the NIH-supported Ph.D.'s, but the M.D.'s tend to remain in research longer whereas the Ph.D.'s tend to move more frequently into other activities, principally teaching and administration.

• A little more than 70% of former NIH post-Ph.D.'s whose employment status was known listed research as their primary work activity during 1968-70. Another 24% of this group listed teaching as the primary activity. This compares with non-NIH postdoctorals who were split 45% into research and 46% into teaching, and with Ph.D.'s without postdoctoral support, of whom 41% were primarily in research and 36% were primarily in teaching.

• For M.D.'s attainment of the Ph.D. degree is also an important factor in career outcomes. Only 20% of the M.D.'s with NIH post-M.D. support but no Ph.D. were engaged primarily in research in 1968-70, whereas almost 50% of those with NIH post-M.D. support and the Ph.D. were so engaged.

• Over all years of experience and at almost all degree levels, research and teaching were less highly paid in 1970 than the alternative work activities of management, administration, or professional services to individuals. M.D.'s whose primary activity was research were paid about 29% more than Ph.D.'s in research and about 62% more in teaching. However the total income differential between M.D.'s and Ph.D.'s is probably greater than this because M.D.'s have more opportunity than Ph.D.'s to supplement their salaries with income from private practice.

• Scientists who worked for educational institutions in 1970 were paid considerably less than those who worked in private industry or government or were self-employed.

C. RELATING MANPOWER FLOWS IN GRADUATE EDUCATION TO ECONOMIC AND DEMOGRAPHIC FACTORS

The relationship between the training programs and the careers of bioscientists was investigated by means of two basically different methodologies. The first could be called a "micro" approach in which groups of individuals were studied and summarized with respect to their career outcomes. The results discussed above emanated from this procedure. The second approach was a "macro" technique where aggregate data on enrollments, degrees, population, federal funds for training and research, salaries, and other economic variables were studied in relation to one another for the 1956-70 period. Out of this analysis came the conclusion that while population and economic growth can account for much of the increase in enrollments and degrees that has occurred in higher education, federal funds for traineeships and fellowships have had a highly significant positive influence on the number of graduate students in relation to the number of baccalaureates and on their distribution by field.

The proportion of total graduate enrollments that goes to the biosciences or the physical sciences tends to follow the pattern set by federal funds for training grants and fellowships in those fields in preceding years. The proportion of Ph.D.'s produced in these fields also seems to react strongly to the behavior of federal student-aid programs. The market mechanism as reflected in salary differentials seems to have its greatest impact at the B.A. level. At the graduate level, the physical sciences were found to be more affected than the biosciences by salary differentials, a result which stems perhaps from the close relationship between careers in bioscience and medicine. Federal funds for research also tend to build up the pool of students in graduate education in the biological and physical sciences. The pull of the market is reflected in medical school enrollments which tend to draw down the pool of graduate students in the biological and physical sciences.

These results have been collected into a set of mathematical relationships which in effect constitute an empirically developed model of the behavior of graduate enrollments and Ph.D. production.

2. MECHANISMS OF SUPPORT AND THEIR RELATIONSHIP TO INDIVIDUALS SUPPORTED AND TO THE TRAINING INSTITUTIONS

It should be noted at the outset that certain important questions cannot be answered on the basis of the information that was gathered in the present study. These questions include the following:

1. What is the appropriate level for funding the training of bioscientists by the federal government?
2. Is there some optimal mixture of forms of support? What is that mixture?
3. What is the net societal benefit to be derived from one or another form of support in relation to the field of inquiry chosen for support?
4. From the student's point of view, which of the possible support mechanisms lead to the most efficient and effective training?
5. What is the optimum allocation of federal funds for research and training among the various disciplines?

Questions such as these, and ones on related topics, are generally outside the scope of this inquiry.

On the other hand, the present study has revealed clearly certain significant consequences of the patterns of federal funding for various support mechanisms in the period covered by the present study. These were summarized in Chapter 1 and are presented in more detail in Chapters 4 and 5. Basically, the limited evidence—some of it anecdotal, but much of it statistical—shows that federal traineeship and fellowship programs have been important factors in attracting students to graduate study in a field and in facilitating the attainment of the Ph.D. It was the opinion of bioscience educators who were interviewed in the course of the Committee's investigation that training grants and fellowships, more the former than the latter, had proven to be quite useful mechanisms for meeting the training objectives for producing well-trained bioscientists. The statistical evidence seems to support that belief, but it is not possible to provide definitive "proof."

A. MECHANISMS OF SUPPORT

There are five main sources of financial support for individuals for graduate research education: fellowships, training grants, research grants, university teaching assistantships, and private means. The current system is pluralistic, since it includes both private and federal support, and commonly embraces more than one source of support. Although the mixture of support sources is more complicated administratively than a single source might be, it has resulted in increased flexibility for the responsible institutions and departments.

1. Fellowships

NIH predoctoral fellowships were made directly to the individual who had already been accepted for graduate training by a university department and who had succeeded in a national competition. Postdoctoral research fellowships are available to either Ph.D.'s or the holders of professional doctorate degrees, such as M.D.'s, for advanced research training.

The national fellowship program[1]—as contrasted with locally administered support programs—allows a more uniform set of standards to be used in the selection of research fellows, and the research fellow has more freedom in selecting his site of training.

On the other hand, there are a number of disadvantages of the national research fellowship. These include a propensity for the fellows to concentrate at only a few schools, and a lack of financial support for the departments in which the fellow is trained. Thus, there is little or no contribution to enriching the scientific milieu of the department. Another disadvantage is the long lead time, generally 9 to 12 months, needed from the time a fellowship application is made until it can be used. The administration of a national fellowship program, involving the evaluation of thousands of individual applications, is no small chore, and its costs must be considered in comparing support mechanisms.

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[1]In addition to this type of national fellowship, there have in the past been fellowship programs such as the NDEA predoctoral fellowships, which were authorized for individual university departments with the selection of the fellows being made locally by the departments.

2. Training Grants

Training grants are awards to one or more departments of a university, medical school, or research institution, to strengthen an existing program for training predoctoral and/or postdoctoral trainees in a specified discipline or specialty. The awards are usually made for five years after external peer review in national competition, and contain funds, in an approximately equal ratio, both for trainee stipends and tuition, and for support of the academic environment (faculty salaries, equipment, supplies, etc.) in the department in which the training takes place. Under training grants, trainees are selected and appointed by the institutional unit receiving the grant, not by some national body.

A most important advantage of the training grant is that the trainee is not tied so closely to a single laboratory or professor, particularly early in his research training, as is the research fellow. Some believe the trainee thus receives a broader education. Also, the training grant allows funds for improvement of the departmental milieu for research. The fact that a new graduate student could be appointed as a trainee during his first year or two of graduate study, and then later be supported by other mechanisms, is considered by some to be an advantage.

3. Research Grants

Some predoctoral and most postdoctoral students receive stipend support from grant (or contract) funds based upon their contribution to the research program as a research assistant. This type of support is limited to those advanced predoctoral students or postdoctoral students who have already become committed to a specific type of training, judged by peer review to be of importance. For them, it provides means of concentrating on their research project. The disadvantages would include the possibility of conflicting responsibilities for education and research. Competence in research by an individual scientist or a department is not necessarily accompanied in equal measure by competence or interest in training.

4. Teaching Assistantships

Predoctoral and postdoctoral trainees may be supported by their institutions as teaching assistants because of their contributions to teaching programs. These teaching assignments are usually at the undergraduate level and restricted to institutions and departments with large undergraduate teaching responsibilities.

In this approach there is no direct cost to the federal government. The direct involvement of the trainee in teaching is also important in the educational process. The disadvantages for research training include a longer time to obtain the degree or complete the research and the fact that most medical schools have little or no funds for teaching assistantships.

5. Private Means

Many students support their training, particularly at the predoctoral level, through private resources which include family aid, private loans, part-time work, or support by a working spouse.

Many persons believe the use of private funds is quite proper, providing economy for the federal government and placing the costs where the benefits are assumed to accrue. Some disadvantages inherent in such a policy are:

1. the personal financial barrier to the training of potential scientists would diminish equality of access to scientific training based on merit alone
2. an extension of the time period necessary for completion of the Ph.D. degree.

In regard to private support, the Association of American Medical Colleges (AAMC) conducted a survey of graduate and postdoctoral fellows and trainees who were completing their training in June 1970. They attempted to assess the number of prospective trainees who might decide not to pursue research training if there were a change from stipends to loans. About 62% of the 4,000 respondents answered "No" to the question: "If no stipend had been available to support your training, but a long-term, low-interest loan had been available, would you have been able to continue your plans for training?" About half of the respondents stated that they were already in debt, some in excess of $15,000. The percentage of negatives was not particularly different when correlated with the size of the debt, the number of dependents, or the trainee's age. On the other hand, a survey of graduate students conducted by the NSF in 1973[2] found that more than 20% of the full-time graduate students in the life sciences reported that loans and other personal resources were their major source of support. Federal support was the major source for 32% of the respondents and institutional and miscellaneous sources accounted for the remaining 48%.

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[2]Graduate Science Education: Student Support and Postdoctorals, Fall 1973, National Science Foundation, Washington, D. C., 1974.

B. SUMMARY OF THE COMMITTEE'S SITE VISITS AND INTERVIEWS

The pursuit of information on the impact of training programs led the Committee into extensive discussions of these alternative mechanisms of support, both within the Committee and between the Committee and members of the bioscience community. By means of site visits and interviews, the Committee solicited the views of people who had given much thought to these issues. The information gathered is anecdotal, but it is relevant to the pros and cons.

Between June 27, 1973, and June 12, 1974, members and staff of the Committee engaged in site visits, either in person or by telephone conference calls. Eight institutions were chosen for the visits, representing various regions of the country and varying degrees of training-grant support, including some which had recently lost such support and one which had never received any training grants from the federal government. The eight institutions were: University of Chicago, University of Washington, University of California at San Francisco, Stanford University, University of Oregon, University of Pittsburgh, Jefferson Medical College, and the Milton S. Hershey Medical College of the State University of Pennsylvania. The federal training grant support currently in effect at these institutions ranges from $8 million annually (University of Washington) to zero (Hershey). One of the institutions reported a 33% decrease in training grant funds during the past year (Jefferson) while others reported losses of lesser degree but nonetheless of considerable impact.

Some 77 faculty and administrators from the eight institutions took part in these discussions. All were helpful in explaining their programs, answering questions, and discussing their budgets, plans, ideas, and hopes with respect to the impact of training grants on the development of individuals and institutions and their relevance to the ultimate delivery of health care. Faculty at all of the institutions agreed that there are certain attributes required for the operation of a worthwhile graduate training program in the biosciences. These are:

1. the ability to engage in reasonably long-range planning (five-six years) with respect to faculty, students, and programs;
2. opportunities for interdepartmental interactions in terms of research projects, seminars, etc.;
3. the necessity for a critical mass of students in the research programs.

All asserted that the means to these ends lies in sufficient money to provide: assurance of funding over a reasonable time-span so that program development and continual recruitment of faculty and students can proceed; latitude in research programs to include interaction of individuals from several departments whose expertise can be conjoined to address the complex research questions posed in such areas as genetics, neurobiology, immunology, etc.; and sufficient personnel—students and faculty—so that research productivity is enhanced and momentum is generated and maintained. Except for Hershey, which from its inception has had agreements for special funding from the state, all institutions have relied on training grants to provide a significant portion of the support necessary for meeting these objectives. In some cases, e.g., Chicago and Washington, training grant monies have been used not only to expand existing programs, but also to add new ones, especially those of an interdisciplinary nature or those which simply did not exist before extramural funding provided the original impetus, e.g., academic anesthesiology, therapeutic radiology. In other institutions, the presence of training grants has enabled the upgrading of existing programs to the critical mass level; before this time they were barely viable.

All institutions which had had training grants asserted that their programs were being eroded by diminishing funding from this source, albeit in different ways. For some it will mean fewer students and constricted programs, both of which will diminish what could have been accomplished under more favorable circumstances. For others it will mean the actual demise of graduate training in certain departments or programs.

A number of respondents believe that without funds for graduate students, many highly qualified undergraduates are turning to careers in medicine, which are perceived to offer a larger financial return during their professional life spans. This notion seems to be substantiated by reports by those who still offer full support (tuition and stipend) to graduate students: competition for places in their programs is as great as that for their medical school, 40:1 (Hershey). Some respondents expressed the view that perhaps too many mediocre scientists had been trained during the 1950's and 1960's when more money was readily available. Yet none would subscribe to the proposition that only the proven and "best" institutions should be funded. Rather they preferred to believe that programs everywhere have the potential to improve given the proper leadership by talented scientists. Still others feel this may be a rather naive and narrow view considering the political and economic complexity of many institutions.

That the graduate training period for a bioscientist can be expected to extend four to eight years provides the basis for the belief by the faculty that they see a need to be able to plan ahead if they would maintain any momentum. Research itself requires this, and the incorporation of students into a research program enhances the necessity for careful long-range planning. When funding is uncertain or hand-to-mouth, some directions of inquiry are of necessity not pursued and interdisciplinary arrangements not attempted. One perceived result, according to some respondents, is a severe limitation to productivity occurring not only because of restrictions to programs but also because this implies a smaller total number of students interacting with each other. The opinion suggests that productivity, at least in the biosciences, is not made manifest in relative isolation but requires the active interchange of ideas and exposure to technologies for the operation of this regenerative process.

Finally, those interviewed seemed to be highly aware of the relationship of their research and training activities to the health-care needs of the wider society. There was little evidence of an "ivory tower." Respondents provided examples of basic research, often combined with technological development, which had resulted in advances in health care. They pointed out the fallacy inherent in simply attempting to produce more medical doctors without also increasing their armamentarium of knowledge, drugs, instruments, and understanding. And a bit wryly some observed that the general population is wont to forget, once a disease is conquered, the dramatic effects that research can have on health care delivery.

3. CHARACTERISTICS OF THE NIH TRAINING PROGRAMS

In this chapter we shall examine some of the significant characteristics of the two primary instruments of NIH training support—the research fellowship and the training grant programs. The fellowship is the older of the two instruments. The legislative authorization for it first occurred in the Ransdell Act of 1930, which created the NIH and established the federal responsibility to conduct and foster biomedical research; and in the National Cancer Act of 1937, which authorized the Surgeon General to establish and maintain research fellowships providing stipends and allowances to individuals specifically for the study of cancer. In succeeding years, Congress has established other Institutes of the NIH and provided them also with broad training authorities in other fields.[1]

The research fellowship program originally supported both predoctoral and postdocotral training. The predocotral program was phased out in 1970 following a reassessment of the program which indicated that predoctoral training could best be accomplished by the training grant mechanism. The fellowship program provided standard stipends determined by the fellow's level of training, and allowances for dependents, tuition, and supplies.

[1]See p. 23 for a list of the Institutes covered in this report and the years they were established.

The training grant evolved from the fellowship concept as the need for a more powerful and versatile instrument was recognized. Training grants are awarded competitively to institutions in support of particular training programs that have been designed and proposed for specific purposes. The training institution selects the trainees and supports them out of the training grant funds. Funds are also available for partial support of faculty, supplies, and other training elements. In this way the institution retains a great deal of freedom in determining how the funds are to be used. At the same time it assumes responsibility for providing a high quality training program.

A. DATA SOURCES

The Central Data Collection System of the NIH maintains the administrative records of the trainees and fellows on a fiscal-year basis. It was not designed to accumulate the records for an individual trainee. Hence, prior to this study, it has been very difficult to estimate the number and characteristics of the people who have been supported by the NIH training programs, because many of them are supported over a period of several years and the composite record of these appointments had not been prepared. Furthermore, prior to 1961, the data were not automated, and from 1961 to 1965, only a punched card system was used.

One of the earliest and most difficult tasks of this study was to establish a unified file of all individuals who have ever participated in the training programs of the NIH. This file, which is called the NIH Roster of Trainees and Fellows, provided the basis for the Committee's follow-up study and is now available to NIH as an administrative tool— a longitudinal file of all the people it has supported. The file was developed by collecting all the records pertaining to individual trainees or fellows from the NIH Central Data Collection System, augmenting these with data supplied by the individual Institutes of the NIH, and summarizing this information for each individual. An attempt was made in this study to collect complete data for the major training grant and fellowship programs of the research Institutes of the NIH for all years in which they operated. The fellowship programs included here are the predoctoral, postdoctoral, special, fellowship-traineeship and direct traineeship programs. Specifically excluded are the Research Career Program Awards which are considered to be for research rather than for training. Since some of the records were as much as 35 years old, there undoubtedly are omissions and errors in the file. Although these may affect individual records and reduce the statistical validity for groups in which there are few cases, it is believed that overall the file is sufficiently accurate to present a reliable historical summary of the training programs.

Data presented in the present report cover the period from 1938 through fiscal year 1971 for training grants and fiscal year 1972 for fellowships.[2] The information collected from the trainees and fellows by the NIH has varied somewhat over the years, but generally consists of biographic data about the trainee and other data describing the terms of the award such as entry and termination dates, stipends and allowances, field of training, funding Institute, etc.

The result of all this is that it is now possible to determine the total number of people supported by the NIH training funds, in what fields, by what Institutes, for how long, and at what academic levels.

1. Questions to Be Answered

The training programs can be examined from many different viewpoints, depending on what it is that we wish to learn from the data. Some questions will be centered on the field of training; others might be concerned more with the academic level of the trainee. So we must try to establish a fairly general scheme of presentation which will satisfy a broad range of inquiry.

The taxonomy of the training programs is such that an individual who participated in them can be classified according to five major descriptive categories as follows:

1. academic level of the trainee
2. type of program (training grant or fellowship)
3. field of training
4. training status (full-time or part-time)
5. NIH Institute sponsoring the training

Of course there are other categories that could be added to the list, such as the training institutions, but the ones listed above seem to define the major dimensions of the programs for purposes of this study.

The dynamic aspects must also be considered, both from the viewpoint of the individual and from that of the programs as a whole. The classification of an individual within any of the five major categories described above can and frequently does change during the course of his training. This poses the problem of how to classify a trainee for de-

[2] Training grants are forward-financed but fellowships are not. This means that trainees on duty in FY 1972 were supported out of funds appropriated in FY 1971. Thus the cut-off point for this report is essentially all trainees and fellows on duty through FY 1972.

scriptive purposes. A convention adopted in parts of this report is to classify trainees according to their characteristics at the first training grant or fellowship award. This method avoids the problem of counting an individual more than once, and therefore is used when it is desired to present overall summaries of the programs. At other times, it is more convenient to consider all individuals within a category whether at first award or not—for example, when describing the length of support for all postdoctoral trainees. The context will clarify which particular classification scheme is being used.

The NIH training programs have undergone a significant evolutionary process since their inception in 1938. This study, which is the first full-scale follow-up of all former trainees and fellows, presents an opportunity to examine the changes that have occurred, at least in terms of the individual appointees. Wherever possible, the analysis will try to incorporate the time element as an additional dimension in order to display these dynamic aspects.

The main purpose of this chapter is to provide an overview of the NIH training programs by describing the kinds of people who participated and the nature of their training. The measurable quantities that can be used for this purpose are as follows:

1. number of people participating
2. length of supported period of training
3. dollar amount of support
4. time lapse from degree to first training award

In the following sections, each of these quantities will be discussed within the taxonomic framework established for this analysis. The discussions will focus on what appear to be the most significant findings—other, more detailed tables are presented in Appendix A.[3]

[3] In considering the data presented in this chapter, it should be noted that the statistics are derived from the complete population of trainees rather than from any random sampling procedure. Under this assumption no confidence intervals or tests of significance are necessary since the observed values are population parameters, not sample estimates. However, the size of group from which the statistic is derived is still relevant to judging its stability in the future. In most cases, the results are based on large numbers, but where this is not the case, it will be noted in the text.

B. THE NUMBER OF PEOPLE PARTICIPATING

Through 1972, almost 94,000 people participated in the research training programs since they began in 1938. By far the major portion of the training has occurred in the last decade, with 85% of the trainees starting their training since 1961. Figures 1 and 2 illustrate the size of the training programs from several different viewpoints.

1. Institute Characteristics

When comparing the Institutes of the NIH, it must be remembered that each one has its own objectives, emphasis, and time frame for its operation. The Institutes have been established by legislation at various times since the National Cancer Institute was established in 1937. The age of each Institute, along with its objectives and fields of interest, will of course play a large part in determining the number and types of people it has supported.

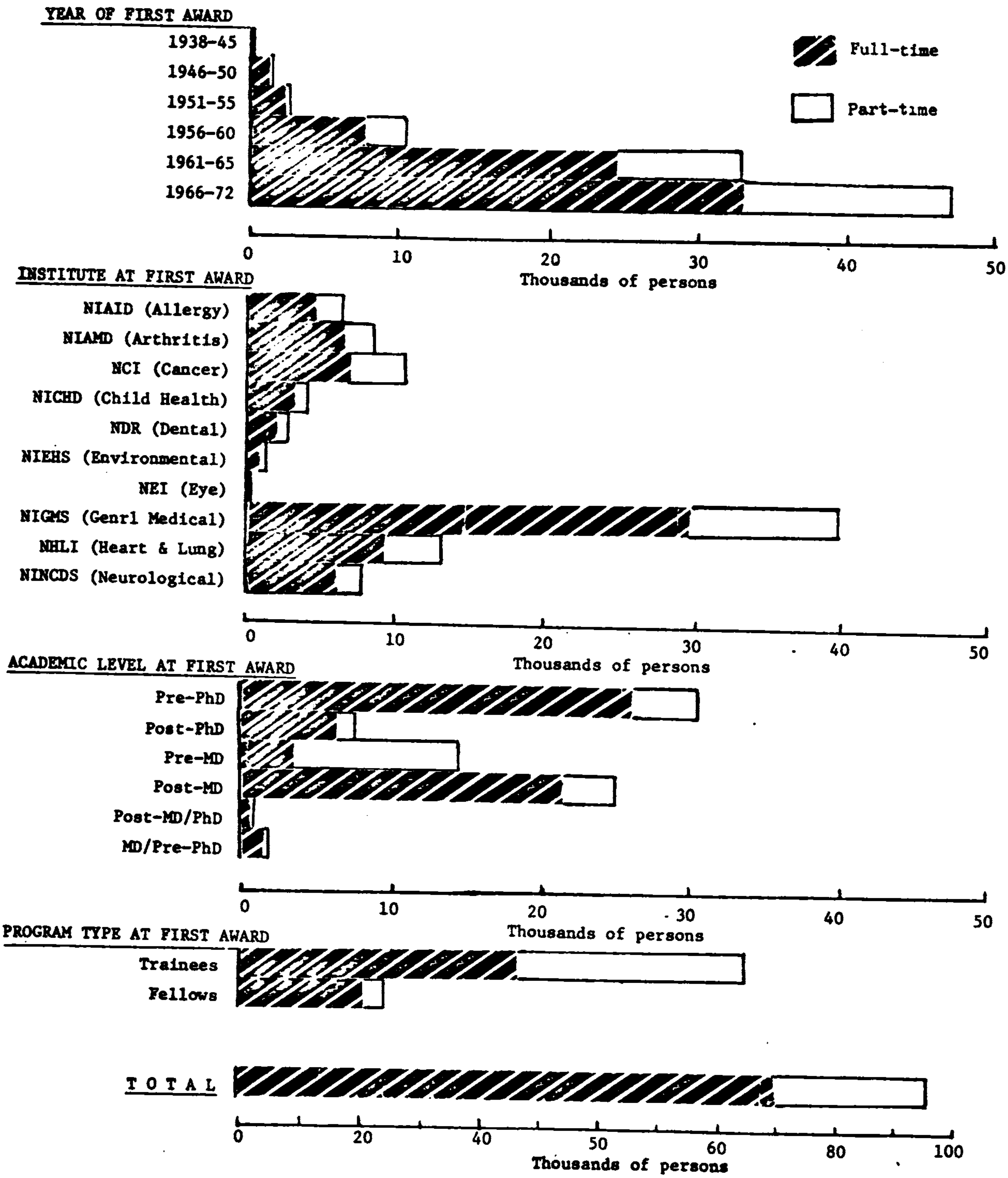
The Institutes covered in this report are as follows:

		Year Established
NCI	National Cancer Institute	1937
NIAMDD	National Institute of Arthritis, Metabolism, and Digestive Diseases	1947
NIAID	National Institute of Allergy and Infectious Diseases	1948
NIDR	National Institute of Dental Research	1948
NHLI	National Heart and Lung Institute	1948
NINCDS	National Institute of Neurological and Communicative Disorders and Stroke	1950
NICHD	National Institute of Child Health and Human Development	1963
NIGMS	National Institute of General Medical Sciences	1963
NEI	National Eye Institute	1968
NIEHS	National Institute of Environmental Health Science	1969

The programs of the National Institute of Mental Health (NIMH) are excluded for all years, as is the National Institute of Aging which was established in 1974.

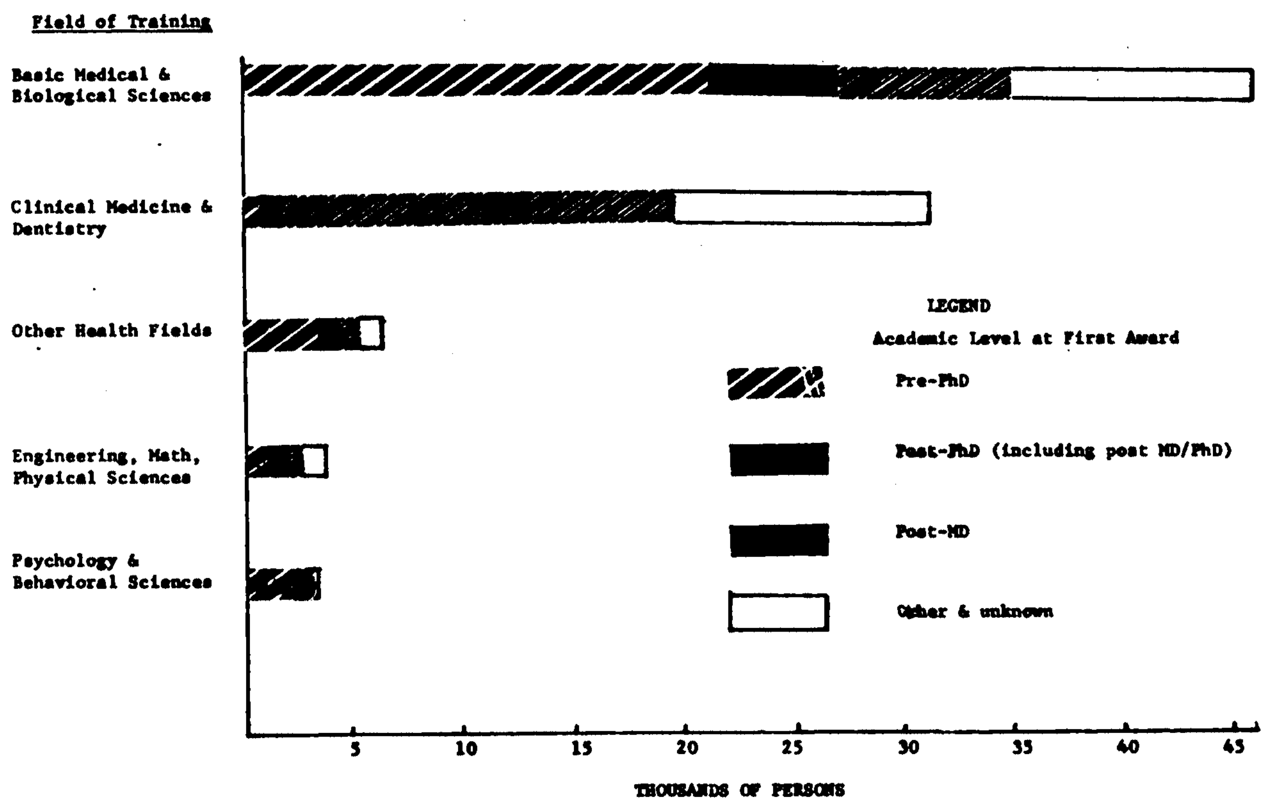
NIGMS has been the largest supporter of research training, having initiated the training of 39,411 persons, or 42% of the total. Most of these (65%) have been in the basic biosciences with special emphasis on biochemistry.

Figure 1 - NUMBER OF PERSONS SUPPORTED BY NIH IN VARIOUS CATEGORIES



Source: NIH Roster of Trainees and Fellows, 1938-72, Summary File B, Commission on Human Resources, NAS/NRC, Washington, D. C., June 5, 1976.

Figure 2 - NUMBER OF PERSONS SUPPORTED BY NIH BY FIELD OF TRAINING AND ACADEMIC LEVEL AT FIRST AWARD



Source: NIH Roster of Trainees and Fellows, 1938-72, Commission on Human Resources, NAS/NRC, Washington, D. C.

NIAMDD has supported most of the research training in the clinical specialties and 87% of these clinical trainees have received research training in internal medicine.

The Cancer Institute (NCI) was the first Institute to sponsor research training, but has supported only about 11% of all trainees. The NCI training programs have been fairly evenly divided between the basic biomedical sciences (41%) and the clinical sciences (36%), in the latter of which the emphasis has been on radiology. The remaining 23% has been distributed over the physical sciences, engineering, and miscellaneous health fields.

The NHLI has been the second largest Institute in terms of the number of people trained, and their programs have also been almost equally divided between the basic biomedical and clinical sciences. In the basic biosciences, the emphasis has been on physiology, while the clinical scientists have specialized in internal medicine and surgery research training.

2. Specialty Field Characteristics

The NIH training programs have covered a wide range of scientific disciplines (see Appendix Table A2 for a list of the broad fields). The basic biomedical sciences account for about one-half of all training fields, the clinical sciences account for about one-third, and the remaining one-sixth is accounted for by other health-related fields, bioengineering, mathematics, physical science, and psychology. The single largest field is internal medicine; 12% of all trainees began their training in this field. "Clinical Medicine-other" is a broad field in which a large number (8%) of trainees are found. It includes such categories as multidisciplinary training and cancer chemotherapy. The basic bioscience fields of biochemistry, microbiology and physiology are the next largest with 8%, 7% and 6%, respectively, of all trainees receiving their first awards in these fields.

3. Characteristics of Training Status (Full-time or Part-time)

For purposes of this study the trainees have been classified as full-time if they participated for at least eight consecutive months at one academic level (pre- Ph.D., post-Ph.D., etc.), and part-time otherwise. Full-time training thus defined is roughly equivalent to one academic year. Part-time training included summer appointments, special purpose appointments, or the category of people who did not complete their training.

Almost three-fourths of the trainees were full-time, with the basic bioscience trainees having a higher full-time rate (78%) than the clinical science trainees (63%). The category of training defined as "Clinical Medicine-Other" has a very low rate of full-time participation (23%) due to the fact that over 80% of the people who were trained in this field were pre-M.D.'s whose training occurred mostly during summer appointments.

4. Academic Level Characteristics

One of the most important dimensions of the training programs is the academic level at which the training occurred, since the goals of the programs and the trainees vary according to the educational stage of the training. Basically, the programs have supported both predoctoral students working for doctorate degrees, and postdoctorals. For postdoctorals the doctorate could be either a research or professional degree. The research doctorate is defined as the Ph. D. or equivalent; the professional doctorate is an M.D., D.D.S., D.V.M. (Doctor of Veterinary Medicine), or the equivalent. (To simplify the exposition, in this report all research doctorates will be designated as Ph. D.'s, and all professional doctorates will be designated as M.D.'s.) The academic levels are defined as follows:

<u>Predoctoral</u> (pre-Ph.D.) - Individuals who do not hold a doctorate (either research or professional) and who are seeking a research doctorate

<u>Postdoctoral</u>:

a. <u>Post-Ph.D.</u> - Individuals who hold a research doctorate or the equivalent

b. <u>Post-M.D.</u> - Individuals whose highest degree is a professional doctorate, and who did not indicate that they were seeking a research doctorate

c. <u>Post-M.D./Ph.D.</u> - Individuals who hold both research and professional doctorates and are seeking additional research training

d. <u>Post-M.D./pre-Ph.D.</u> - Professional doctorates who indicated they were seeking a research doctorate

Table 1 - DISTRIBUTION OF TRAINEES AND FELLOWS BY ACADEMIC LEVEL AND PROGRAM TYPE AT FIRST AWARD, 1938-72

Program Type at First Award

Academic Level at First Award	Trainees			Fellows			Total[a]		
	No.	% of Row Total	% of Col. Total	No.	% of Row Total	% of Col. Total	No.	% of Row Total	% of Col. Total
Pre-PhD	27624	36.3	89.9	3075	17.5	10.0	30714	32.8	100.0
Post-PhD	3772	5.0	52.0	3480	19.8	48.0	7252	7.7	100.0
Pre-MD	14426	19.0	99.9	3	---	0.1	14437	15.4	100.0
Post-MD	21000	27.6	84.1	3965	22.5	15.9	24980	26.6	100.0
Post-MD/PhD	465	0.6	71.0	189	1.1	28.9	655	0.7	100.0
Post-MD/Pre-PhD	1314	1.7	83.0	270	1.5	17.0	1584	1.7	100.0
Other	5073	6.7	95.7	228	1.3	4.3	5301	5.7	100.0
Unknown	2382	3.1	27.0	6408	36.4	72.7	8814	9.4	100.0
Total	76056	100.0	81.1	17618	100.0	18.8	93737	100.0	100.0

Source: NIH Roster of Trainees and Fellows, 1938-72, Summary File B, Commission on Human Resources, NAS/NRC, Washington, D.C., August 5, 1975. (See Appendix A for more detailed tables.)

[a]Total figures included 63 individuals with unknown program type.

Pre-professional doctorates (pre-M.D.) - Individuals whose highest degree is less than a doctorate and who are seeking a professional doctorate and are taking time out for research training

Other - Individuals without a doctorate degree who indicated they were not seeking any degree or who were seeking a baccalaureate or nursing degree

Table 1 shows how the trainees and fellows were distributed by academic level at first award.

Many trainees receive their first support as pre-Ph.D.'s and continue their training as post-Ph.D.'s after they receive their degree. But unless this pattern is clearly pointed out, the data in Table 1 may be misinterpreted. It is shown there that over 30,000 trainees started as pre-Ph.D.'s and less than 8,000 started as post-Ph. D.'s. But about 13% of these pre-Ph.D.'s had a subsequent post-Ph.D. appointment. Overall, about 13,000 trainees had a post-Ph.D. appointment at some time during their training period.

As pointed out earlier, up to 1948, fellowships for either Ph.D.'s or M.D.'s were the only mechanisms used for support. But in 1948 the first training grants were awarded to a few professional schools for the purpose of strengthening their teaching capabilities. Under these initial grants, the funds could be used for equipment and support of faculty, but not for stipends to trainees. Later, in 1950, funds for stipends were included and the training grants also became a mechanism for supporting trainees. The training grant proved to be a very popular form of support because of the flexibility it offered to the training institutions in the allocation of funds.

Under the training grant mechanism, the support of pre-Ph.D.'s grew rapidly as shown below (Table 2). In time, the predoctorals had become a significant component of the training programs.

Table 2 - GROWTH OF PRE-PH.D. TRAINING

Period	Pre-Ph.D.'s as Percentage of all Trainees and Fellows
1956-60	10
1961-65	33
1966-72	40

A special part-time fellowship program for medical and dental students was initiated in 1954 for the purpose of stimulating "student interest in research, to permit early identification of research talent and to provide selected individuals with a research experience as a supplement to their formal education. In 1957 another program of fellowships was established, permitting medical and dental students to spend a year in research between their pre-clinical and clinical years."[4] These programs were small ones: only three individuals could be identified in the file as having received their first award as a pre-M.D. fellow (See Appendix Table A1).

A large number of pre-M.D.'s were supported on training grants. Most of these were part-time trainees who received their training during the summer between semesters. A smaller group were classified in this study as full-time pre-M.D.'s although they were not strictly medical students at the time they were supported on the training grant. Some dropped out of medical school for a year to receive research training. Others received support under the medical-scientist training program of NIGMS which was specifically designed to provide research training for professional school students whose career goals were to be scientists rather than practitioners. The training received under this program was equivalent to a combined M.D./Ph.D. program.

Overall, of those receiving full-time training, 47% have been non-M.D.'s, 40% have been M.D.'s, and 13% unknown. For part-time trainees, it is the other way around: 58% have been M.D.'s or pre-M.D.'s, 21% non-M. D.'s, and 21% unknown.

5. Proportion of Total Graduate Enrollments Supported by NIH

The proportion of total graduate enrollments supported by the NIH rose quickly to a peak in 1964 and has tended to decrease since that time. As shown in Figure 3, this trend is especially noticeable in the biological sciences where the approximate proportion supported by NIH was the largest (28%) of all fields. In 1960, NIH provided support to 640 pre-Ph. D.'s out of 13,060 graduate students enrolled in the biosciences (5%); in 1971 it was 6,058 out of 36,499 (17%).

In the health professions, the peak proportion (16%) was reached in 1967, some three years later than in the biological sciences, and this field also exhibits a declining proportion in the last few years.

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[4] <u>NIH Training Programs Now and in the Next Decade</u>, Office of the Associate Director for Extramural Research and Training, NIH, Bethesda, Maryland, 1970, p. 3.

As a proportion of total graduate enrollments in all science fields, the NIH-supported group has never been above 4%.

It should be noted that the comparison between the NIH-supported people and total graduate enrollments is complicated by the fact that the field definitions used by the Office of Education, which tabulates the total enrollment data, do not exactly coincide with those used by NIH.[5] Also practically all the NIH-supported pre-Ph.D. trainees are Ph.D. candidates, whereas many graduate students are not. Of course, those who are not Ph.D. candidates are not in the "pipeline" as long as those who are. It is difficult to tell to what extent and in what direction these factors influence the comparison, but their presence does have some bearing on the interpretation of the numbers.

6. Proportion of Ph.D.'s with Pre-Ph.D. or M.D./Pre-Ph. D. Support from the NIH

A logical sequel to the discussion in the previous section is a presentation of data on the proportion of doctorate recipients each year who had received pre-Ph.D. or M.D./pre-Ph.D. support from the NIH. As Figure 4 shows, these proportions are larger than the corresponding proportions in Figure 3 and they follow a similar pattern with a lag of perhaps two to four years. This implies that either the selection process has worked well, or that pre-Ph.D. support has a catalytic effect on Ph. D. attainment, or both—propositions which will be explored further in the next chapter.

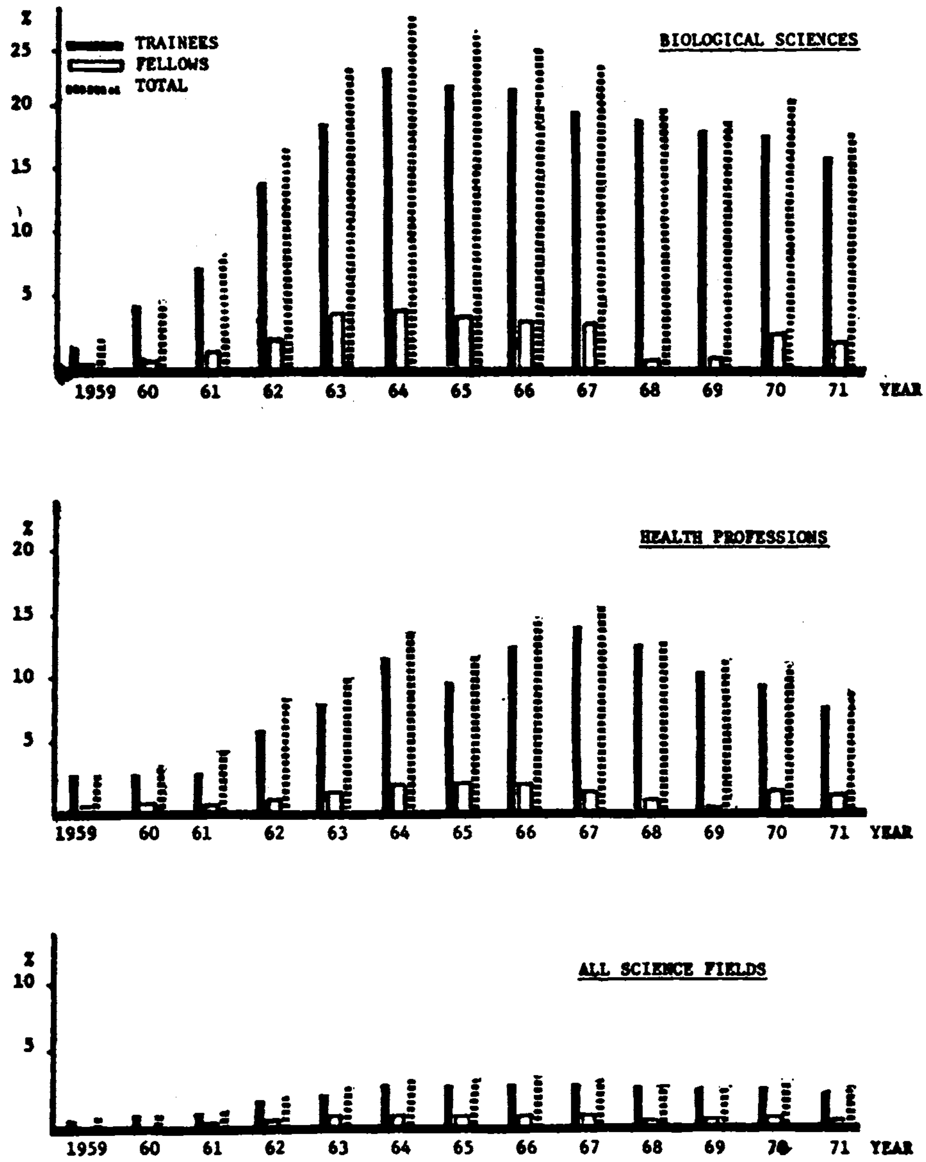
C. LENGTH OF TRAINING SUPPORT

The typical trainee has been supported for about two years, but the distribution of length of support is not at all symmetrical around this average value; it is highly skewed to the right. Some people have been supported in research training for more than five years, although these are exceptional and infrequent cases.

The length of support depends on the academic level of the trainee. Those trainees who were seeking a Ph. D. received more support than others

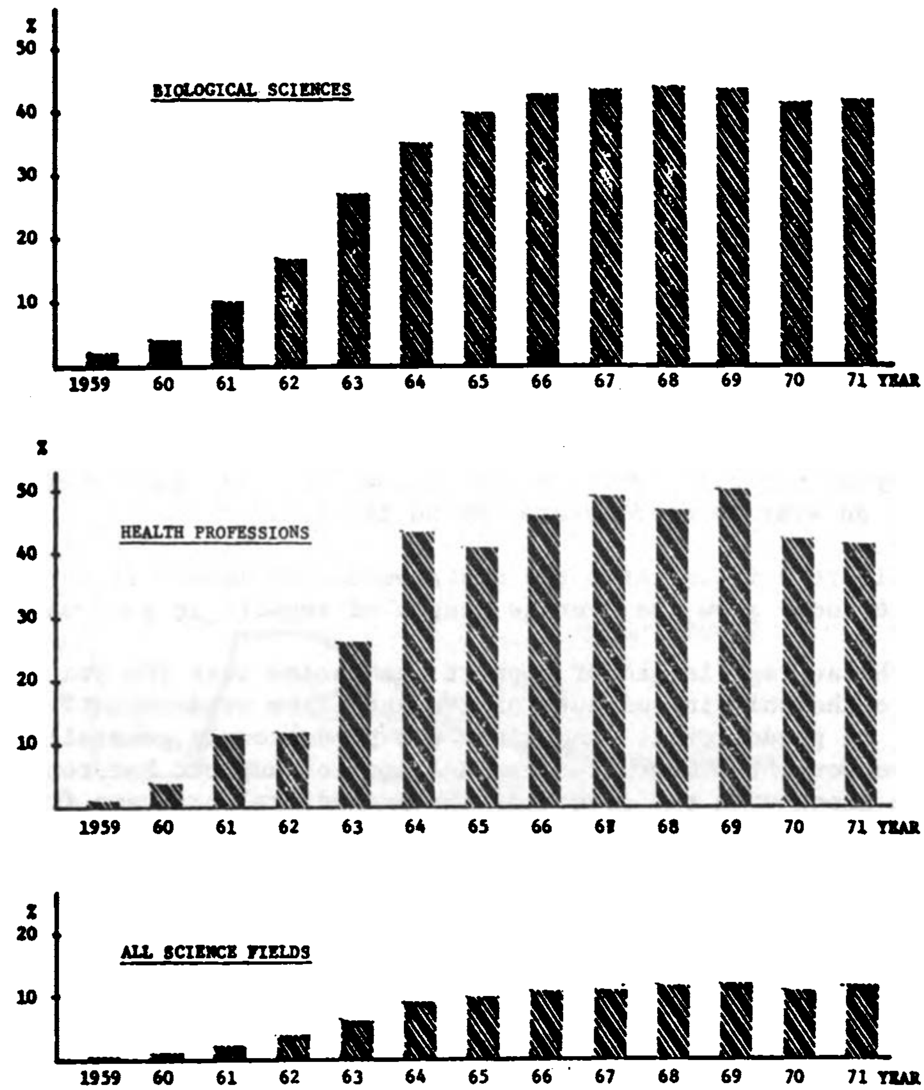
[5]The biological sciences as defined by the Office of Education include the following fields: anatomy and histology, bacteriology (virology, mycology, parasitology, microbiology), biochemistry, biology, biophysics, botany, cytology, ecology, embryology, entomology, genetics, molecular biology, nutrition, pathology, pharmacology, physiology, zoology, and other biosciences. The basic biological sciences as defined by the NIH are shown in Appendix Table A2.

Figure 3 - PROPORTION OF TOTAL GRADUATE ENROLLMENTS SUPPORTED BY NIH TRAINEESHIPS OR FELLOWSHIPS (PRE-PhD's AND MD's SEEKING PhD's)



Sources: NIH Roster of Trainees and Fellows, 1938-72, Commission on Human Resources, NAS/NRC.
Students Enrolled for Advanced Degrees, Office of Education, U. S. Department of Health, Education and Welfare, Washington, D. C., annual editions since 1959.

Figure 4 - PROPORTION OF PHD RECIPIENTS EACH YEAR WHO HAD PRE-PHD OR MD/PRE-PHD SUPPORT FROM NIH



Sources: NIH Roster of Trainees and Fellows, 1938-72, Doctorate Records File, 1935-72, Commission on Human Resources, NAS/NRC, Washington, D. C.

(than post-Ph.D.'s for example) simply because it takes longer to achieve this goal. Full-time pre-Ph.D.'s were supported for the longest period (26 months on the average), closely followed by M.D.'s seeking Ph. D.'s who received an average of 24 months of support. But since the average for all students is about 7 years from B.A. to Ph. D. in the biosciences, the NIH-supported period represents just about 30% of the total time for those who received such support.

The shortest period of support has gone to pre-M.D.'s, most of whom were trained on a part-time basis.

Individuals whose first award was a fellowship received about four months less support than those who began on training grants, 23.3 versus 27.0 months. This is a reflection of the fact that fellows usually received their first award at a more advanced academic level than did trainees. At the pre-Ph.D. level for example, the trainees have received their first appointment to a training grant at an average of 2½ years beyond the B.A., whereas the fellows have received their first award at an average of 3½ years beyond the B.A.

Figure 5 illustrates the distribution of length of support; Figures 6 and 7 show the average length of support in various categories.

The average length of support has varied over the years due primarily to the shifting mixture of students from predominantly post-doctoral to predoctoral. And since the predoctorals generally receive longer support, the overall average length of support has tended to increase along with the growth of the predoctoral programs from 1950-65. Figure 7 shows the time pattern of average length of support. The decrease from 1966 to 1972 reflects only the fact that many of the recent trainees have not yet finished their training.

Figure 5 - DISTRIBUTION OF LENGTH OF NIH SUPPORT AT EACH ACADEMIC LEVEL

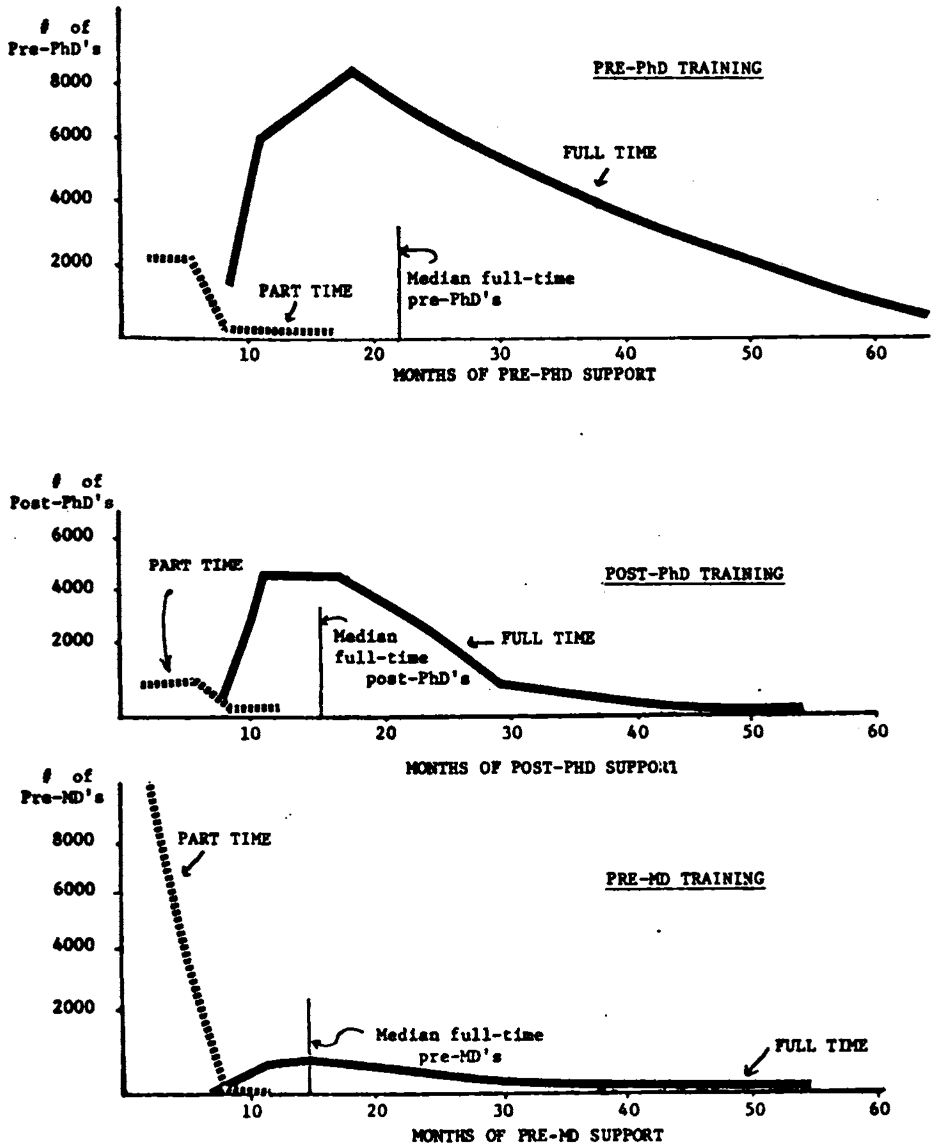
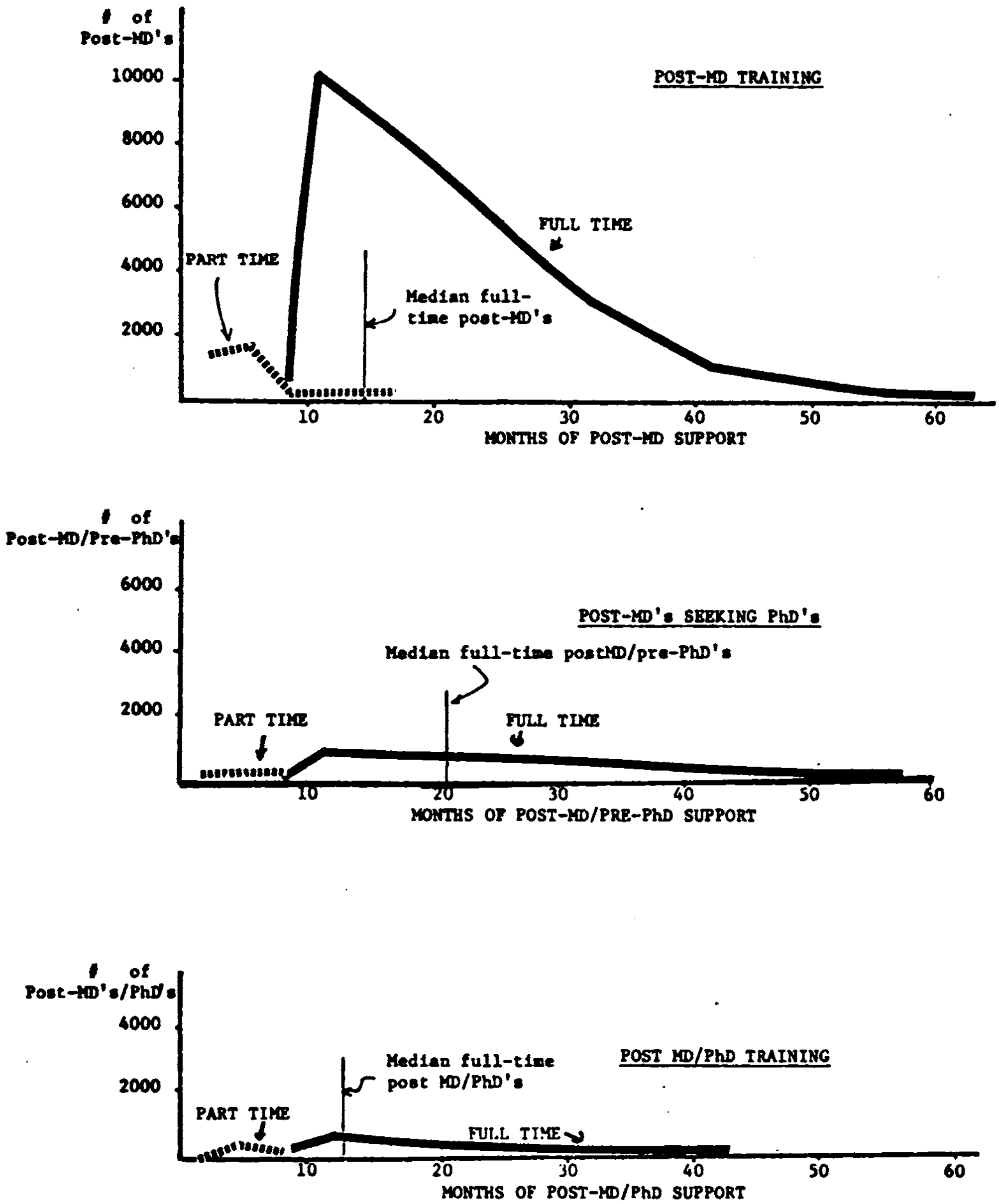
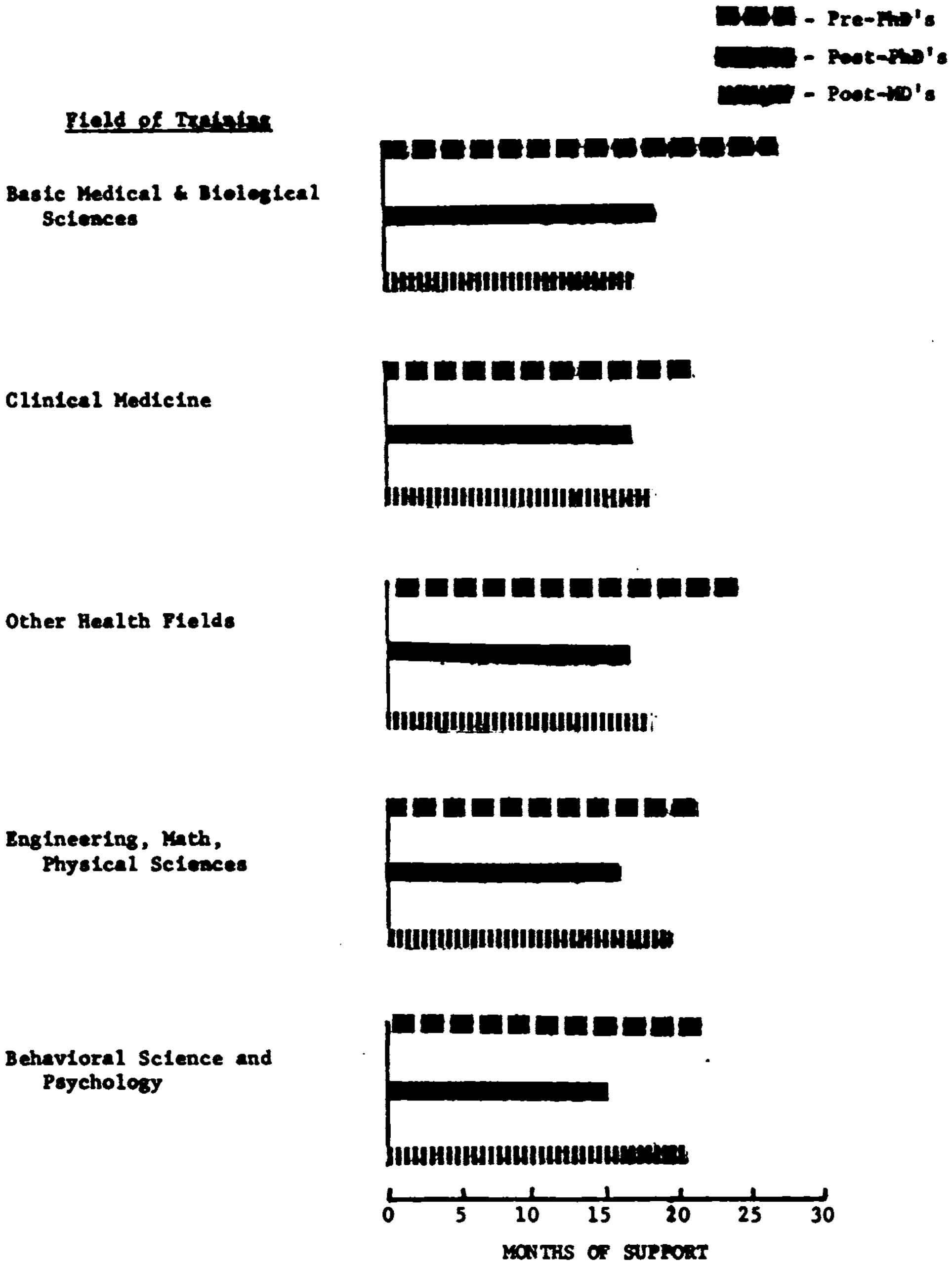


Figure 5 (cont.) - DISTRIBUTION OF LENGTH OF NIH SUPPORT AT EACH ACADEMIC LEVEL



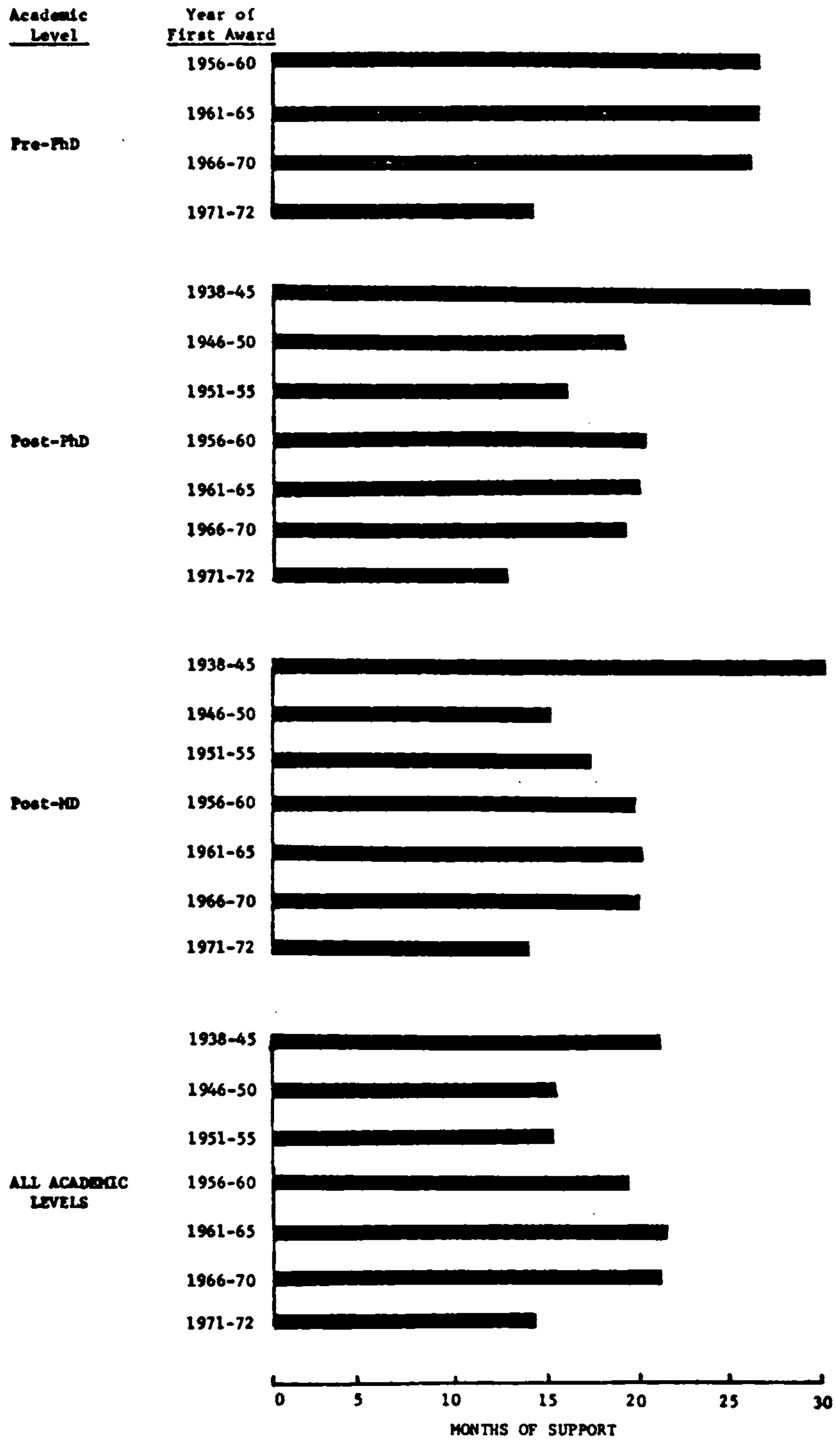
Source: NIH Roster of Trainees and Fellows, Summary File B, 7/28/74, NAS/NRC, Commission on Human Resources, Washington, D. C.

Figure 6 - MEAN LENGTH OF NIH SUPPORT FOR FULL-TIME TRAINEES AND FELLOWS BY SPECIALTY FIELD AND ACADEMIC LEVEL



Source: NIH Roster of Trainees and Fellows, 1938-72, Commission on Human Resources, NAS/NRC, Washington, D. C.

Figure 7 - MEAN LENGTH OF NIH SUPPORT FOR FULL-TIME TRAINEES AND FELLOWS AT EACH ACADEMIC LEVEL, BY YEAR OF FIRST AWARD



Source: NIH Roster of Trainees and Fellows, 1938-72, Commission on Human Resources, NAS/NRC, Washington, D. C.

D. TOTAL DOLLARS OF SUPPORT

The NIH training programs provide support to the trainees and fellows in the form of stipends based on the individual's academic level, and allowances for dependents, tuition, travel, and supplies. The 1974 annual stipend levels for fellows and the ceilings for traineeships were as follows:[6]

1. Predoctoral
   - (a) $2,400 (first post-B.A. year)
   - (b) $2,600 (years between first and terminal year)
   - (c) $2,800 (terminal year)

2. Postdoctoral
   - (a) $6,000 (no relevant post-Ph.D. experience)
   - (b) $6,500 (one year relevant post-Ph.D. experience)
   - (c) $7,000 (two or more years relevant post-Ph.D. experience)

3. Special Fellowships

   Annual stipends for special fellowships are determined on an individual basis. Previous training and experience, current salary, etc. are factors used in determining the special stipend level.

In the case of postdoctoral and special fellowships, the institution may receive up to $1,000 for supplies. For predoctoral fellows, the institution may receive an allowance of $2,500 in lieu of tuition, supplies, and all other required fees.

These levels have been in effect since 1967. From 1958-67, changes in stipend levels have occurred at irregular intervals, as shown in Table 3.

In FY 1975, the predoctoral stipends were raised to $3,900 at all levels and the dependents allowance was eliminated. Postdoctoral stipends now range from $10,000 to $14,000 and the institutional allowance has been raised to $3,000.

The median stipend per month of support for a trainee during 1966-70 was about $242 per month at the pre-Ph.D. level and $518 per month at the post-Ph.D. level. For fellows who receive their first award during the same period, the figures were $250 per month for a pre-Ph.D. and $534 per month for a post-Ph.D. (Tables 5 and 6).

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[6]PHS Grants Policy Statement, publication #(OS)74-50,000, USDHEW, Washington, D. C., July 1, 1974, p. 63.

Table 3 - NIH STIPEND LEVELS, FISCAL YEARS 1958-1968[a]

Fiscal Year	Stipend Levels: Predoctoral	Stipend Levels: Postdoctoral
1958	$1600-2000	$3800-4600
1959	1800-2200	4500-5500
1960	1800-2200	4500-5500
1961	1800-2200	5000-6000
1962	1800-2200	5000-6000
1963	1800-2200	5000-6000
1964	1800-2200	5000-6000
1965	2400-2800	5000-6000
1966	2400-2800	5000-6000
1967	2400-2800	6000-7000

Source: Effects of NIGMS Training Programs on Graduate Education in the Biomedical Sciences, National Institute of General Medical Sciences, National Institutes of Health, Public Health Service, U. S. Department of Health, Education and Welfare, 1969.

[a]Prior to July 1, 1965, training project directors could pay stipends at any level justified by "institution policy"; since July 1, 1965, the official stipend levels are maximal.

The total cost to NIH for a typical fellow whose first award was during 1966-70 was about $8,200 for a pre-Ph.D. and about $11,000 for a post-Ph. D. These costs covered an average period of 18 months for a pre-Ph.D. fellow and 17 months for a post-Ph. D. They include the stipend and dependency allowances which go to the fellows, and allowances for tuition and supplies, which go to the institution.

Over time, the amount of support per month of training has just about kept up with the increase in the cost of education for the student. The average charge for tuition, room and board for a full-time university student has increased at about 4% per year from 1957 through 1970.[7] During roughly the same period, irregular increases in stipends and allowances have increased the median dollars of support per month of training for a pre-Ph.D. trainee about 5% per year and about 3% per year for a post-Ph.D., as shown in Table 4.

Table 4 - AVERAGE ANNUAL RATES OF CHANGE IN STIPENDS AND ALLOWANCES PAID BY NIH, 1956-70

TRAINEES	$/Months of training
Pre-Ph.D.	+5%
Post-Ph.D.	+3%
Pre-M.D.	+3%
Post-M.D.	+6%
Post-M.D./Ph.D.	+4%
Post-M.D./Pre-Ph.D.	+7%
FELLOWS	
Pre-Ph.D.	+4%
Post-Ph.D.	+4%
Post-M.D.	+6%
Post-M.D./Ph.D.	+6%

[7] Digest of Educational Statistics, U. S. Office of Education, USDHEW, Washington, D. C., 1973, p. 74.
Projections of Educational Statistics, U. S. Office of Education, USDHEW, Washington, D. C., 1969 and 1972 editions, plus unpublished data of the National Center for Educational Statistics, USOE, USDHEW.

Table 5 - MEDIAN AMOUNT OF SUPPORT PAID TO NIH TRAINEES AT EACH ACADEMIC LEVEL

(Table entries are dollars unless indicated otherwise)

	Fiscal Year of First Award	Academic Level					
		Pre-Ph.D.	Post-Ph.D.	Pre-M.D.	Post-M. D.	Post M.D./Ph.D.	M.D./ Pre-Ph.D.
Median Stipend Per Month of Support	1956-60	204	424	200	336	406	313
	1961-65	238	494	216	423	473	456
	1966-70	242	518	257	502	512	521
	Total, All Years	241	514	241	458	475	502
	Average Annual Rate of Increase 1956-70	1.7%	2.2%	2.5%	4.1%	2.3%	5.2%
Median Total Dollars Per Month of Support	1956-60	208	424	200	336	406	326
	1961-65	258	511	219	433	482	498
	1966-70	338	581	271	583	579	648
	Total, All Years	312	560	251	489	498	586
	Average Annual Rate of Increase 1956-70	5.0%	3.2%	3.1%	5.7%	3.6%	7.1%
Median Total Dollars of Support	1956-60	3578	4166	1537	4392	4549	3409
	1961-65	4759	6548	1331	6420	6211	8496
	1966-70	8261	8258	1368	8241	8916	12449
	Total, All Years	7071	7404	1372	7173	6441	9868
	Average Annual Rate of Increase 1956-70	8.7%	7.1%	1.2%	6.5%	7.0%	13.8%

Source: NIH Roster of Trainees and Fellows, 1938-72, Summary File B. Commission on Human Resources, NAS/NRC, Washington, D. C., July 5, 1975.

Table 6 - MEDIAN AMOUNT OF SUPPORT PAID TO NIH FELLOWS AT EACH ACADEMIC LEVEL

(Table entries are dollars unless indicated otherwise)

	Fiscal Year of First Award	Academic Level					
		Pre-Ph.D.	Post-Ph.D.	Pre-M.D.	Post-M.D.	Post M.D./Ph.D.	M.D./Pre-Ph.D.
Median Stipend Per Month of Support	1956-60	199	428	--	435	519	(a)
	1961-65	182	468	(a)	503	634	477
	1966-70	250	534	(a)	759	859	744
	Total, All Years	228	486	226	472	603	527
	Average Annual Rate of Increase 1956-70	2.3%	2.2%	(a)	5.9%	5.2%	4.5% (from 1961)
Median Total Dollars Per Month of Support	1956-60	317	455	--	456	551	(a)
	1961-65	428	578	(a)	659	689	716
	1966-70	463	656	(a)	841	971	846
	Total, All Years	449	587	276	572	678	757
	Average Annual Rate of Increase 1956-70	3.9%	3.7%	(a)	6.3%	5.8%	1.5% (from 1961)
Median Total Dollars Of Support	1956-60	5294	8003	--	7278	9821	(a)
	1961-65	9713	10388	(a)	9965	8846	12569
	1966-70	8167	10703	(a)	12553	12386	13281
	Total, All Years	9142	9676	2083	8962	9541	12731
	Average Annual Rate of Increase 1956-70	4.4%	2.9%	(a)	5.6%	2.3%	0.5%

Source: NIH Roster of Trainees and Fellows, 1938-72, Summary File B, Commission on Human Resources, NAS/NRC, Washington, D.C., July 5, 1975.

(a) Less than 10 observations.

Table 5 shows the median dollars of support paid to NIH trainees and Table 6 shows the same for fellows. The total dollars of support have in some cases increased somewhat faster than the dollars per month because the number of months of support have also tended to increase slightly during this time period. This stretching-out of the support period is most noticeable for the M.D.'s seeking Ph.D.'s on training grants. In this case, the length of supported training has increased at about 6% per year since 1956, resulting in a 14% per year increase in total dollars of support at this academic level.

E. TIME LAPSE FROM DEGREE TO FIRST TRAINING APPOINTMENT

Most of the pre- and post-Ph.D.'s begin to receive NIH support within one year after the degree, but the time lapse to first appointment can be as long as ten years in some cases, as shown in Figure 8. Most of the M. D.'s begin their research training after the residency, as implied by the mean time lapse of about 4½ years from time of M.D. to first post-M.D. appointment.

The early years of the training programs were characterized by long periods of elapsed time from degree to first training appointment at each academic level. In the 1938-45 period for example, the average time lapse for the post-Ph.D.'s was over 4 years after the Ph. D., but this has decreased over the years and in the most recent period for which we have data, the average time lapse was less than 2 years. In the 1956-60 period the pre-Ph.D.'s received their first appointment at an average of 3½ years after the B.A., and this also has decreased over time to 2½ years in 1971-72. After this initial period for establishment of a new program, the time lapse seems to level off to a fairly stable value. The only discernible time trend occurs with the post-Ph.D.'s where the average time lapse of 30.6 months in the 1956-60 period decreases steadily to 20.6 months in the 1971-72 period (see Table 7).

Among the Institutes of the NIH the median time lapse from B.A. to first pre-Ph.D. appointment was smallest for the National Institute of General Medical Sciences (NIGMS) whose training programs have emphasized predoctoral support. The Dental Institute stands out as having the smallest average time lapse for post-M.D.'s, understandably because many of its trainees are dentists who do not take a residency (post-M.D. is the generic name for the category of all professional doctorates). On the other hand, the NIDR has the highest average time lapse of any Institute supporting post-Ph.D.'s, although only 111 of these have been supported by NIDR. These results seem to be in accordance with the relative emphasis that has occurred within the training programs of the Dental Institute.

Table 7 - MEDIAN TIME LAPSE FROM DEGREE TO FIRST TRAINING APPOINTMENT

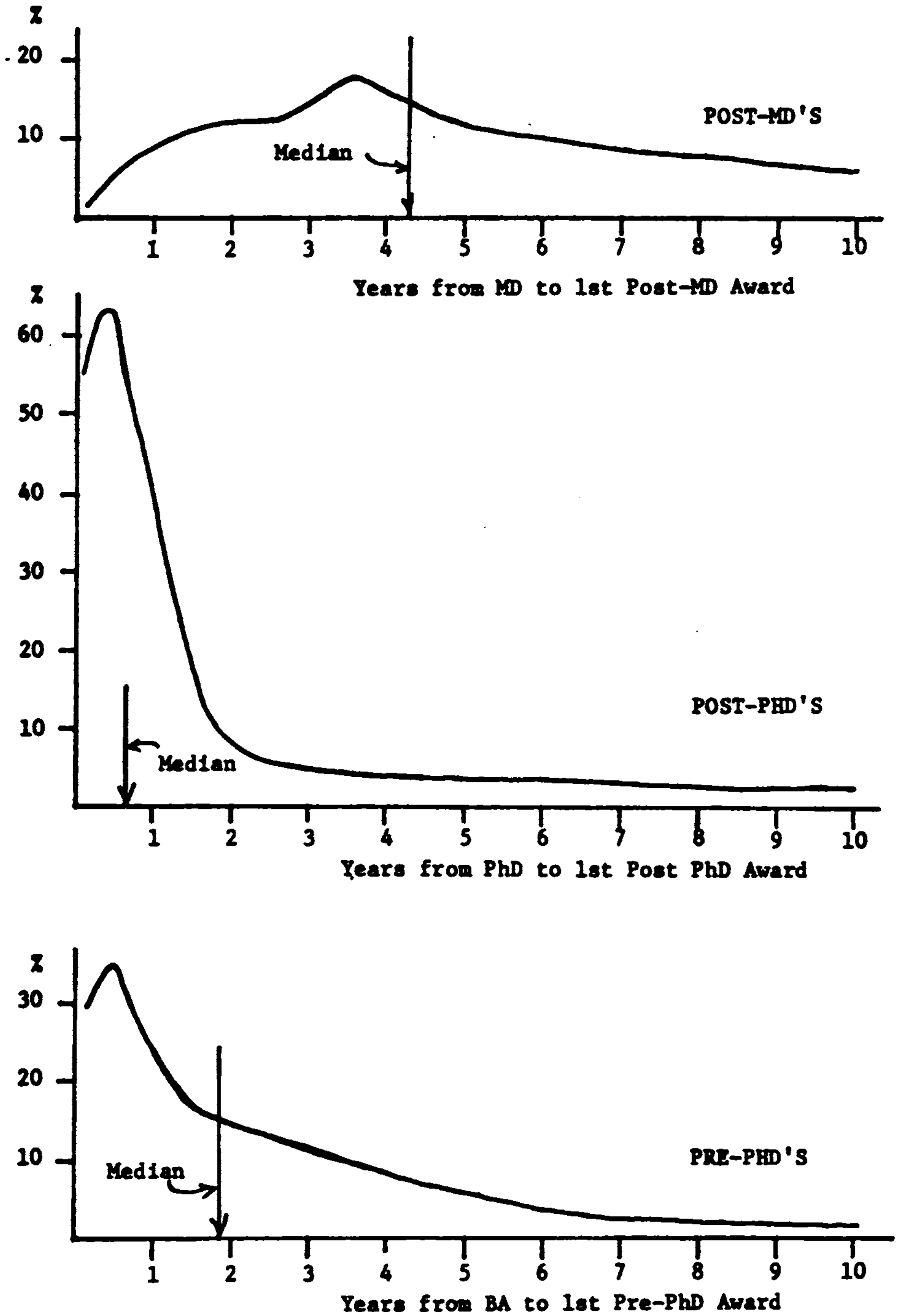
by academic level, year of first appointment and institute
(months of elapsed time)

Academic Level	Year of 1st Appt	INSTITUTE																					
		NIAID		NIAMD		NCI		NCHD		NIDR		NIEHS		NEI		NIGMS		NHLI		NINDS		TOTAL	
		Mos.	#	Mos.	#	Mos.	#	Mos.	#	Mos.	#	Mos.	#	Mos.	#	Mos.	#	Mos.	#	Mos.	#	Mos.	#
BA to 1st Pre-PhD Appointment	1956-60	71.8	34	(a)	(a)	38.5	28	----	----	34.5	10	----	----	----	----	29.6	182	26.2	31	----	----	31.0	288
	1961-65	25.6	840	30.4	112	30.4	390	24.9	279	24.9	235	27.9	155	----	----	16.5	6426	25.4	619	31.8	110	19.0	9266
	1966-70	25.1	1047	27.2	122	17.9	400	24.1	1487	24.9	296	27.6	885	(a)	(a)	16.5	9449	25.7	596	38.9	244	21.5	14527
	1971-72	24.0	276	24.9	35	17.8	98	26.1	344	26.5	64	36.8	160	(a)	(a)	15.4	1672	25.9	102	31.2	58	20.2	2815
	Total all years	25.4	2197	28.5	272	25.7	916	24.8	2110	25.1	605	28.1	1200	(a)	(a)	16.4	17829	25.6	1348	37.7	412	20.1	26896
PhD to 1st Post PhD Appointment	1938-45	----	----	----	----	50.5	14	----	----	----	----	----	----	----	----	----	----	----	----	----	----	50.5	14
	1946-50	----	----	----	----	12.5	46	----	----	(a)	(a)	----	----	----	----	6.5	40	(a)	(a)	----	----	8.4	95
	1951-55	4.0	16	13.6	18	10.8	142	----	----	(a)	(a)	----	----	----	----	4.5	30	15.1	43	15.5	16	12.3	265
	1956-60	15.5	103	15.8	41	9.4	251	----	----	(a)	(a)	----	----	----	----	16.5	142	24.9	200	10.5	70	14.9	811
	1961-65	8.7	250	10.0	118	7.7	273	8.5	86	20.5	34	(a)	(a)	----	----	11.0	1198	16.5	172	11.8	199	10.7	2336
	1966-70	5.5	321	5.1	330	4.9	385	9.7	368	7.5	47	5.7	55	4.5	10	6.8	1422	4.7	261	6.3	285	6.2	3484
	1971-72	4.5	125	9.0	125	9.9	159	6.0	101	20.5	26	4.3	25	7.2	46	7.4	606	11.8	121	6.1	129	7.8	1463
	Total all years	7.3	815	7.6	632	7.6	1270	8.6	555	16.0	111	6.0	86	6.8	56	9.1	3438	12.5	806	8.6	699	8.5	12834
MD to 1st Post-MD Appointment	1938-45	----	----	----	----	(a)	(a)	----	----	----	----	----	----	----	----	(a)	(a)	----	----	----	----	----	----
	1946-50	----	----	----	----	(a)	(a)	----	----	(a)	(a)	----	----	----	----	(a)	(a)	(a)	(a)	----	----	71.7	13
	1951-55	(a)	(a)	(a)	(a)	(a)	(a)	----	----	(a)	(a)	----	----	----	----	(a)	(a)	28.2	25	(a)	(a)	50.5	50
	1956-60	56.5	154	50.6	652	51.9	306	----	----	37.8	215	----	----	----	----	52.5	348	50.8	353	37.2	701	44.3	2729
	1961-65	52.6	670	53.4	2260	54.0	879	65.9	231	39.3	559	(a)	(a)	----	----	42.8	1893	61.4	2263	40.5	1896	51.1	10656
	1966-70	62.7	674	50.9	2116	52.5	948	63.1	505	31.2	446	50.1	34	38.6	225	29.3	1553	53.5	2116	41.7	2214	50.1	10831
	1971-72	51.0	138	56.9	455	61.3	284	51.3	92	25.2	95	69.0	12	49.6	129	42.2	324	65.0	473	43.8	431	51.1	2433
	Total all years	54.4	1639	51.8	5491	53.9	2428	62.7	828	36.9	1316	50.8	51	39.9	354	41.7	4127	58.3	5231	40.1	5247	50.3	26712
PhD to 1st Post MD/PhD Appointment	1946-50	----	----	----	----	(a)	(a)	----	----	----	----	----	----	----	----	(a)	(a)	(a)	(a)	----	----	(a)	(a)
	1951-55	----	----	(a)	(a)	(a)	(a)	----	----	(a)	(a)	----	----	----	----	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
	1956-60	(a)	(a)	(a)	(a)	11.2	12	----	----	(a)	(a)	----	----	----	----	48.5	10	77.9	17	17.8	20	46.5	77
	1961-65	66.5	18	34.5	20	28.5	22	(a)	(a)	42.5	8	----	----	----	----	38.5	45	38.5	27	63.2	21	46.5	163
	1966-70	21.5	11	24.5	24	38.5	14	(a)	(a)	15.5	10	(a)	(a)	(a)	(a)	24.5	50	25.8	39	34.5	25	26.0	164
	1971-72	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	42.5	9	----	----	(a)	(a)	22.5	11	27.5	13	(a)	(a)	37.8	66
	Total all years	26.5	42	36.5	62	37.5	54	34.5	15	29.2	29	(a)	(a)	(a)	(a)	33.5	122	44.5	78	38.0	75	35.2	482

Source: NIH Roster of Trainees and Fellows, 1938-72, Summary File B, Commission on Human Resources, NAS/NRC, Washington, D. C., June 5, 1974.

(a) Too few observations with known time lapse to provide a reliable estimate.

Figure 8 - TIME LAPSE FROM DEGREE TO FIRST NIH AWARD



Source: NIH Roster of Trainees and Fellows, Summary File B, Commission on Human Resources, NAS/NRC, Washington, D. C., June 5, 1974.

In terms of specialty fields, the pre-Ph.D.'s begin supported training earliest in biochemistry, biophysics, and pharmacology; for post-Ph.D.'s, support begins earliest in pharmacology, microbiology, and multidisciplinary studies; and for post-M.D.'s, neurology, dentistry, and the physical sciences tend to be supported earliest (see Appendix Table A5).

4. CAREER PATTERNS

In this chapter we discuss what is perhaps the most significant part of this follow-up study, the careers of the former NIH trainees and fellows and those in comparison groups. The object of this investigation was first to develop suitable descriptions of career patterns, and second, to try to discern what influence, if any, training-grant or fellowship support from NIH has had on these patterns.

Career patterns are difficult to describe, and even more difficult to measure. Quality criteria—always difficult to deal with— must be involved. Uncertainties about whether different groups can properly be compared are large. Since people often change their employers and work activities, the time element becomes an important consideration. What quantities then should be used to describe career achievements and what criteria should be used to evaluate them?

There obviously is more than one way of viewing and assessing a career. But the choice can be narrowed somewhat for purposes of this study by approaching the problem from the point of view of the general intent and goals of the training programs.

The ultimate goal of biomedical research is the alleviation of disease and the improvement of the health-care delivery system. The primary goal of the NIH training programs is to insure that a cadre of highly trained and highly able persons is available for conducting research in the biosciences and related fields. Thus the training programs, while not unmindful of the end product, have a specialized function to perform, namely to provide an adequate quantity and quality of brainpower to perform the research.

It is in this context that career patterns of bioscientists and other scientists are examined in this chapter. We have directed our investigation of career patterns toward those questions which relate to the stated goals of the training programs. In broad terms, these questions can be posed as follows:

1. Have the NIH training programs been effective in attracting able students into careers in biomedical research?

2. Do the former trainees and fellows pursue active research careers?

3. Do the former trainees and fellows become productive scientists and do they contribute to medical knowledge?

Without claiming any finality for our answers—since the retrospective evaluation of such complex programs is a very uncertain art—we shall try to answer each of these broad questions. They can be broken down into more specific, operational ones for which answers may be sought in quantitative terms. Thus for question 1 we will seek to determine if Ph.D. rates and graduate enrollments in bioscience and related fields have been affected in any way by the training programs. In this chapter we report on Ph.D. attainment rates and the time-lapse from B.A. to Ph.D. for those who had NIH support compared to those without such support. The impact of the training programs on graduate enrollments is a more involved question requiring a different type of analysis and will be deferred until the next chapter.

Question 2 involves the extent of participation in research, and for this question, our approach will be to ascertain what the primary work activity was for each member of the study group during the 1968-70 period. These are the years for which survey data files generally provided career information. Then the study group will be divided into age cohorts and the percentage in each cohort that was engaged primarily in research or development will be computed. This provides a measure of the extent of participation in research activities for each age cohort. By examining this percentage from one cohort to the next, we can obtain approximate information about the stability of research activity over a span of years. The same procedure will be followed for other work activities such as teaching, administration, or professional services to individuals. These were generally the choices listed on the survey questionnaires from which the data on primary work activity were compiled.

To develop this idea somewhat further, ideally what we would like to have is longitudinal data for each member of the group for a decade or more. Such data would show the employment history for each person and would give a much clearer picture of the variation in work activity over the length of a career. However, data limitations precluded this possibility. The survey data that we relied on for career information—mainly the National Register of Scientific and Technical Personnel, The Medical and Dental School Faculty Rosters, and the AMA File of Licensed Physicians—could not provide sufficient longitudinal information on their respondents. Instead, what we have done in effect is to take a "snapshot" of the primary work activities of a large group of individuals during a single short time period, group them by age, and then try to infer something about the career patterns of the whole group. The reader must be warned that this method cannot be relied upon to reveal fine differences.

To be sure, for the members of the NIH supported groups, we do have some longitudinal data covering their period of training. In addition, from the NIH Roster of Trainees and Fellows and the fellowship program files of other organizations, it was possible to trace individuals who might have had both predoctoral and postdoctoral support from such other sources. The training histories of the individuals were then combined with Ph.D. attainment information from the Doctorate Records File to provide different combinations of training experience and degree attainment. The career patterns of the members of the study group were subsequently examined according to the type of training pathway that had been taken.

The difficulties in trying to examine career achievements with imperfect measures are apparent. At the very least, the "snapshot" technique will provide information on what the members of the study group were doing in the 1968-70 period. At most it will give a rough idea of their career patterns.

In addition to primary work activity, we have also tabulated the type of employer for each member of the study group during 1968-70. This will provide information on the proportion of each cohort that was employed by a university or medical school, employed by industry, or was self-employed. As a complement to this analysis we have compiled some data on incomes derived from the different types of employment and work activities.

The third general question to be addressed in this chapter is concerned with the productivity of the individuals in the study group and the possible influence of their contributions to biomedical knowledge. For a quantitative assessment of these issues we have investigated for each member of the study group (some 500,000 individuals) the number of publications and citations that have appeared in the world's scientific literature during 1961-72. This was done by analysis of the Science Citation Index developed by the Institute for Scientific Information. The Index is a compilation of the authors, titles and cited references from a large portion of the world's scientific journals. It was designed to act primarily as a bibliographic tool for performing literature searches, but has also proved useful in a number of other ways. Sociometric studies similar to this one have used the Index to attempt to measure the impact of a scientist's work by counting the number of his publications and citations to his publications appearing in the literature. One approach has been to assume that a scientist's productivity can be crudely measured by counting his output of papers and articles. This assumption is open to serious challenges. There are situations where an author is credited with a large number of papers but none have had very great impact; conversely, some authors publish infrequent but highly significant papers. An alternative procedure that overcomes some of these problems is to count citations (excluding self-citations) rather than publications, but even this technique has imperfections. Papers on methodology for example tend to be cited more heavily than other papers of equal importance. Despite these deficiencies, a number of studies have concluded that there is a positive relationship between quantity and quality, and between the frequency of citation and impact of published research.[1] We shall present the results of such analysis for the study group with the caveats just stated.

A. COMPARISON GROUPS

It has been possible in developing data for this study to analyze the experience of several groups of supported and non-supported people, in addition to that of the NIH trainees and fellows. Files of people supported on training grants and fellowships under the National Defense Education Act of 1958 (NDEA), the National Science Foundation, and the Woodrow Wilson Foundation were made available to the NRC for this purpose. Also data about a group of people who applied for NIH or NSF support and were not successful, or who were successful but did not activate their awards, were available to provide comparison information about a group composed of people not supported by these fellowships or traineeships.

This last group will be referred to in this report as the "non-supported" group, but it is important to note that while it is a group which did not receive training grant or fellowship support from the NIH, NSF, NDEA or WW programs, these persons may have received support from other sources such as the Veterans Administration, the Atomic Energy Commission, the National Aeronautics and Space Administration, private scholarships, loans, research grants, teaching assistantships, etc. The groups will be used to provide comparisons with the NIH-supported group in terms of the career outcomes analyzed in the succeeding sections of this chapter.

[1] Cole, S. and Cole, J., "Scientific Output and Recognition: A Study in the Operation of the Reward System in Science," American Sociological Review, vol. 32, no. 3, June 1967. Also Garfield, E., "Citation Index for Studying Science," Nature, vol. 227, 669-671, August 15, 1970, and Wade, N., "Citation Analysis: A New Tool for Science Administration," Science, vol. 188, May 2, 1975.

The NIH and NSF training grant and fellowship programs have been the major sources of graduate support in the biosciences. Since all former NIH and NSF trainees and fellows were included in this study, it was possible to distinguish between those who did and those who did not receive support from these sources. Thus it appears reasonable to attempt an examination of the impact of these programs on Ph.D. attainment in the biosciences. This is not true in the physical sciences. The AEC and NASA had large training grant and fellowship programs in the physical sciences, but data on students supported by these programs were not available in this study. Therefore in this chapter no analysis of the effect of training grants or fellowships on Ph.D. attainment rates in the physical sciences will be made. In the next chapter, a different set of data provide a means of examining the impact of federal support in the physical sciences.

B. PH.D. ATTAINMENT RATES AND B.A. TO PH.D. TIME LAPSE

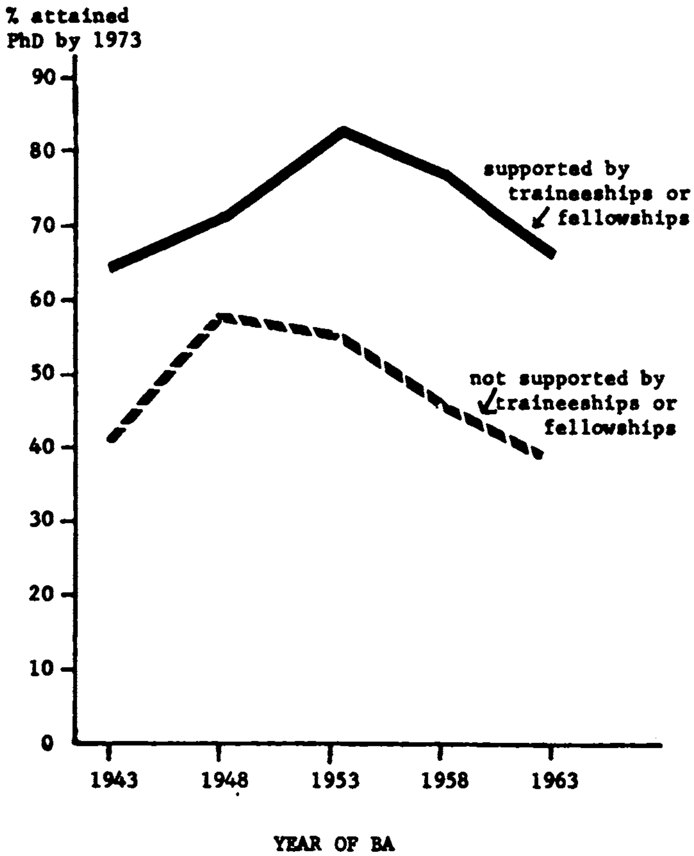
By collating the NIH group and the comparison group with the 1973 Doctorate Records File, it was possible to determine the Ph.D. attainment rates for each group and the average time-lapse from B.A. to Ph.D. The attainment rate is measured by the percentage of each group that had received the Ph.D. by 1973.

1. Supported versus Non-supported

In general, the supported groups have achieved a substantially higher Ph.D. attainment rate than the non-supported group (Figure 9, Table 8, and Appendix Table A4). In the biological sciences, 70% of the people who had training grant or fellowship support at the pre-Ph.D. level between 1956 and 1965 had attained their Ph.D.'s by 1973, compared to 42% of a similar cohort who were not so supported.

As with this and other comparisons among the supported and non-supported groups, any differences in outcomes might be due to differences in ability among the groups. Unfortunately, we have no means of controlling for the ability factor in this study since reliable ability measures are not available for the supported and non-supported groups. Some exploratory analyses were made, using Graduate Record Examination (GRE) scores on the verbal test, which indicates that the supported pre-Ph.D.'s again had a higher Ph.D. attainment rate than the non-supported ones with verbal ability constant. But since verbal ability is not an adequate measure of overall ability, these results are not conclusive.

Figure 9 - PHD ATTAINMENT RATES FOR SUPPORTED AND NON-SUPPORTED GROUPS IN THE BIOLOGICAL SCIENCES



Sources: NIH Roster of Trainees and Fellows, 1938-72, Comprehensive File of Doctoral Scientists and Engineers, 1935-73, Cumulative Index of NSF Trainees and Fellows, 1952-71, Commission on Human Resources, NAS/NRC, Washington, D. C.

NDEA Fellows, 1959-72, Office of Education, U. S. Department of Health, Education and Welfare, Washington, D. C.

Woodrow Wilson Fellows, 1958-69, Woodrow Wilson National Fellowship Foundation, Princeton, N. J.

Table 8 - PHD ATTAINMENT RATES AND TIME LAPSE, BA-PHD, FOR SUPPORTED AND NON-SUPPORTED PRE-PHD'S IN THE BIOLOGICAL SCIENCES

Year of BA	Source of Pre-PhD Support			Received PhD by 1973 #	Received PhD by 1973 % of Total	Received PhD by 1973 Mean Time Lapse BA-PhD (Yrs)	Did Not Receive PhD by 1973 #	Did Not Receive PhD by 1973 % of Total	Total #
1956-60	NIH	Trainees	Full-time	1582	76.4	8.0	488	26.6	2070
			Part-time	243	59.9	7.4	163	40.1	406
			Total (incl unk)	1845	73.7	7.9	660	26.3	2505
		Fellows	Full-time	727	93.4	6.9	51	6.6	778
			Part-time	22	100.0	6.2	--		22
			Total (incl unk)	770	93.7	6.9	52	6.3	822
		Total	Full-time	2309	81.1	7.7	539	18.9	2848
			Part-time	265	61.9	7.3	163	38.1	428
			Total (incl unk)	2615	78.6	7.6	712	21.4	3327
	NDEA[b]			84	64.1	11.7	47	35.9	131
	Woodrow Wilson Fellows			51	63.0	6.1	30	37.0	81
	NSF	Trainees		17	70.8	11.5	7	29.2	24
		Fellows		258	89.9	6.8	29	10.1	287
		Total		275	88.4	7.1	36	11.6	311
	Total with Known Support[a]			2706	77.5	7.7	786	22.5	3492
	No trainee or fellowship suppt.			634	46.3	8.4	734	53.7	1368
1961-65	NIH	Trainees	Full-time	3633	65.6	6.2	1908	34.4	5541
			Part-time	311	40.3	6.2	460	59.7	771
			Total (incl unk)	3956	62.5	6.2	2378	37.5	6334
		Fellows	Full-time	1110	88.7	5.6	141	11.3	1251
			Part-time	32	88.9	5.8	4	11.1	36
			Total (incl unk)	1179	88.9	5.6	147	11.1	1326
		Total	Full-time	4743	69.8	6.0	2049	30.2	6792
			Part-time	343	42.5	6.2	464	57.5	807
			Total (incl unk)	5135	67.0	6.0	2525	33.0	7660
	NDEA[b]			703	62.5	6.4	421	37.5	1124
	Woodrow Wilson Fellows			50	76.9	5.8	15	23.1	65
	NSF	Trainees		150	72.8	6.5	56	27.2	206
		Fellows		381	87.8	5.6	53	12.2	434
		Total		531	83.0	5.8	109	17.0	640
	Total with Known Support[a]			5711	66.3	6.0	2895	33.7	8606
	No trainee or fellowship suppt.			614	39.0	6.4	958	61.0	1572
Total, 1956-65	NIH	Trainees	Full-time	5215	68.5	6.7	2396	31.5	7611
			Part-time	554	47.1	6.7	623	52.9	1177
			Total (incl unk)	5801	65.6	6.7	3038	34.4	8839
		Fellows	Full-time	1837	90.5	6.1	192	9.5	2029
			Part-time	54	93.1	6.0	4	6.9	58
			Total (incl unk)	1949	90.7	6.1	199	9.3	2148
		Total	Full-time	7052	73.2	6.6	2588	26.8	9640
			Part-time	608	49.2	6.7	627	50.8	1235
			Total (incl unk)	7750	70.5	6.5	3237	29.5	10987
	NDEA[b]			787	62.7	7.0	468	37.3	1255
	Woodrow Wilson Fellows			101	69.2	6.0	45	30.8	146
	NSF	Trainees		167	72.6	7.0	63	27.4	230
		Fellows		639	88.6	6.1	82	11.4	721
		Total		806	84.8	6.2	145	15.2	951
	Total with Known Support[a]			8417	69.6	6.5	3681	30.4	12098
	No trainee or fellowship suppt.			1248	42.4	7.4	1692	57.6	2940

Sources: NIH Roster of Trainees and Fellows, 1938-72, Comprehensive File of Doctoral Scientists and Engineers, 1935-73, Cumulative Index of NSF Trainees and Fellows, 1952-71, Commission on Human Resources, NAS/NRC, Washington, D. C.

NDEA Fellows, 1959-72, Office of Education, U. S. Department of Health, Education and Welfare, Washington, D. C.

Woodrow Wilson Fellows, 1958-69, Woodrow Wilson National Fellowship Foundation, Princeton, N. J.

[a] The total with known support is less than the total from all sources of support because some people had multiple sources of support and are counted in each one, but are counted only once in the total.

[b] The NDEA program is operationally equivalent to a traineeship even though it is called a fellowship program. For this analysis, the NDEA people are considered to be trainees rather than fellows.

2. Fellows versus Trainees

The fellows do somewhat better than the trainees in terms of Ph.D. attainment, because they tend to receive their fellowships at a later stage in their education.

The pre-Ph.D. trainees received their first award at an average of 30 months after the B.A. while the pre-Ph.D. fellows received theirs at an average of 41 months after the B.A. The net result is that the Ph.D. attainment rate for the 1956-65 cohort of NIH fellows in bioscience was 91% compared to 66% for NIH trainees.

3. NIH versus Other Groups

The NIH supported group[2] compares very favorably with the other groups in the study (Figure 10). In the biosciences, the NIH fellows had the highest Ph.D. attainment rate of all groups in the 1956-65 cohort.

The NIH and NSF trainees in bioscience do equally well in terms of Ph.D. achievement, followed by the NDEA trainees and the non-supported group.

4. Woodrow Wilson Fellows

Although the Woodrow Wilson Fellowship program was suspended in 1971, the fellows are referred to in Table 5 because their fellowship support provides an interesting contrast to that given by either NIH or NSF. Woodrow Wilson Fellowships were given only for the first year of graduate study whereas NIH and NSF fellows receive support for several years. Furthermore, the Woodrow Wilson program has emphasized teaching careers in the arts and humanities rather than the sciences which have been primarily the province of NIH and NSF.

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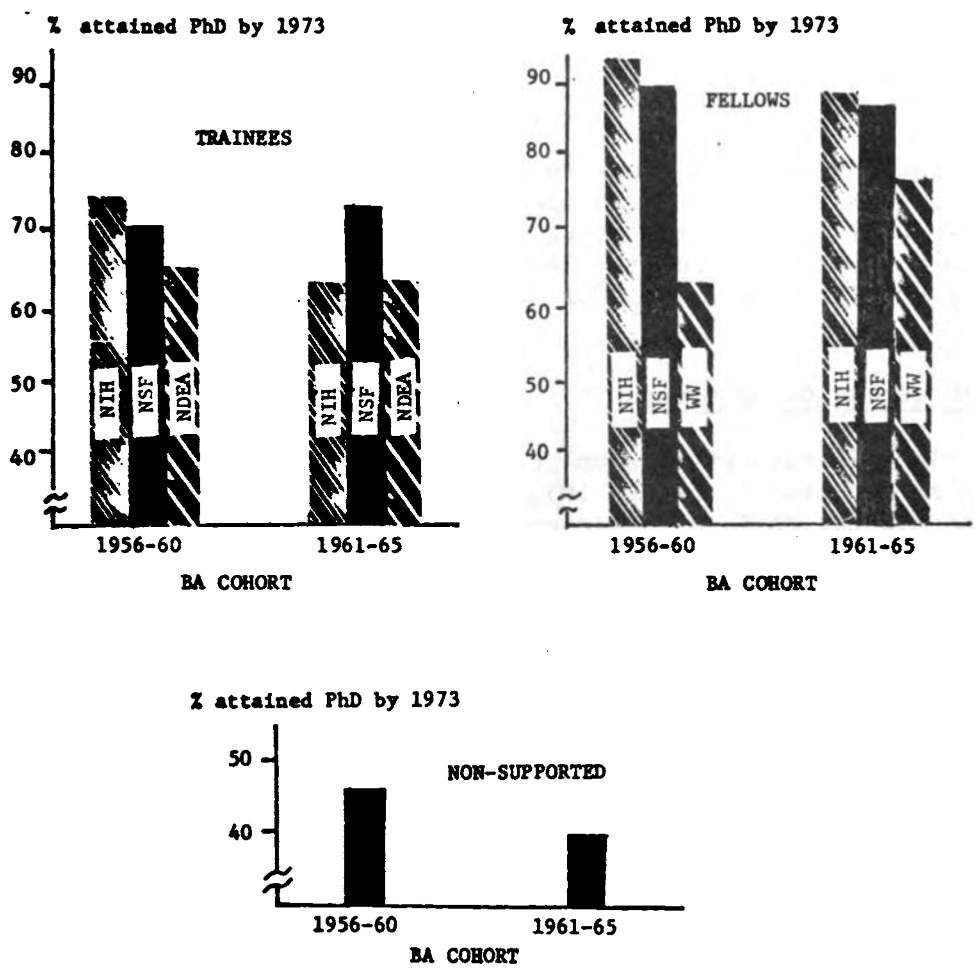
[2] The NIH group represents people who received traineeship or fellowship support from NIH, but many of these also received support from NSF and other sources. There is some overlap in the groups considered in this study. Prior to 1956 about 6% of the supported group had multiple sources of support; after 1956 this figure was twice as high, about 12%. For this analysis, a person was counted in each group for which he received support.

Figure 10 - PHD ATTAINMENT RATES FOR TRAINEES, FELLOWS AND NON-SUPPORTED GROUPS IN THE BIOLOGICAL SCIENCES



Sources: NIH Roster of Trainees and Fellows, 1938-72, Comprehensive File of Doctoral Scientists and Engineers, 1935-73, Cumulative Index of NSF Trainees and Fellows, 1952-71, Commission on Human Resources, NAS/NRC, Washington, D. C.

NDEA Fellows, 1959-72, Office of Education, U. S. Department of Health, Education and Welfare, Washington, D. C.

Woodrow Wilson Fellows, 1958-69, Woodrow Wilson National Fellowship Foundation, Princeton, N. J.

5. Full-time versus Part-time Training

The Ph.D. Attainment rates of those in the NIH group who had full-time support (8 or more consecutive months) differ from those with part-time support, but the difference is not always in favor of the full-time people. For bioscience trainees during 1956-65, the attainment rate for the full-time group was 68% compared to 47% for the part-time trainees. For fellows during this same period, the statistics are reversed: the part-time fellows in bioscience had an attainment rate of 93% compared to 90% for the full-time fellows. The reason for the reversal is understandable: many part-time pre-Ph.D. fellows received their fellowship just before completing the Ph.D. and specifically for that purpose. If they were on the fellowship for less than eight months before receiving the degree, they are classified as part-time fellows. The more general case however is that of the part-time pre-Ph.D. trainee. He or she typically is at an earlier stage of training than a fellow and does not complete the training because of financial pressures, family responsibilities, or other personal reasons. By far the majority of part-time people were trainees rather than fellows, and most of these did not continue on to the Ph.D.

6. M.D.'s Seeking Ph.D.'s

In addition to supporting pre-Ph.D.'s, NIH has also provided support to a group of M.D.'s who were seeking Ph.D.'s. Their Ph.D.'s attainment rates are generally somewhat lower than the pre-Ph.D.'s as shown below. The difference is most noticeable with the fellows where the Ph.D. attainment rate for the non-M.D.'s was 13 to 27 percentage points higher than for the M.D.'s seeking Ph.D.'s. Because of the time required for medical school and the residency, the M.D.'s generally take longer than the non-M.D.'s to achieve the Ph.D. Since many of the M.D.'s in the younger cohorts shown in Table 9 were still in the Ph.D. pipeline in 1973, their attainment rates are not exactly comparable to the non-M.D.'s.

Table 9 - PHD ATTAINMENT RATES OF PRE-PHD'S AND MD'S SEEKING PHD'S IN THE BIOSCIENCES

Year of B.A.	NIH Pre-Ph.D.'s: Trainees %	Trainees # Pre-Ph.D.'s	Fellows %	Fellows # Pre-Ph.D.'s	Total %	Total # Pre-Ph.D.'s	NIH MD/Pre-Ph.D.'s: Trainees %	Trainees # MD/Pre-Ph.D.'s	Fellows %	Fellows # MD/Pre-Ph.D.'s	Total %	Total # MD/Pre-Ph.D.'s
1951-55	79.7	748	92.6	202	82.4	950	74.0	100	79.1	67	76.0	167
1956-60	73.7	2505	93.7	822	78.6	3327	65.2	158	73.8	103	68.6	261
1961-65	62.5	6334	88.9	1326	67.0	7660	54.1	109	62.3	77	57.5	186

Sources: NIH Roster of Trainees and Fellows, 1938-72, Comprehensive File of Doctoral Scientists and Engineers, 1935-73, Commission on Human Resources, NAS/NRC, Washington, D. C.

C. EMPLOYMENT

Ph.D. attainment discussed above represents an important milestone in the development of a bioscientist and usually marks the beginning of the professional career especially for non-M.D.'s. After that comes further postdoctoral training or employment which in this study is characterized by a person's work activities, type of employer and income. We now turn to these.

The National Register of Scientific and Technical Personnel[3] was the main source of data on employment characteristics and work activity. The

[3] The National Register was a biennial survey of members of professional and scientific disciplines conducted by the National Science Foundation between 1956 and 1970. It provides the most comprehensive body of employment information about U.S. scientists and engineers that is available, but because of its source of data it tends to be weighted toward academia. The Register was discontinued in 1970 and replaced by the Manpower Characteristics System. M.D.'s who responded to the Register are not representative of the general population of M.D.'s most of whom are in private practice.

last year in which that survey was conducted was 1970, so an attempt was first made to obtain career information from that file in order to utilize the most recent data.

If a member of the study group was not found in the 1970 National Register, the next most recent one (1968) was searched to see if the individual could be located there. In this sense the employment information covers the 1968-70 time period.

The medical and dental school faculty rosters, and the AMA file of physicians were also used to obtain career information for roughly the same time period.[4]

1. Primary Work Activity

The kinds of work activities that the former NIH trainees engage in are of primary interest because one of the main goals of the training programs is to encourage participation in research. To be examined here is the extent to which the trainees pursue a research career and how long such a career lasts.

The data indicate that the extent and length of participation in research activities seem to be positively related to the amount of training and education received. Individuals with the most advanced training participate to the greatest extent and seem to stay longest in research. This pattern holds for M.D.'s as well as non-M.D.'s, and for NIH-supported trainees as well as those supported by other programs.

The non-M.D. group seems to be separable in terms of career patterns into four groups characterized by the following:

1. Individuals who did not receive the Ph.D. (non-Ph.D.)
2. Those who had no pre-Ph.D. support, received the Ph.D., but received no post-Ph.D. support (no pre-Ph.D. - Ph.D.)

[4]The Medical School Faculty Roster is maintained by the Association of American Medical Colleges, and the Dental School Faculty Roster is maintained by the Division of Dental Health, Bureau of Health Resources Development, Health Resources Administration, in cooperation with the Association of American Dental Schools. The Physicians File is maintained by the American Medical Association and contains detailed information on all physicians in the United States.

3. Those who had pre-Ph.D. support, attained the Ph.D., but received no post-Ph.D. support (pre-Ph.D. - Ph.D.)

4. Those who received post-Ph.D. support (post-Ph.D.)

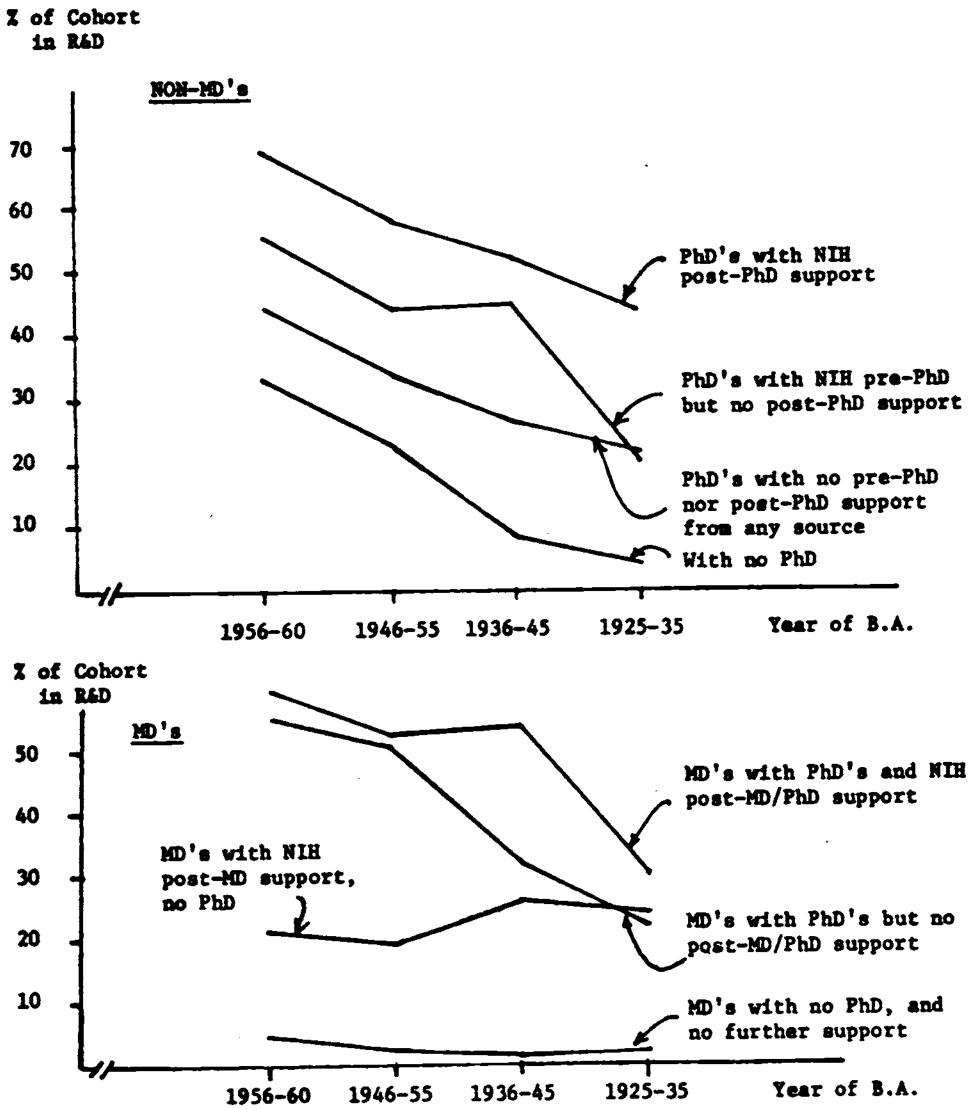
The term "support" in this study means a traineeship or fellowship from NIH, NSF, NDEA or the Woodrow Wilson Foundation, but it is quite possible for educational assistance to have come from sources other than these. There were insufficient data available on individuals who were not supported by traineeships or fellowships but who had support from research projects, teaching assistantships, instructorships, or other university support. Having stated this caveat, we note that the use of the above classification does result in groups with apparently different career outcomes as illustrated in Figure 11. That figure displays the patterns of research activity of former NIH-supported trainees compared to non-supported groups. The curves represent the age-research activity profiles for each group. About 69% of the youngest cohort (B.A. year 1956-60) with NIH post-Ph.D. support was engaged primarily in research and development during 1968-70. This participation rate, which was the highest of any group in the study, tapered off to about 44% for the oldest cohort (B.A. year 1925-35). At the other extreme are those without a Ph.D. About 33 % of the youngest cohort in the group participated in research, and this trails off to less than 5% for the 1925-35 B.A. cohort. In between these extremes are those Ph.D.'s with and without NIH pre-Ph.D. support, the former having the higher participation rate.

The group without Ph.D.'s includes some people who received pre-Ph.D. support from NIH, NSF, or NDEA. The older cohort of this supported group represent people who dropped out of the education stream before completing the Ph. D. program. They are not generally considered to be professional bioscience researchers although some of them are associated with such research and make contributions to it. Only about 3% of this supported group without Ph.D.'s in the pre-1945 B.A. cohort was participating in research during 1968-70. Most of the others were engaged in teaching. But for the younger cohort of this same group, those whose B.A. was subsequent to 1960, the proportion doing research in 1968-70 was 56%, which was almost as high as for those with Ph.D.'s, indicating that many of these people are probably still in the Ph.D. pipeline.

The M.D.'s can also be classified into groups according to a similar set of characteristics which apparently lead to different career outcomes:

1. M.D.'s with no further support, and no Ph.D.
2. M.D.'s who received NIH post-M.D. support but not the Ph.D.
3. M.D.'s who received the Ph.D. but no further support
4. M.D.'s who received the Ph.D. and also NIH post-Ph.D. support

Figure 11 - PROPORTION OF EACH BA COHORT WHOSE PRIMARY WORK ACTIVITY WAS RESEARCH AND DEVELOPMENT DURING 1968-70



Source: Appendix Table A6

Those physicians who enter upon a research career seem to remain in research throughout their careers, without exhibiting as strong a tendency as the Ph.D.'s to gravitate toward teaching or administration. The exception seems to be that group of M.D.'s with Ph.D.'s with no post-Ph.D. support, whose initial rate of participation in research is high but decreases in the older cohorts. The physicians also display the positive relationships between the amount of training and education, and the rate of participation in research. Overall, about 21% of the M.D.'s who have received post-M.D. support from NIH, but did not receive the Ph.D., listed research and development as their primary work activity in 1968-70; another 65% listed gave professional services to individuals as their primary activity, 10% listed teaching and the remaining 4% were in administration. However, for those M.D.'s with NIH post-M.D. support who attained the Ph.D., 50% listed research and development as their primary work activity in 1968-70, and only 18% listed professional services to individuals.

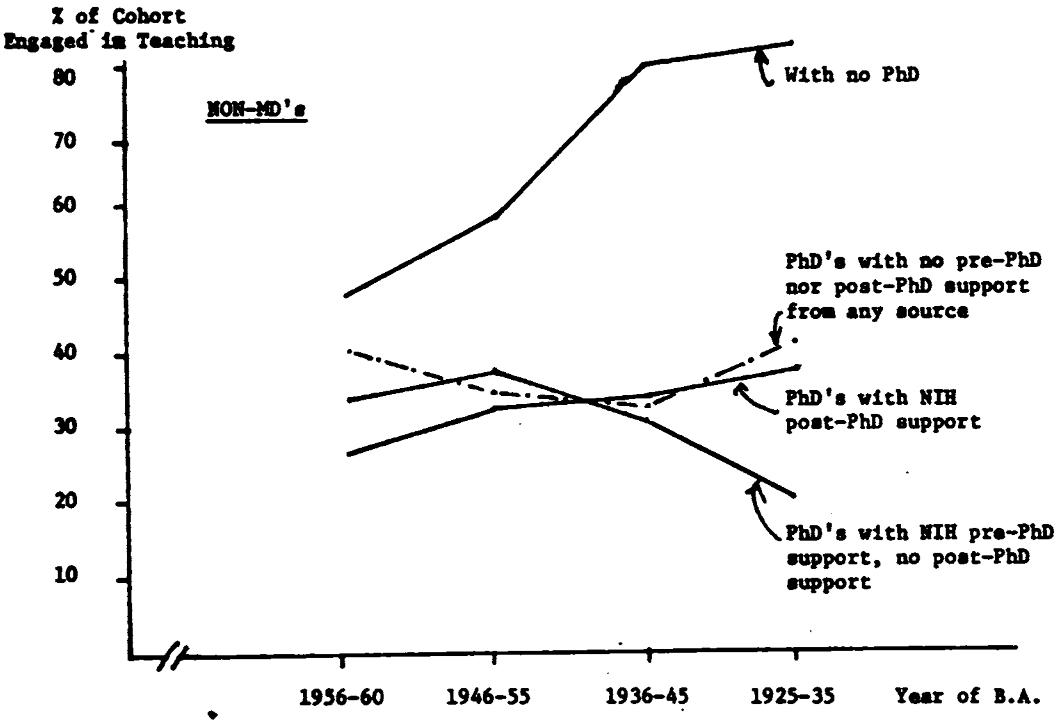
Each year roughly 1% of the non-M.D.'s cease doing research as their primary work activity, as indicated by the slopes of the curves in Figure 11. The kind of things they do after leaving research depends upon their background (Figures 12 and 13). Those without Ph.D.'s drop out of research rather quickly, move strongly into teaching, and tend to continue teaching without very much movement into management or administration. Ph.D.'s with post-Ph.D. training support remain in research longest, then move into teaching with very little movement into management or administration. Ph.D.'s without post-Ph.D. training support move from research to management or administration. Their participation in teaching is rather steady throughout all cohorts, but the older cohorts participate less in research and much more in management.

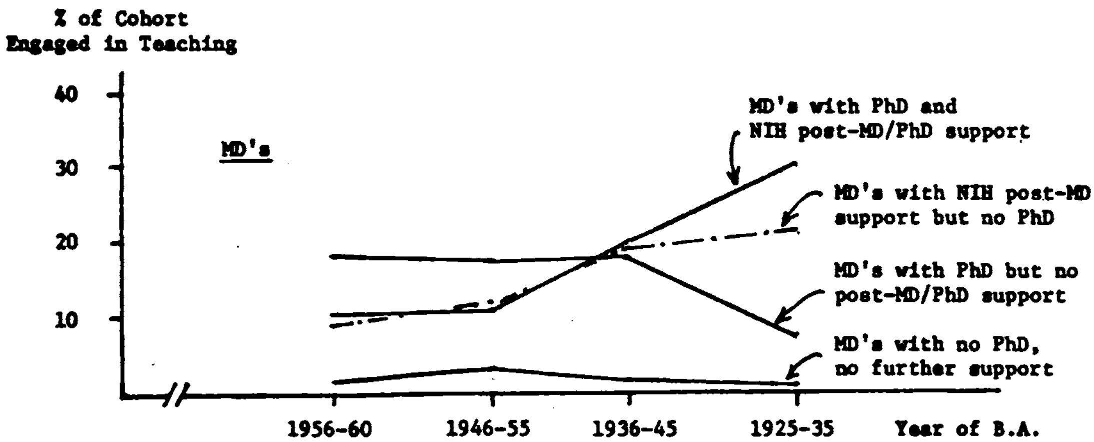
For M.D.'s (Figures 12 and 13), the general tendency is from research to management or administration, with no strong trend toward increased teaching activity for any group of M.D.'s.

2. Type of Employer

In contrast to the tendency for the non-M.D.'s to reduce their research activity with age, the same group shows a fairly steady tendency to remain employed by medical/dental schools or universities. As Figure 14 shows, the Ph.D.'s with post-Ph.D. support are employed more often by medical/dental schools and universities than any other group, with about 80% of each cohort being so employed. Even those applicants for graduate training programs who could not be identified as having received a Ph.D. are in large proportion employed by professional schools and universities. Recall that most of these are people who applied for but were not awarded fellowships; others were awardees who did not activate their awards. This group should not be considered as a representative sample of all graduate students because the fact that they applied for fellowships indicates an

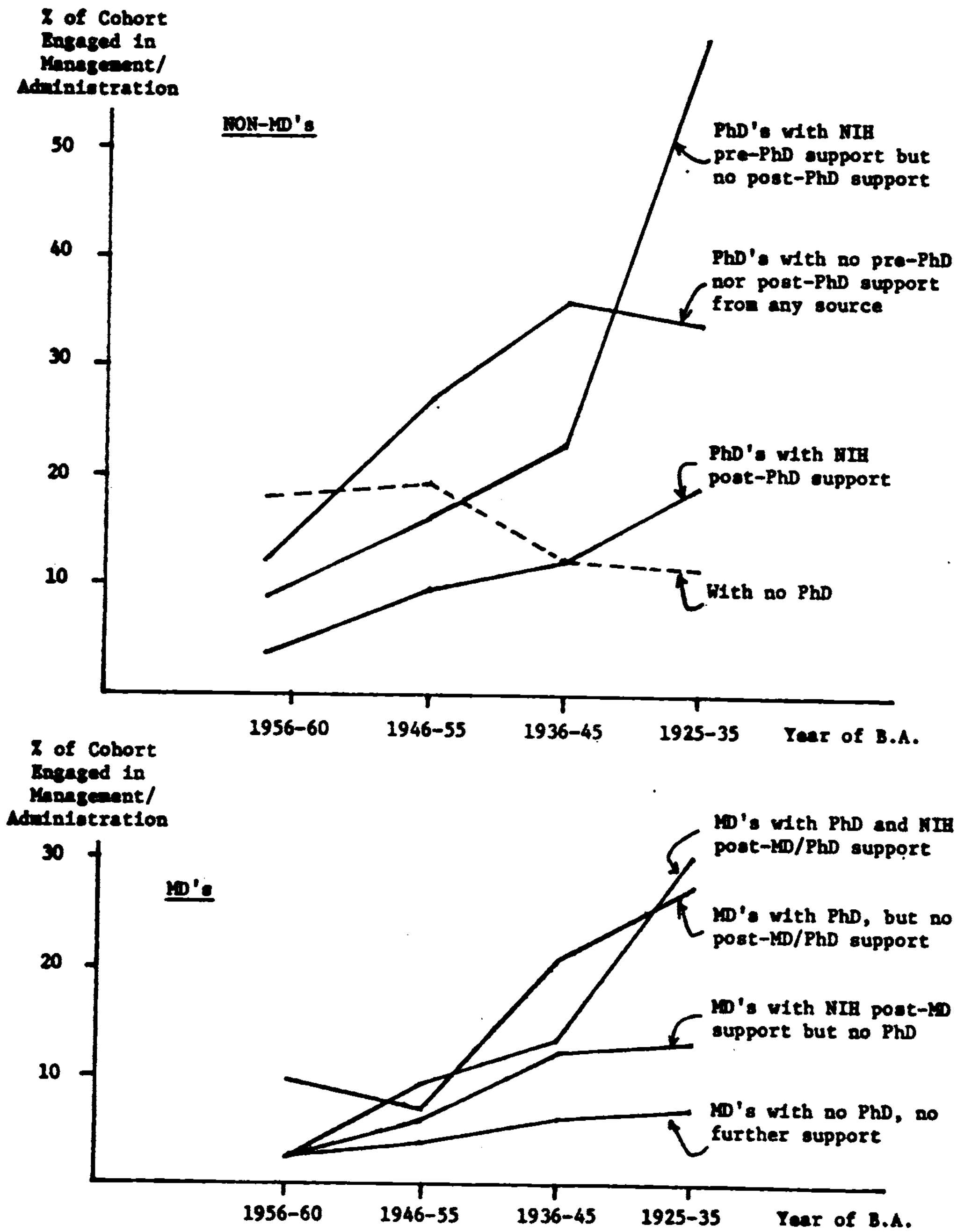
Figure 12 - PROPORTION OF EACH B.A. COHORT WHOSE PRIMARY WORK ACTIVITY WAS TEACHING DURING 1968-70





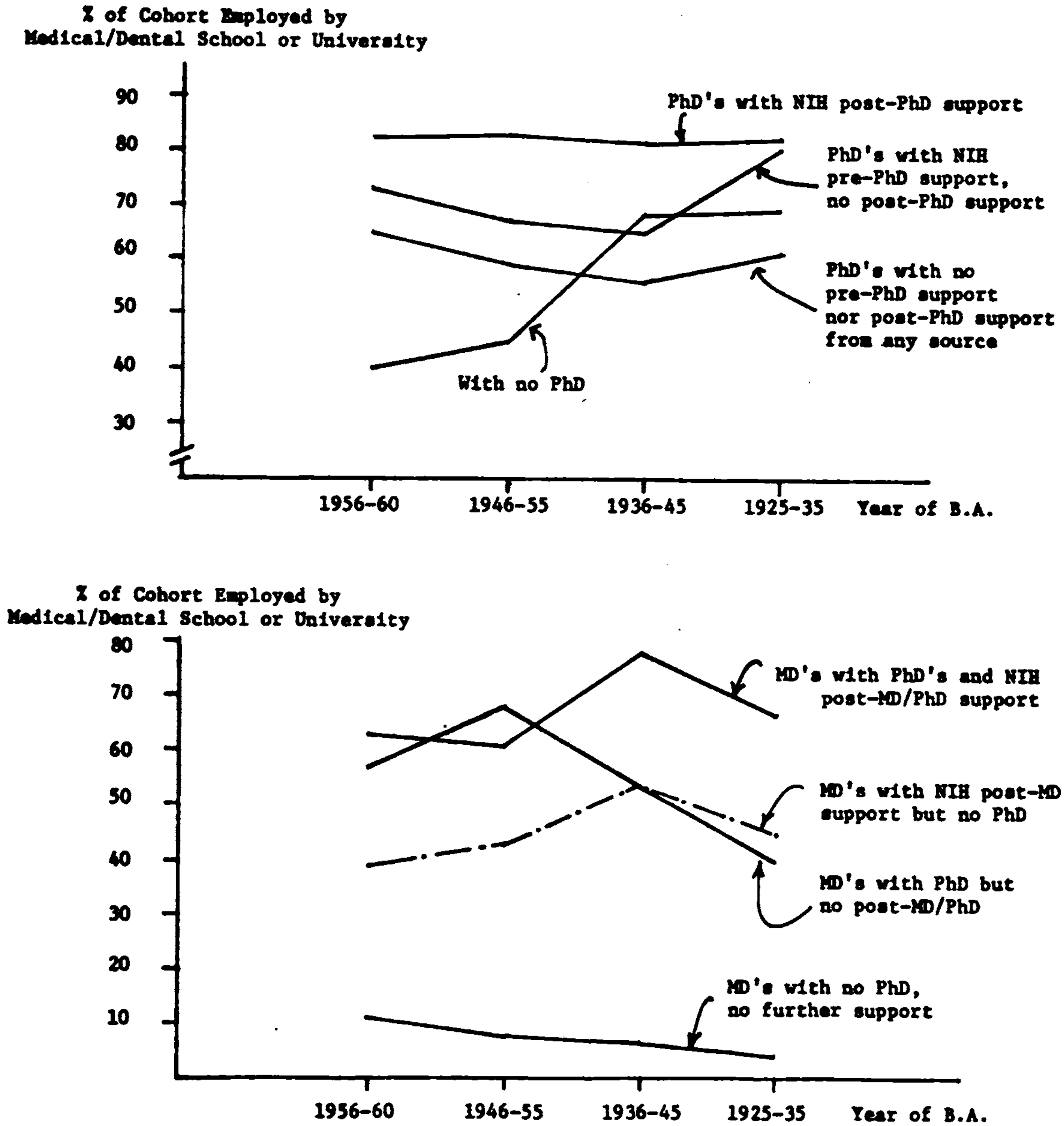
Source: Appendix Table A6

Figure 13- PROPORTION OF EACH B.A. COHORT WHOSE PRIMARY ACTIVITY WAS MANAGEMENT OR ADMINISTRATION DURING 1968-70



Source: Appendix Table A6

Figure 14 - PROPORTION OF EACH B.A. COHORT WHOSE EMPLOYER WAS A MEDICAL/DENTAL SCHOOL OR UNIVERSITY DURING 1968-70



Source: Appendix Table A6

above-average interest in teaching or research careers. Also the responses to the National Register of Scientific and Technical Personnel from which these data were derived tend to be weighted toward the academic community which makes up a large part of the disciplinary and professional groups that were surveyed for the Register. Therefore the proportion of this non-Ph.D. group that is employed by professional schools and universities is probably higher than would be expected in a strictly random sample of all non-Ph.D. scientists and engineers.

Over all cohorts, the largest proportion of M.D.'s employed by medical/dental schools and universities occurs among those who received post-M.D./Ph.D. support. Over two-third of the group were so employed. Those M.D.'s with post-M.D. support or with the Ph.D. also had a large proportion employed by professional schools or universities. Less than 8% of M.D.'s with no Ph.D. nor support beyond the M.D. are employed in this category.

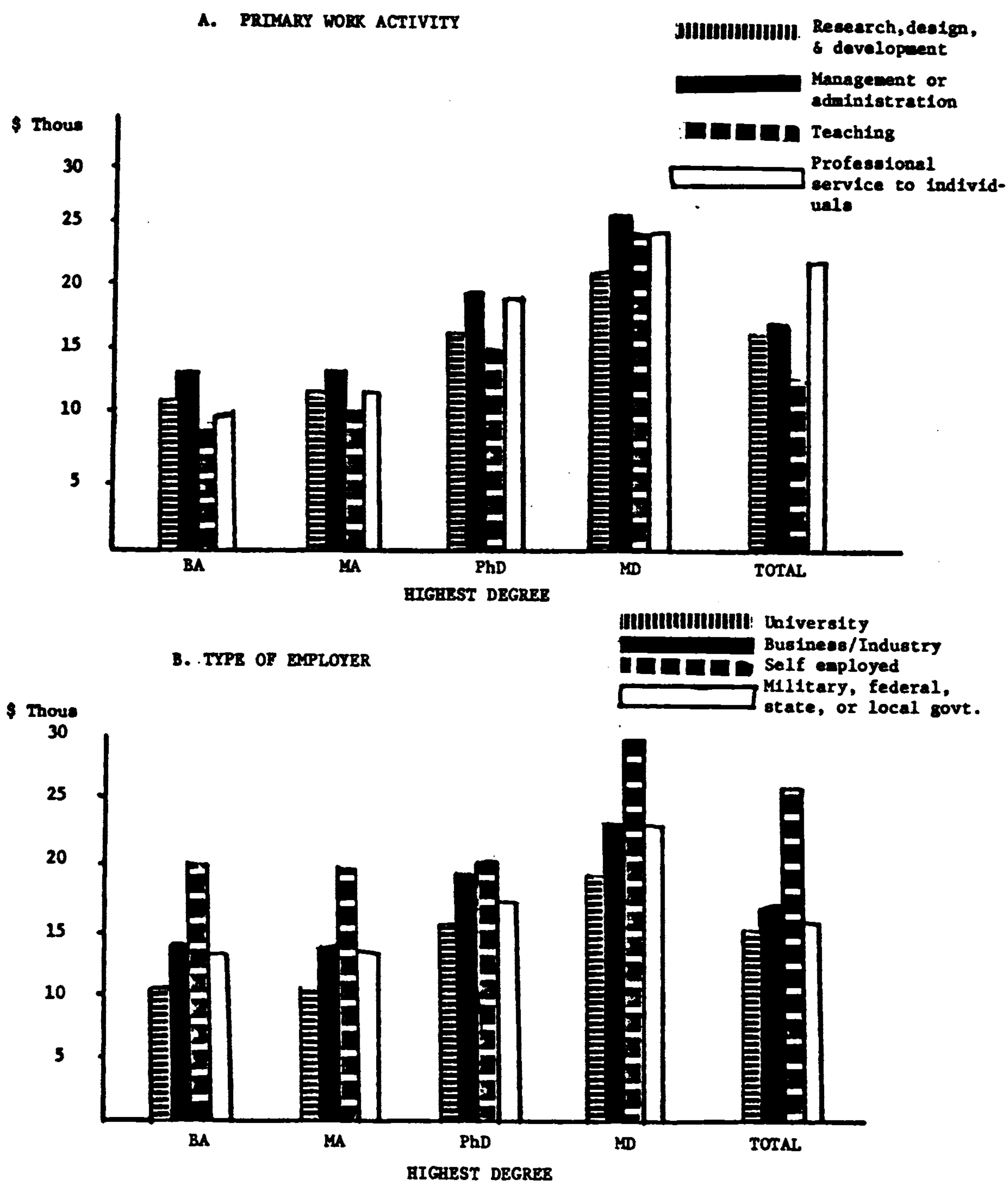
3. Salaries of Bioscientists in 1970

The National Register of Scientific and Technical Personnel provides extensive data on the salaries of scientists engaged in various work activities, for several different types of employer, and at different degree levels. These data indicate that research and teaching in the biosciences are on a lower pay scale than the alternative work activities of management, administration and professional services to individuals. Figure 15 and Table 10 show that at almost all degree levels, teaching is the lowest paid work activity of all those reported in the Register, equated for years of experience. Research and development pays somewhat more than teaching, but still less than other activities. The 1970 median reported salary of a Ph.D. bioscientist in research with 10-14 years of experience was $17,100 versus $20,200 for one in management or administration; for an M.D., the difference was 20%, $22,000 versus $26,400 (Figure 16).

Salaries can also be examined according to the various types of employers. From this point of view, people who work for educational institutions are paid considerably less than those who work for other types of employers. In 1970, the median salary of bioscientists with 10-14 years of experience working for a university on a calendar-year basis was about 10% less than that in business and industry, about 2% less than that in government and military service, and about 40% less than the median for self-employed persons (Figure 15, Table 11).

The 1970 National Register data provide evidence that the earnings differential in favor of M.D.'s carries over to these work activities and employer types. In the field of bioscience in 1970, an M.D. was paid 29% more than a Ph.D. when both were engaged in research and develop-

Figure 15 - 1970 MEDIAN REPORTED SALARY OF BIOSCIENTISTS WITH 10-14 YEARS OF EXPERIENCE



Source: National Register of Scientific & Technical Personnel, 1970, NSF, Washington, D.C.

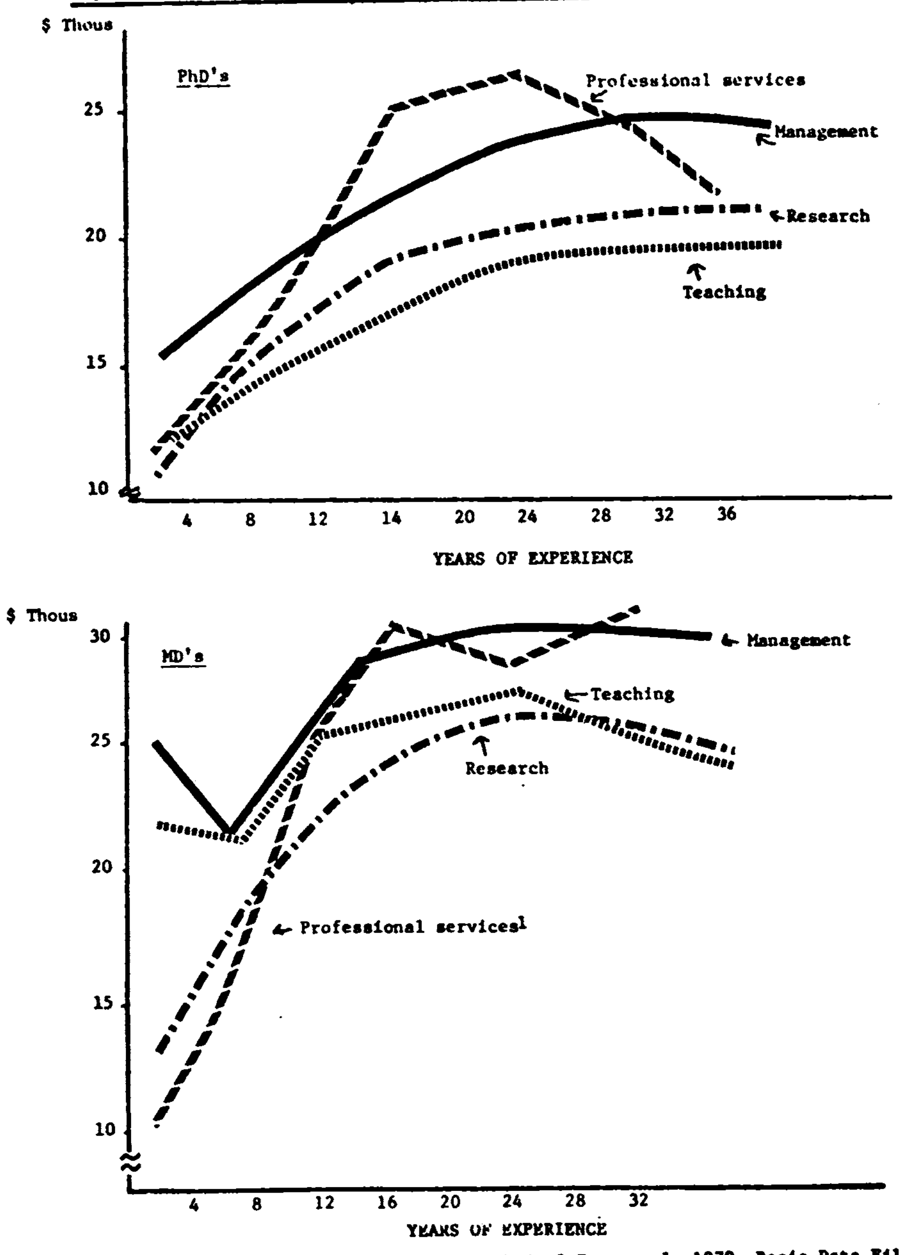
Table 10 - 1970 MEDIAN REPORTED SALARIES OF BIOSCIENTISTS, by degree, primary work activity, and years of experience (full-time employed on a calendar year basis)

Degree	Primary Work Activity	Years of Experience 0-4	5-9	10-14	15-19	20-29	≥30	Total	Base N
		(Thousands of Dollars)							
PhD	Mgt/Admin	15.3	17.9	20.2	22.2	23.9	25.0	21.5	3,080
	Res/Desgn/Dev	11.5	14.7	17.1	19.0	20.3	21.6	15.6	10,272
	Teaching	11.9	14.0	15.5	17.2	19.3	19.6	14.1	6,683
	Prof Servs	11.1	15.6	20.5	25.5	26.5	23.8	18.5	131
	Other	12.5	14.4	15.9	19.4	20.7	21.9	16.8	320
	Total, Known	11.9	14.8	17.2	19.5	21.1	22.1	15.8	20,486
Profes-sional Medical	Mgt/Admin	26.3	21.7	26.3	28.9	30.2	30.3	28.8	704
	Res/Desgn/Dev	12.8	18.9	22.3	24.7	26.7	25.2	21.8	1,807
	Teaching	21.0	21.8	25.6	26.6	28.1	25.0	25.4	702
	Prof Servs	10.2	14.4	25.5	29.0	29.0	32.3	20.9	665
	Other	8.2	11.0	25.5	21.7	28.0	28.8	15.5	94
	Total, Known	11.4	18.9	23.7	26.1	28.4	27.9	23.6	3,972
MA	Mgt/Admin	10.4	11.9	14.1	16.2	17.6	18.1	14.8	1,270
	Res/Desgn/Dev	8.5	10.7	12.8	13.8	14.2	17.1	11.1	1,958
	Teaching	8.2	9.9	11.1	12.3	12.2	12.0	10.7	3,361
	Prof Servs	8.0	10.9	12.4	13.2	11.5	18.0	11.3	118
	Other	9.0	11.5	13.3	14.9	14.5	18.0	12.4	432
	Total, Known	8.6	10.5	12.2	13.9	14.3	14.9	11.4	7,139
BA	Mgt/Admin	9.5	11.7	14.0	14.5	16.1	18.2	14.2	1,142
	Res/Desgn/Dev	7.4	10.1	11.9	13.2	14.1	14.2	9.9	1,713
	Teaching	7.4	8.3	10.0	10.3	10.1	9.6	8.3	1,107
	Prof Servs	7.4	10.4	10.1	12.5	12.6	10.8	10.6	214
	Other	8.1	10.4	12.1	13.2	13.9	15.0	10.7	587
	Total, Known	7.6	9.9	11.9	13.2	14.5	15.3	10.5	4,763
Other	Mgt/Admin	--	--	--	--	--	--	--	(a)
	Res/Desgn/Dev	6.7	--	10.5	--	--	16.5	10.5	11
	Teaching	--	--	--	--	--	--	--	(a)
	Prof Servs	--	--	--	--	--	--	--	(a)
	Other	--	--	--	--	--	--	--	(a)
	Total, Known	7.1	9.7	10.5	--	--	20.5	12.3	25
Total, All Known Degrees	Mgt/Admin	12.0	14.4	17.6	20.5	22.2	23.9	19.4	6,227
	Res/Desgn/Dev	9.9	13.8	16.8	18.5	20.0	20.9	14.8	15,817
	Teaching	9.3	11.1	13.3	15.8	17.7	18.1	12.7	11,870
	Prof Servs	9.2	12.7	19.6	22.0	24.8	28.0	15.0	1,135
	Other	8.7	11.3	13.3	15.2	16.4	19.0	12.4	1,438
	Total, Known	9.8	13.1	15.9	18.3	20.2	21.2	14.5	36,487

Source: National Register of Scientific and Technical Personnel, 1970, NSF, Washington, D.C.

(a) less than 10 observations

Figure 16 - 1970 MEDIAN SALARY PROFILES OF BIOSCIENTISTS IN VARIOUS WORK ACTIVITIES



Source: National Register of Scientific and Technical Personnel, 1970, Basic Data File, National Science Foundation, Washington, D. C.

[1]The income data in this chart was derived from a biennial survey of members of professional societies. The M.D.'s who responded to this survey were mainly employed by medical schools and universities and cannot be considered representative of the general population of M.D.'s, most of whom are in private practice and whose median income in 1970 was about $41,000.

Table 11 - 1970 MEDIAN SALARIES OF BIOSCIENTISTS,
by degree, type of employer, and years of experience
(full-time employed on a calendar year basis)

Degree	Type of Employer	Years of Experience 0-4	5-9	10-14	15-19	20-29	≥ 30	Total	Base N
		(Thousands of Dollars)							
PhD	Bus/Industry	15.9	17.5	19.7	21.9	23.0	24.2	19.2	1,888
	Elem/Jr Coll/2-Yr Tech	10.1	12.0	13.6	15.0	16.0	15.7	13.8	184
	Med/Dental School	11.7	15.1	18.1	20.3	22.3	23.4	17.0	3,902
	University	10.7	13.8	15.9	17.7	19.7	20.6	14.2	10,257
	Hosp/Clinic	11.8	16.0	17.9	20.9	23.6	19.6	17.4	536
	Self	----	15.0	20.5	22.1	29.2	23.0	23.6	59
	Mil/Fed, St, Loc Govt	12.1	15.1	17.0	19.6	21.0	23.3	17.1	2,765
	Other	10.3	14.4	17.6	19.4	21.2	22.5	16.6	895
	Total, Known	11.9	14.8	17.2	19.5	21.1	22.1	15.8	20,486
Professional Medical	Bus/Industry	14.2	22.1	23.6	29.2	27.1	27.6	26.5	157
	Elem/Jr Coll/2-Yr Tech	9.0	----	12.0	13.0	----	----	11.5	21
	Med/Dental School	13.2	19.2	23.9	26.1	28.8	27.8	24.0	2,062
	University	11.2	13.2	20.0	20.5	25.7	24.0	20.6	222
	Hosp/Clinic	9.0	18.4	23.9	28.3	31.4	37.3	24.0	430
	Self	16.5	22.6	31.0	38.0	38.0	35.5	30.7	179
	Mil/Fed, St, Loc Govt	11.2	17.5	23.0	25.0	26.7	27.7	21.8	778
	Other	9.0	18.0	23.0	26.3	28.3	26.2	23.8	123
	Total, Known	11.4	18.9	23.7	26.1	28.4	27.9	23.6	3,972
MA	Bus/Industry	11.0	12.7	14.1	16.2	18.1	20.5	14.2	935
	Elem/Jr Coll/2-Yr Tech	8.2	9.9	11.3	12.5	12.3	12.1	11.0	2,562
	Med/Dental School	7.8	10.1	11.5	12.7	14.0	15.7	10.4	279
	University	6.7	8.5	11.0	12.7	12.6	14.7	9.8	1,461
	Hosp/Clinic	9.6	10.7	13.0	13.8	15.0	16.5	12.1	244
	Self	6.0	8.2	20.5	10.5	23.6	13.5	15.8	50
	Mil/Fed, St, Loc Govt	8.9	11.5	13.1	15.0	15.3	17.1	12.9	1,408
	Other	8.5	11.0	12.8	13.2	13.6	15.7	11.5	200
	Total, Known	8.6	10.5	12.2	13.9	14.3	14.9	11.4	7,139
BA	Bus/Industry	10.2	11.3	13.7	14.2	16.2	17.2	13.2	1,059
	Elem/Jr Coll/2-Yr Tech	7.5	8.3	10.0	10.5	10.2	9.4	8.3	992
	Med/Dental School	6.6	8.5	10.3	10.6	13.5	14.0	8.0	283
	University	4.9	7.5	10.6	12.7	13.0	13.5	6.4	530
	Hosp/Clinic	7.9	10.3	10.8	10.7	11.3	10.8	10.0	307
	Self	13.5	18.0	20.5	17.2	18.0	10.5	14.6	59
	Mil/Fed, St, Loc Govt	8.1	10.8	12.6	13.8	15.0	16.7	12.1	1,343
	Other	7.2	9.0	12.6	11.5	13.6	12.7	10.1	190
	Total, Known	7.6	9.9	11.9	13.2	14.5	15.3	10.5	4,763
Other/No Degree	Bus/Industry	13.5	----	----	----	----	----	----	(a)
	Elem/Jr Coll/2-Yr Tech	----	----	----	----	----	----	----	(a)
	Med/Dental School	----	----	----	----	----	----	----	----
	University	----	----	----	----	----	----	----	(a)
	Hosp/Clinic	----	----	----	----	----	----	----	(a)
	Self	----	----	----	----	----	----	----	----
	Mil/Fed, St, Loc Govt	----	----	----	----	----	----	----	(a)
	Other	----	----	----	----	----	----	----	(a)
	Total, Known	7.1	9.7	10.5	----	15.0	20.5	12.3	25
Total, All Known Degrees	Bus/Industry	13.3	14.8	16.9	18.8	20.4	21.8	16.7	4,063
	Elem/Jr Coll/2-Yr Tech	7.7	9.4	11.1	12.2	12.2	11.8	10.4	3,766
	Med/Dental School	10.5	15.3	19.8	21.8	24.6	24.5	18.3	6,554
	University	9.4	13.0	15.3	17.2	19.2	20.1	13.6	12,491
	Hosp/Clinic	9.1	13.1	17.4	19.6	21.6	19.1	15.0	1,533
	Self	14.4	19.6	26.7	29.4	27.4	24.0	23.3	349
	Mil/Fed, St, Loc Govt	9.9	13.0	15.2	17.6	19.0	21.5	15.0	6,314
	Other	8.8	13.3	16.6	18.2	20.2	21.9	15.3	1,417
	Total, Known	9.8	13.1	15.9	18.3	20.2	21.2	14.5	36,487

Source: National Register of Scientific and Technical Personnel, 1970, National Science Foundation, Washington, D. C.

(a) less than 10 observations

ment work, and 62% when both were engaged in teaching, equating for years of experience. The differential exists because the alternative of private practice open to the M.D. creates a market situation such that a premium must be paid in order to attract M.D.'s into research or teaching careers. In contrast to the Ph.D., the M.D. can often earn substantial income from practice in addition to the salary paid by a university or medical school.

The relative earning power of B.A.'s, Ph.D.'s, and M.D.'s is illustrated in Figure 17. The B.A. and Ph.D. scientists and engineers reach their peak earnings at about 34 years of experience, the M.D.'s somewhat earlier at about 28 years of experience. At his peak, the typical Ph.D. bioscientist was paid 30% less than the M.D.'s who responded to the NSF survey with the same number of years of experience. Furthermore, because the National Register survey was weighted toward academia, the median salary of the M.D.'s reported in the National Register ($24,000) was 41% less than the median income for all U. S. physicians in 1970 ($41,000). Table 10 shows the median salary profile by degree level and primary work activity; Table 11 shows similar data for type of employer. These data have not been adjusted to constant dollars.

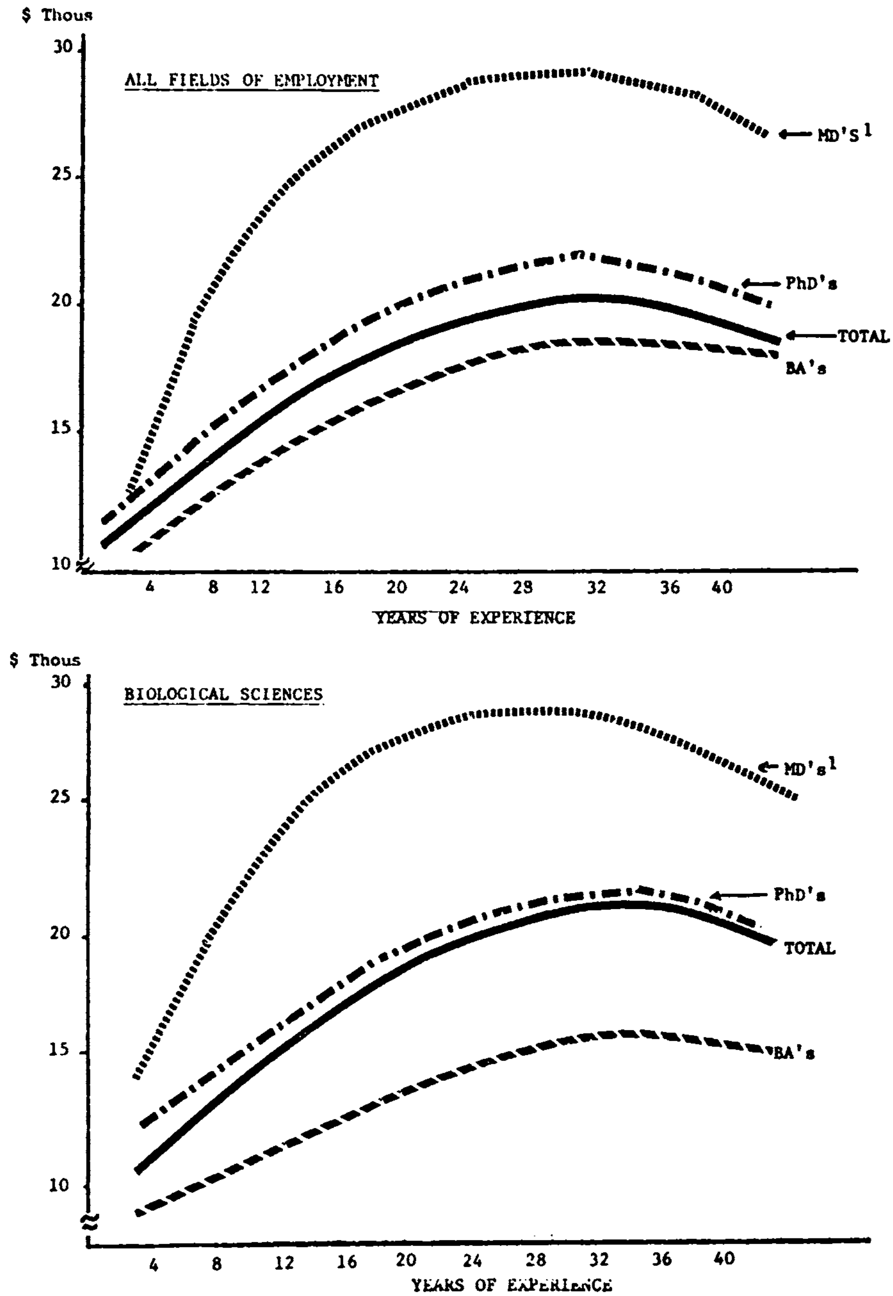
D. PUBLICATIONS AND CITATIONS

In the previous section it was shown that the interaction between research training and a research commitment results in the production of a stream of individuals with the greatest rate of participation in research activities. We would expect that a similar relationship might apply to the number of publications that an individual produces or the number of citations to such publications in the scientific literature. In this section we shall examine this relationship.

For this study, we used the computerized files of the Science Citation Index, referred to above, for the period 1961-1972. These files, which totaled more than 25 million citations and more than 5 million publications, were matched by name of author against the rosters of the individuals in the study groups to gather the data on the total number of publications and citations credited to each person during this 1961-1972 period. (The citations could of course refer to works published before 1961).

The matching of these files was the most difficult of all collation procedures used in this study. The only identifying information available from the Science Citation Index about the authors is the last name and initials whereas in other files, date of birth, academic degrees, sex, etc. were usually available to provide more positive identification. For this reason, only those individuals whose names were unique in the study group files were used in this analysis of publication and citation data. For example, if two different individuals, both named John A. Smith were in the

Figure 17 - MEDIAN SALARY PROFILE OF SCIENTISTS AND ENGINEERS AT VARIOUS DEGREE LEVELS



Source: American Science Manpower, 1970, NSF, Washington, D.C.

[1]The income data in this chart was derived from a biennial survey of members of professional societies. The MD's who responded to this survey were mainly employed by medical schools and universities and cannot be considered representative of the general population of MD's, most of whom are in private practice and whose median income in 1970 was about $41,000.

study group, it was not possible to distinguish between them in the Citation Index because of lack of other identifying information and so they were omitted from this analysis. However if a name appeared only once in the study group, the chance that all citations to that name in the Citation Index were one and the same person were greatly improved. Hence these unique names were the only ones used in this analysis of publication and citation data. While this procedure reduced the number of individuals in the study set to about 300,000, it also minimized the chances of mismatching them with the names in the Citation Index. Statistically, the omission of these data did not, in our opinion, impair the validity of the test of the broad relationships being studied.

The study showed that the average number of publications and citations per person tends to increase with the amount of education and training received. And as with work activity and type of employer, this kind of relationship can be shown to hold for M.D.'s and non-M.D.'s, and for NIH-supported scientists as well as non-NIH supported ones. Figure 18 and Table 12 shows the results of the analysis for non-M.D.'s in the biosciences. Each curve in Figure 18 represents a different pathway of education or training. In 18 (a) the average number of publications per person in each age bracket is displayed, and in 18 (b) the average number of citations per person in each age group is shown.

The researchers who publish most are those with post-Ph.D. support; their publication rate is generally twice as high as those Ph.D.'s without postdoctoral support. This is true of postdoctorals supported by NIH and also of non-NIH postdoctorals. As Table 12 shows, there is very little difference in publication rate between these two groups of postdoctorals. Whether or not a bioscientist had pre-Ph.D. support does not seem to affect his research output directly so long as he attains the Ph.D. Those Ph.D.'s with predoctoral but no postdoctoral support do not seem to publish any more frequently than those Ph.D.'s without predoctoral support who do not take a postdoctoral. The non-Ph.D. bioscientists have the lowest publication rate in each age group, a fact which conforms to the rate of participation in research of this group.

The story told by the citation data for the non-M.D.'s in bioscience is almost identical to that of the publications. The only noticeable difference is the tendency for the average number of citations per person to continue to increase for the older Ph.D.'s with postdoctoral support instead of tapering off as do the average publications per person. Otherwise the structure is identical.

For the M.D.'s, the number of publications and citations is even more closely related to the attainment of the Ph.D. (Figure 19, Table 12). The M.D.'s with Ph.D.'s and post M.D./Ph.D. support generally have the highest publication rate of all M.D.'s and they are closely followed by the

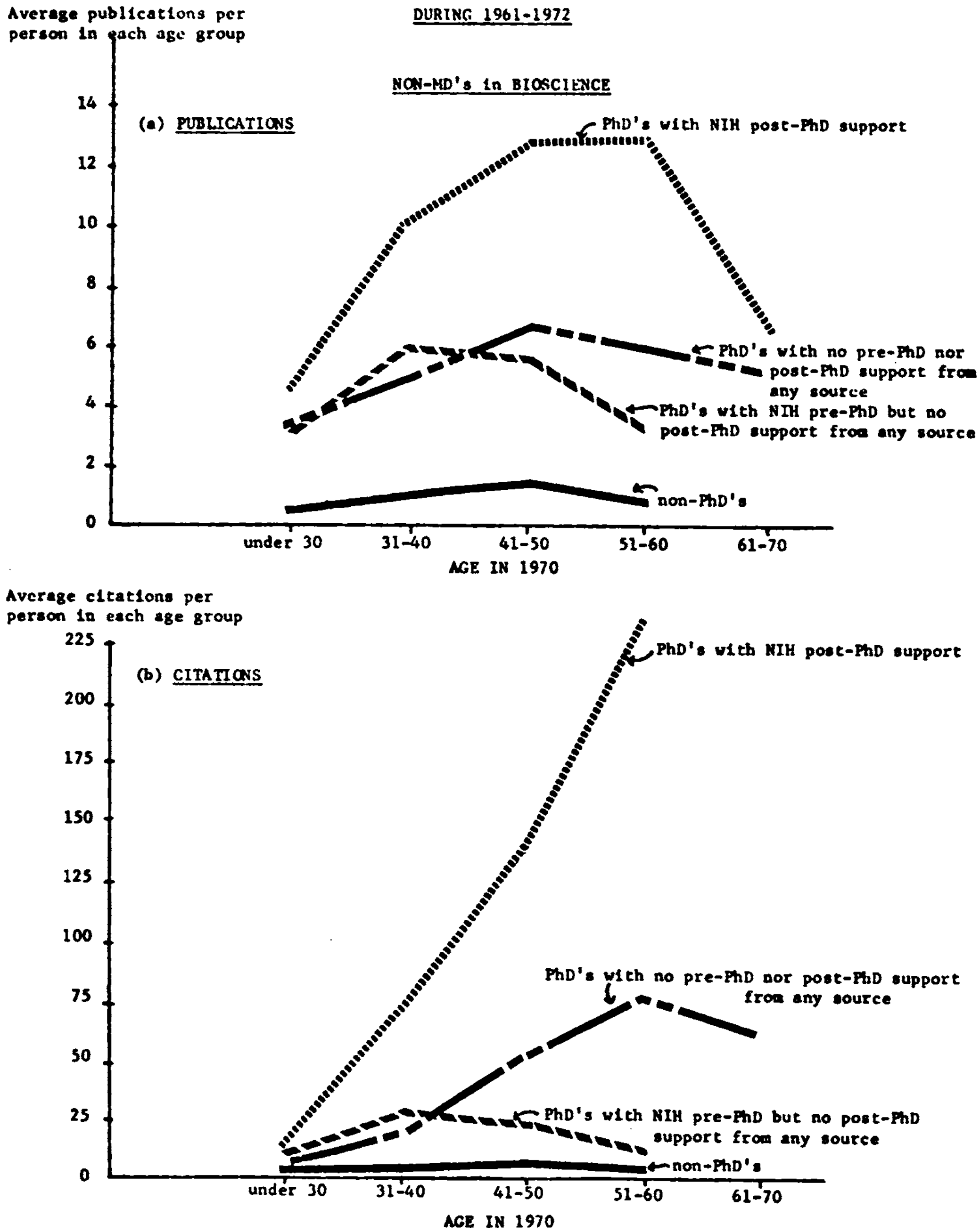
Table 12 - AVERAGE NUMBER OF PUBLICATIONS AND CITATIONS PER PERSON IN EACH AGE GROUP DURING 1961-1972

TRAINING PATHWAY	AGE IN 1970														
	Under 30			31-40			41-50			51-60			61-70		
	Pub Per Person	Cit Per Person	Number of Persons	Pub Per Person	Cit Per Person	Number of Persons	Pub Per Person	Cit Per Person	Number of Persons	Pub Per Person	Cit Per Person	Number of Persons	Pub Per Person	Cit Per Person	Number of Persons
NON-MD BIOSCIENTISTS															
1. NIH pre-PhD's →no PhD	0.6	1.2	8830	1.0	2.8	2041	1.4	5.1	471	0.8	2.1	81	(a)	(a)	(a)
2. No pre-PhD→PhD→no post-PhD	3.3	8.9	386	4.9	21.8	753	6.5	52.7	556	5.9	75.9	301	5.1	60.8	93
3. NIH pre-PhD→PhD→no post-PhD	3.1	9.4	2009	5.8	26.2	1520	5.5	24.5	233	3.2	11.5	29	(a)	(a)	(a)
4. Non-NIH pre-PhD→PhD→no post-PhD	2.6	6.0	704	5.9	34.8	646	6.2	45.7	465	3.9	71.4	54	(a)	(a)	(a)
5. Total--PhD's with pre-PhD support	2.9	5.8	2713	5.8	28.8	2166	6.0	38.6	698	3.7	50.5	83	(a)	(a)	(a)
6. PhD→NIH post-PhD	4.4	13.3	610	10.2	73.1	1148	12.7	138.0	647	13.0	241.2	151	6.6	178.5	39
7. PhD→non-NIH post-PhD	4.8	19.2	113	9.0	62.0	218	12.5	130.4	414	9.3	150.5	166	6.5	98.4	37
8. Total--PhD's with post-PhD support	4.5	14.2	723	10.0	71.3	1366	12.7	135.0	1061	11.1	193.7	317	6.5	139.5	76
MD'S															
9. NIH pre-MD→no post-MD→no PhD	1.1	2.8	2850	2.0	7.5	991	0.9	3.2	32	--	--	--	--	--	--
10. No NIH pre-MD→no post-MD→no PhD	0.7	1.2	2504	1.2	4.6	4232	1.8	10.4	4028	1.3	9.9	2857	1.0	6.9	1784
11. Total--MD's with no further support, no PhD	0.9	2.1	5354	1.4	5.2	5223	1.8	10.3	4060	1.3	9.9	2857	1.0	6.9	1784
12. NIH pre-MD→NIH post-MD→no PhD	2.8	6.7	560	5.6	20.0	541	(a)	(a)	(a)	--	--	--	--	--	--
13. No NIH pre-MD→NIH post-MD→no PhD	2.0	3.6	1878	6.0	26.4	7575	8.7	58.8	2367	8.9	72.3	211	5.1	39.5	33
14. Total--MD's with NIH post-MD, no PhD	2.2	4.3	2438	5.9	26.0	8116	8.7	58.6	2376	8.9	72.3	211	5.1	39.5	33
15. NIH pre-MD→no NIH post-MD→PhD	4.9	21.7	33	6.9	63.9	12	--	--	--	--	--	--	--	--	--
16. No NIH pre-MD→no NIH post-MD→PhD	(a)	(a)	(a)	16.6	70.1	30	22.8	226.0	30	22.3	197.5	30	(a)	(a)	(a)
17. NIH pre-MD→NIH post-MD→PhD	7.3	16.5	26	8.0	45.3	22	(a)	(a)	(a)	--	--	--	--	--	--
18. No NIH pre-MD→NIH post-MD→PhD	4.4	14.6	96	10.9	50.2	449	12.5	126.0	187	14.0	221.8	30	(a)	(a)	(a)
19. Total--MD's with PhD, no further support	4.9	16.2	157	11.0	51.5	512	13.9	139.2	218	18.4	209.6	60	15.7	200.7	10
20. MD's with PhD's and NIH post-MD/PhD support	5.3	39.6	24	13.6	84.1	262	16.8	143.4	197	11.7	224.0	38	(a)	(a)	(a)

Source: Science Citation Index, 1961-72, Institute for Scientific Information, Philadelphia, Pa., Commission on Human Resources, NAS/NRC, Washington, D. C.

(a) Less than 10 observations.

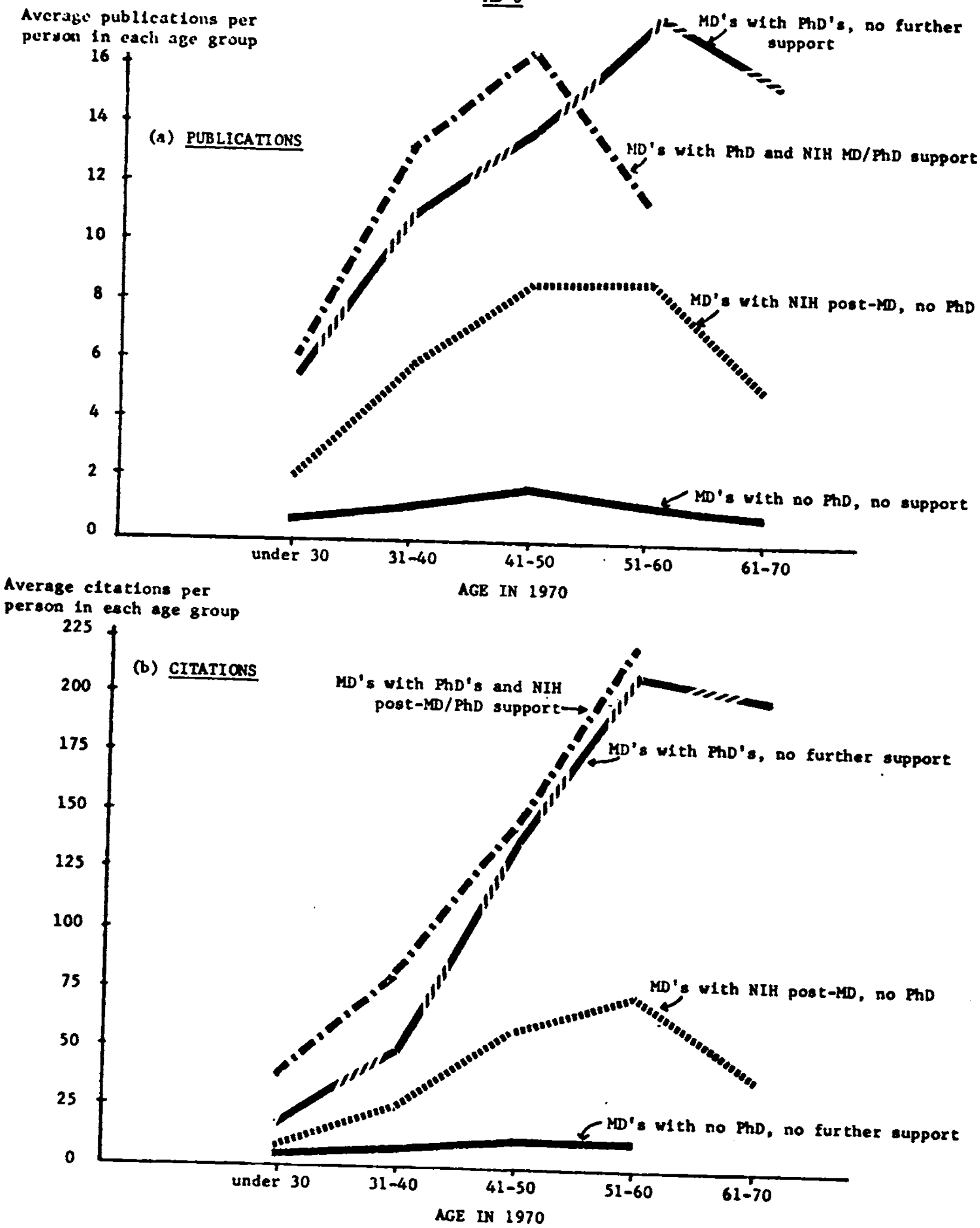
Figure 18 - AVERAGE NUMBER OF PUBLICATIONS AND CITATIONS PER PERSON IN EACH AGE GROUP DURING 1961-1972



Source: Science Citation Index, 1961-72, Institute for Scientific Information, Philadelphia, Pa., Commission on Human Resources, NAS/NRC, Washington, D. C.

Figure 19 - AVERAGE NUMBER OF PUBLICATIONS AND CITATIONS PER PERSON IN EACH AGE GROUP DURING 1961-1972

MD's



Source: Science Citation Index, 1961-72, Institute for Scientific Information, Philadelphia, Pa., Commission on Human Resources, NAS/NRC, Washington, D. C.

M.D.'s with Ph.D. but no post-M.D./Ph.D. support. In fact, both of these groups of M.D.'s with Ph.D.'s publish more frequently than all groups of non-M.D.'s with Ph.D.'s, except possibly for those with postdoctoral support.

The M.D.'s with no Ph.D. but with NIH post-M.D. support are in the middle range in terms of publications and citations. They are comparable to the Ph.D. groups with no postdoctoral support in this respect.

The M.D.'s who do not receive additional research training either in the form of a Ph.D. or a post-M.D. fellowship or traineeship produce fewer papers and are cited least frequently. They correspond to the bioscientists without Ph.D.'s in terms of their numbers of publications and citations.

In summary, a consistent pattern is apparent from the analyses of primary work activity, and publication and citation data. Higher levels of education and training are associated with larger numbers of papers published and citations received. The patterns are generally consistent for non-M.D.'s and M.D.'s and over all age groups.

But one should be cautious about inferring any cause and effect relationship here. The association noted above might be primarily a reflection of the desire of those inclined towards research careers to acquire additional education and training. If this is the case then it is this predisposition towards research rather than the additional education or training that is the real underlying cause of a high level of research activity. The Ph.D. degree, and the supported period of training, seem to take on the role of a catalyst that produces the required impetus towards a research career in those so inclined. In this view, the predisposition towards research becomes the necessary condition and the education and training become the sufficient conditions for a high level of research activity.

previous chapter were drawn by looking at the career outcomes of groups of individuals with and without training-grant or fellowship support, the results of this chapter emanate from the interrelationships that exist among the many variables involved in graduate education.

A. MODELING THE FACTORS INFLUENCING THE GROWTH OF GRADUATE EDUCATION

Since 1920, college attendance at all levels has increased faster than the population. The percentages of the college-age population who graduate from college, who enroll in graduate school, and who obtain Ph.D. degrees have been steadily increasing for at least 50 years. However, despite contrary impressions, the growth rates for the last 15 years are not much different from those of the first 18 years of the period since 1920, as shown in Table 13.

Although it is interesting to look at the growth in higher education in absolute numbers, most of the variables move together and are strongly correlated over time, making it difficult to separate their effects. A better understanding of the forces involved can be obtained by viewing them in relative terms. There is a natural relationship among the variables in Table 13 that arises from the flow of students through the education process. These quantities constitute a progression of events, each one largely limited by the previous one. Thus it is to be expected that the annual production of B.A.'s would vary in response to changes in the 20-24 age group; that graduate enrollments should vary largely in response to the number of B.A.'s awarded in the previous year; and that the annual production of Ph.D.'s should vary according to the level of graduate enrollments in prior years. Superimposed on this process are the economic and personal factors that influence career decisions.

In a steady state situation, therefore, where outside influences

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Market for College Trained Manpower, Harvard University Press, Cambridge, Massachusetts, 1971.

Robert McGinnis has studied the impact of federal funds on graduate enrollments and Ph.D.'s awarded as well as on size of faculty and other aspects of graduate education in Federal Funding and Graduate Education in Bioscience, Commission on Human Resources (formerly Office of Scientific Personnel), National Academy of Sciences, Washington, D. C., February 1, 1972. (Unpublished)

Stephen Dresch has examined some of the economic factors accounting for the growth in graduate education since World War II. See An Economic Perspective on the Evolution of Graduate Education, National Board on Graduate Education, National Academy of Sciences, Washington, D. C., March 1974.

Table 13 - ANNUAL GROWTH RATES OF POPULATION AND GRADUATE EDUCATION

	1920-38	1956-70	1920-71
	%	%	%
Population, age 20-24	1.3	3.8	0.8
BA degrees	6.4	6.8	4.9
Graduate enrollments	10.1	9.1	7.3
PhD degrees	9.2	9.8	7.0

Growth rates were derived from basic data provided by the following sources:

Historical Statistics of the United States, Colonial Times to 1957 Continuation to 1962 and Revisions, Bureau of the Census, U. S. Department of Commerce, Washington, D. C., 1965.

Statistical Abstract of the United States, Bureau of the Census, U. S. Department of Commerce, annual editions, Washington, D. C., 1966-72.

Current Population Reports, Bureau of the Census, U. S. Department of Commerce, series P-25, Washington, D. C., 1970.

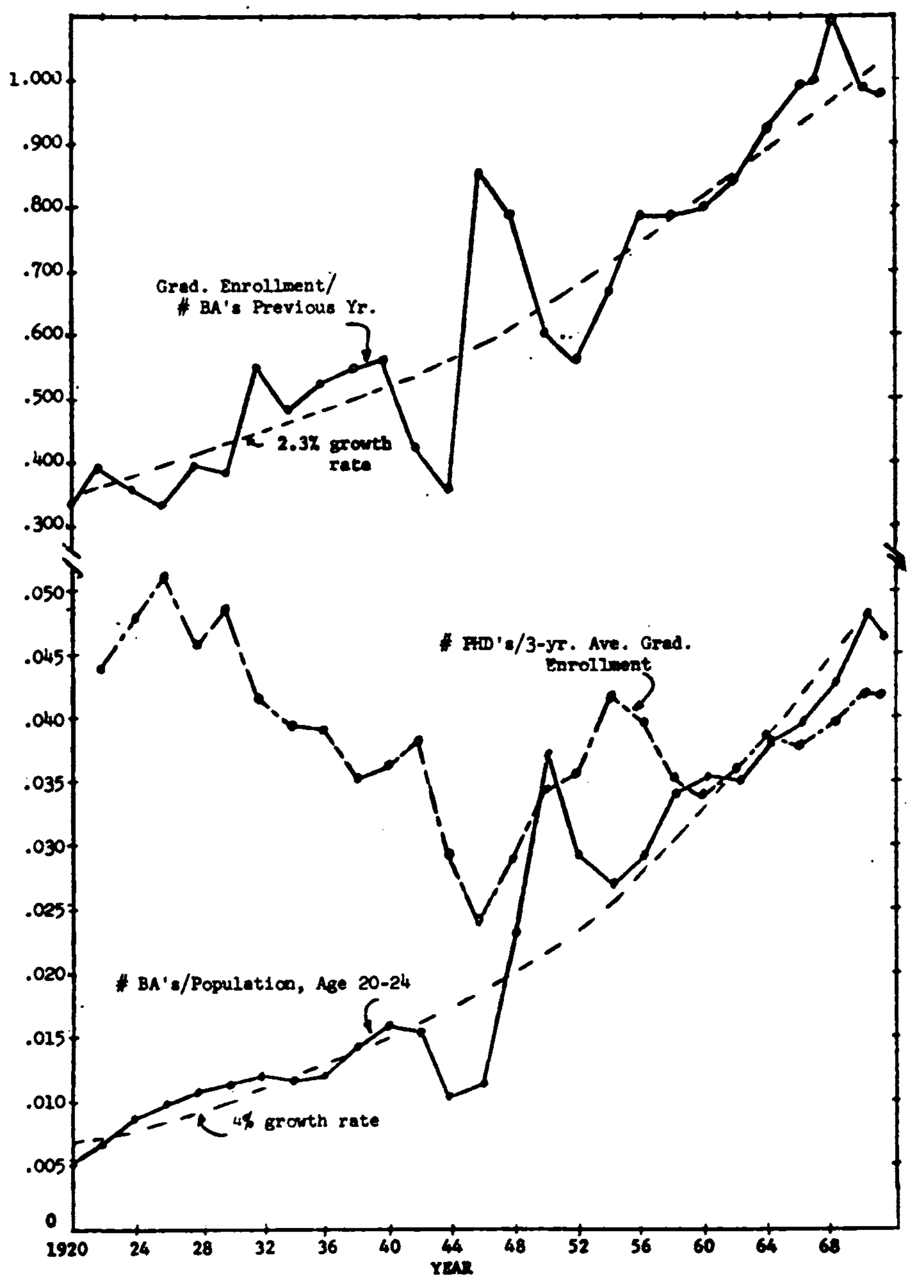
such as market forces or government policies are constant, and where student preferences are stable, the ratios of enrollments and degrees granted to the population pool from which they are drawn (i.e., BA/population 20-24, graduate enrollments/BA_{i-1} [i.e., B.A.'s awarded in previous year], PhD completions/graduate enrollment) should remain essentially unchanged. Hence, any significant deviations of these ratios from a constant value can be presumed to be caused by other than simple demographic factors.

Clearly, as Figure 20 shows, these ratios have not been constant over the years. The ratio BA/P(20-24) has grown at an average rate of about 4% per year since 1920; graduate enrollment/$BA's_{i-1}$ has grown at about 2.3% per year; while PhD's/$\overline{EN}$ (where $\overline{EN}$ = three-year moving average of graduate enrollments) decreased at about 2% per year from 1920 to 1946 and since then has increased at a rate of 1.3% per year. Further, these increases are not the consequence of stable, smooth growth but the overall result of an irregular pattern which includes periods of decline as well as of increase.

Thus, it is apparent that non-demographic factors have been operating to increase the proportion of the population participating in higher education. Several economic factors emerge as possible explanations for these observed changes: salaries of college graduates relative to those of non-graduates, federal financial support for students in higher education, aggregate personal income, and federal funds for research and development. Since these economic factors, especially those determined by federal policy, are of primary interest to this study, an attempt has been made here to separate the effects of the economic variables from those of the demographic ones. This has been done by starting with a population of the approximate age of B.A. recipients (20-24 years old) and examining the behavior of ratios similar to those shown in Figure 20.

It is important to note that, with one exception, this study considers only factors which are associated with student demand for graduate education as measured by enrollments. This is because we assume that throughout the period examined, the supply of both undergraduate and graduate places was sufficient to absorb all student demands without any change in admission standards or the real costs of tuition. Thus, in economic parlance, supply of places in graduate school is treated here as if it were infinitely elastic, and, therefore, could have had no influence on the numbers of students enrolled or graduated. There is no question that some schools did indeed raise their admission standards and limit their graduate enrollments in the face of unprecedented student demands, and a few may even have raised tuition in response to these forces. Nevertheless, on the whole, American

Figure 20 - TRENDS IN DEGREES AND ENROLLMENTS 1920-71



Sources: Historical Statistics of the United States, Colonial Times to 1957, Continuation to 1962 and Revisions, Bureau of the Census, U. S. Department of Commerce, Washington, D. C. , 1965.

Statistical Abstract of the United States, Bureau of the Census, U. S. Department of Commerce, Washington, D. C., annual editions, 1966-72.

Current Population Reports, Bureau of the Census, U. S. Department of Commerce, series P-25, Washington, D. C., 1970.

institutions of higher education absorbed a high percentage of those willing and financially and intellectually able. The obvious exception involves medical education, where lack of places clearly has been a deterrent to enrollments. Medical school enrollment, therefore, is included as an explanatory variable in this study because inability to enter a medical school may have induced some individuals to opt for graduate education in the life sciences.

Further, it should be noted that among the explanatory variables considered, there is no variable to reflect unfilled job vacancies for graduates or unemployment rates among graduates. Lack of adequate data precluded the use of such variables. Consequently these factors are manifested only to the extent that labor market conditions are reflected in earnings of graduates, for which data, although not in full detail, are available.

The basic method of the study is multiple regression analysis[2] in which the dependent variables, which are measures of graduate student flows defined in relative rather than absolute terms, are regressed on a group of explanatory variables by a method explained in detail below.[3]

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[2]Here we must necessarily become somewhat technical in our discussion. The general reader who does not wish to explore these details may skip ahead to page 86 for a summary of the methodology.

Multiple regression is a statistical procedure in which a series of observed values of the primary variable (the dependent variable) is collected jointly with a set of observed values of other variables (the "explanatory" variables) which are thought to affect the behavior of the primary variable. By examining the correlations among the dependent and explanatory variables, a linear function of the explanatory variables is constructed which provides the best fit to the pattern formed by the observed values of the dependent variable. The values of the dependent variable differ from one another partly by chance and partly because they are associated with varying values of the explanatory variables. In this sense, the explanatory variables are said to "explain" part of the variation in the dependent variable. The object of regression analysis is to construct a linear function of explanatory variables which accounts for as much of the variation in the dependent variable as possible. For a good technical explanation of regression analysis and its ramifications see J. Johnston, Econometric Methods, McGraw-Hill, New York, 1972.

[3]Since all of the explanatory variables were considered to be exogenous, no simultaneous equation estimation procedure was used. Each equation was treated independently by ordinary least-squares or a step-wise variation thereof.

One set of equations was developed in which the dependent variable is an aggregate quantity for all fields of study combined. Another set was developed for such specific broad fields of graduate study as bioscience and physical science, including engineering. Here, dependent variables are defined in most equations as ratios of graduate students enrolled or receiving degrees in a specific field in relation to the total of all fields. In other equations the dependent variable is defined as the ratio of first-year graduate enrollments in a field to the pool of B.A.'s presumed qualified for entrance to graduate study in that field.

The particular procedure used to estimate the equations is step-wise[4] regression, in which the specific explanatory variables included in an equation are selected sequentially from the complete set of explanatory variables on the basis of their contribution to the reduction in the error variance in the dependent variable. A variable is retained in the final equation only if its inclusion significantly reduces this variance. At the same time, if the inclusion of a new variable reduces the contribution of another previously included variable below the level of significance, that earlier variable is dropped from the equation. As applied here, this method also used lagged values of certain explanatory variables—that is, student aid, salaries, aggregate income—so that it selected not only the "best" variables but their "best" lags from the standpoint of maximization of reduced error variance. Use of lagged variables where data permit provides estimates of the time it takes for student flows to respond to changes in explanatory factors, and thus enhances the explanatory power of the model.

The variables chosen by this step-wise regression technique, however, may not be those most meaningful from a logical, conceptual, or "common-sense" standpoint. To allow for this, the procedure was modified to insure that each variable selected not only makes a significant reduction in the error variance, but also has the logically correct sign and has what seems to be a logical relationship with the dependent

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[4]A more detailed description of the step-wise procedure is as follows: The first explanatory variable selected is the one with the highest simple correlation with the dependent variable. Then, from the remaining variables the one which most decreases the remaining variation in the dependent variable is added. To these variables is then added the variable which again most explains the remaining variation, and so on until no explanatory variables are left whose inclusion would further significantly reduce the residual variation. If during this process the significance of a variable included in an earlier step is reduced below the critical confidence level (.05) by the inclusion of a variable at a later stage it is eliminated from the equation.

variable. The equations presented below are those which emerged from this approach which combines the selection of the most potent explanatory variables with informed judgment regarding logical and conceptually meaningful relationships. The variables included in these equations also were adjusted for the problem of multicollinearity as discussed later in this section.

An alternative approach would have been to make an a priori specification of the explanatory set of variables which conceptually could determine the behavior of the dependent variable, and then to see if the hypothesis was supported by the data. This approach was tried in a number of cases as described in Appendix B. In general, the a priori approach yielded less satisfactory results in terms of logical and statistical properties than the empirical one embodied in the step-wise procedure.

In a regression equation, the influence of each "explanatory" variable is measured by its statistical properties, i.e., the regression coefficient, and standard error.[5] The net regression coefficient is an estimate of the change in the dependent variable associated with a change of one unit in the explanatory variable. It is not really a good measure of the relative importance of each explanatory variable because its magnitude largely depends on the units of measurement. What is needed to compare the relative influence of the different explanatory variables is a measure of the proportion of the variance in the dependent variable that is accounted for by each explanatory variable in the equation acting independently. The measure that is generally used for this purpose is the standardized partial regression coefficient.[6] Under

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[5]In a step-wise procedure such as this, where special constraints are put on the selection of the variables, the usual interpretation of the standard error and significance levels is no longer valid. They may still be used as indices but cannot be given the frequency interpretation usually associated with them.

[6]See for example G. W. Snedecor and W. G. Cochran, Statistical Methods, 6th edition, Iowa State University Press, Ames, Iowa, 1967, p. 398. The standard partial regression coefficients are defined as $b_i(S_i/S_0)$ where b_i is the regression coefficient of the i^{th} explanatory variable, S_i and S_0 are the standard deviations of the i^{th} variable and the dependent variable respectively. Let Y be the dependent variable and X an explanatory variable. The standard partials measure the change in Y as a fraction of Sy, per change in X equal to Sx. Thus if X has a standard partial regression coefficient of 0.95, it means that a change of 1 standard deviation in X will produce a change of .95Sy in Y. On the other hand, the ordinary regression coefficient measures the change in Y per unit change in X. Hence the standard partials represent a means of evaluating the explanatory variables according to their normal range of variation.

certain conditions, this measures the contribution of each explanatory variable to the variation associated with the dependent variable. The problem is that this interpretation is strictly applicable only under the condition that the explanatory variables in the equation be independent (uncorrelated), a condition that is rarely met in practice. In most applications, the explanatory variables are intercorrelated to some extent (this condition is called multicollinearity) and the values of the regression coefficients calculated from the data are very sensitive to these intercorrelations. For example, two highly correlated explanatory variables in an equation will have coefficients much smaller than they would have if collinearity were not present. As multicollinearity becomes weaker, the utility of the standard partial regression coefficients as a measure of relative importance becomes greater. Multicollinearity is a troublesome factor in many ways in regression analysis, and therefore an attempt has been made here to minimize its effects. Wherever possible, an explanatory variable has been prevented from entering an equation if it was highly correlated with variables already selected. This was possible in cases where another variable could be substituted without sacrificing too much explanatory power. As it turned out, in many of the equations the explanatory variables are ratios, and these are not so highly intercorrelated to preclude the use of the standard partial regression coefficients to measure the relative importance of the variables.

To summarize, the general approach to determining the net effect of economic variables, including federal financial assistance, on changes in the proportions of students enrolled or graduating entails development of multiple regression equations. The overall set of potential explanatory variables derives from concepts of the determinants of student flow into higher education. The selection of particular variables from among this set, and the estimation of their relative impact on the flows, was determined by the application of a modified step-wise regression procedure.

The general intent of this analysis is to provide an empirical examination of the forces that have impinged on the flow of students in graduate education. However it is well recognized that regression analysis, and especially the step-wise procedure applied here, cannot provide <u>proof</u> of any cause and effect relationships, no matter how well designed or comprehensive a study is conducted. The most that can be achieved is to show that the dependent variables are closely correlated with certain other variables over the set of data points used in the analysis. <u>But such correlation by no means proves causation</u>—for several reasons. First, the set of variables used in any relationship may only be proxies for the true causal factors that influence the behavior of the dependent variable. Second, the correlation between the dependent variable and the so-called explanatory variables may exist only by chance over the data set analyzed, but may not exist at all for data points outside the set. Analyses of time series data and small samples are especially vulnerable to this pitfall and unfortunately neither large samples nor adequate cross-sectional data were available in this study to verify the results. Therefore no claim of proof is being made here that any of the empirically derived relationships are causal. The equations were developed using variables which conceivably and logically could bear cause and effect relationships to the dependent variables. Inferences were then drawn on the assumption that the "explanatory" variables used in the equations are closely related to the true causal factors. The conclusions reached in this study rest heavily on this assumption. Validation of the results must await verification from additional data and further analyses.

The data were in the form of annual values, i.e., time series for the 1956-70 period. The complete set of data used in this analysis is presented in Appendix C. The candidate "explanatory" variables fall into the following categories (it should be noted that data permit some of these variables to be lagged, thus introducing opportunities to estimate rates of response):

1. Federal expenditures for fellowships and traineeships broken out by field
2. Federal funds for research by field
3. Salaries of physicians and dentists; salaries of bioscientists, physicists and chemists at the Ph.D., M.A. and B.A. levels; faculty salaries (professor, associate professor, assistant professor, instructor); incomes of college graduates, incomes of high school graduates
4. Veterans Administration funds for education
5. Medical school applicant and enrollment data
6. Selective Service Administration data on registrations and inductions
7. Number of bioscientists, chemists, physicists, and total scientists at the Ph.D., M.A., and B.A. levels as reported in the National Register of Scientific and Technical Personnel
8. Aggregate real disposable personal income

B. PRINCIPAL FINDINGS

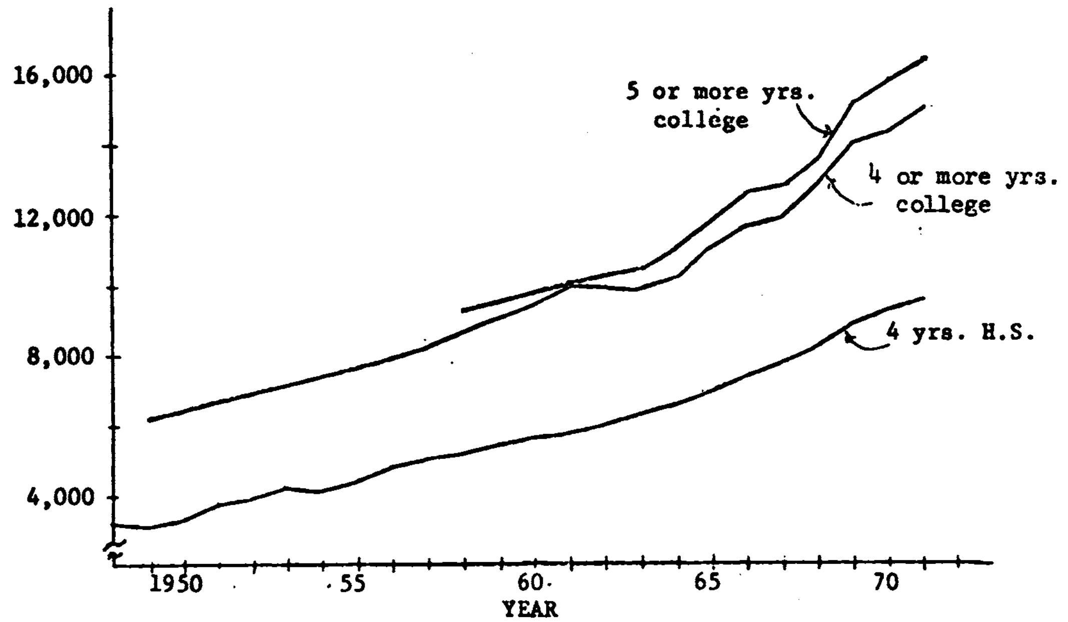
When the "explanatory" variables (to the extent that they are available) are examined statistically in relation to the trends in degrees and enrollments, the empirical evidence indicates that federal aid to students in graduate education has had the greatest influence on degree and enrollment ratios, followed by income and by expenditures for research. Income seems to have its greatest impact on the ratio of B.A.'s to population age 20-24, while federal aid to graduate students has had a strong influence on the proportions enrolling in graduate school and obtaining Ph.D. degrees. It should be noted that B.A.'s as used here includes first professional degrees such as L.L.B., M.D., D.D.S., etc., because this is the way the data were defined and collected by the Office of Education up to 1961. Graduate enrollments are those enrolled in a program leading to an M.A. or Ph.D. degree or the equivalents.

Salaries of college graduates in all fields have increased steadily in absolute terms, but not relative to others in the labor force (Figure 21). There is still a considerable differential in lifetime earnings between those with and without a college degree, but this differential has been rather constant and by itself does not seem to account for the increasing proportions of graduate enrollments and Ph.D. degrees. This conclusion is consistent with the observed low rates of return to Ph.D.'s due to the large amount of income foregone during their training period.[7] Rather, this differential seems to provide a constant

[7] See, for example, Duncan Bailey and Charles Schotta, "Private and Social Rates of Return to Education of Academicians," American Economic Review, March 1972.

Figure 21 - AVERAGE ANNUAL INCOME OF MALES 25 YEARS AND OVER

(current dollars)



Sources: Current Population Reports, Bureau of the Census, U. S. Department of Commerce, series P-25, Washington, D. C., 1970

Miller, Herman P., "Annual and Lifetime Income in Relation to Education: 1939-1959," The American Economic Review, vol. 50, pp. 962-985 (1960).

incentive to attend college while the growth in absolute income and in student aid provide the means for doing so. Another way of looking at it is to consider participation in higher education as an investment in human capital, and that given the difficulty of commercial educational borrowing, more and more such personal investment takes place as personal incomes rise, providing sources of funds. At the baccalaureate and first professional degree level, incomes seem to play a major role in career choices. Incremental investment in graduate education, however, appears to have been somewhat more heavily influenced by direct student aid programs than by salary differentials.

C. AGGREGATE EQUATIONS (ALL FIELDS COMBINED)

To see how these principal findings were arrived at, consider first of all the ratio of B.A.'s awarded per year in all fields to the 20-24 year old population. Figure 22a indicates how this variable behaved over the period of study. Equation (1) shows the best results that could be obtained from the regression analysis. (The values in parentheses under each explanatory variable are the standard partial regression coefficients which under the conditions outlined above, attempt to measure the relative importance of each explanatory variable in the equation. All regression coefficients are significant at the .05 level except where noted.)[8]

B.A. equation:

$$(1)\quad (BA/P)_i = -0.01 + \underset{(0.98)}{0.0043(\$B)_i} + \underset{(0.35)}{8.2 \times 10^{-6}(SA)_{i-1}}\ ; \quad R^2 = 0.95$$

where BA/P = (Baccalaureate/Population Ratio). Number of B.A.'s relative to 20-24 year old population.

$B = (BA salaries). Real median salary of all professional and technical personnel whose highest degree is a B.A.: ($thousands, deflated by the Consumer's Price Index [CPI]).

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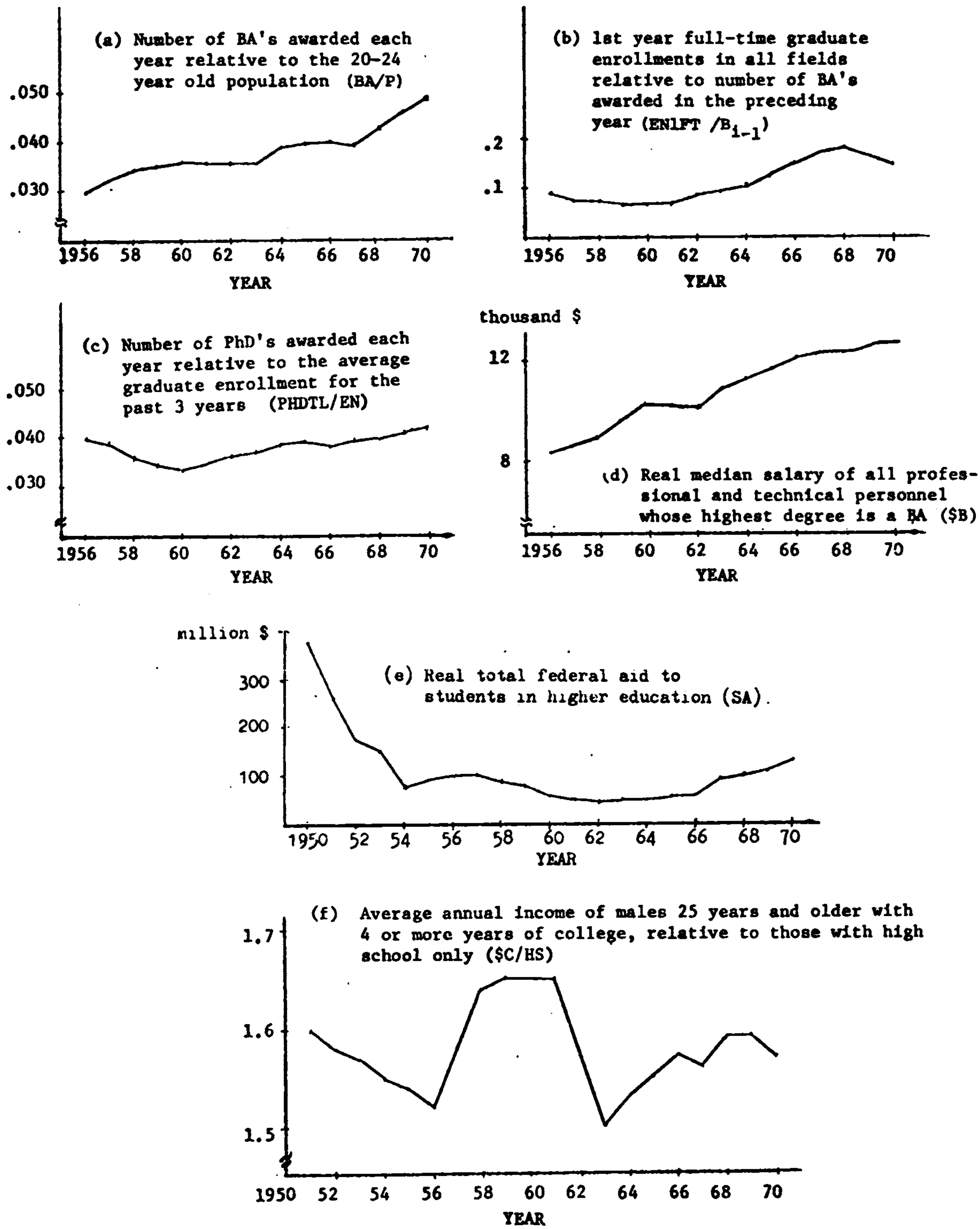
[8]The Durbin-Watson test indicates that positive, first order autocorrelation is present in at least some of the equations presented in this chapter. No attempt has yet been made to correct this condition, although further work on these models would require that attention be given to this problem. The main consequences of autocorrelation are a serious underestimate of the sampling variances of the regression coefficients and predictions with excessively large variances. See J. Johnston, *op. cit.*, p. 246. Regarding the significance levels, see footnote 5, p. 85.

Figure 22 - GRADUATE ENROLLMENTS, DEGREES, AND SOME "EXPLANATORY" VARIABLES



SA = (Student Aid, higher education). Real total federal aid to students in higher education; includes all traineeship and fellowship stipends plus VA benefits for higher education: ($millions, deflated by the CPI).

R^2 = The coefficient of determination, a measure of the goodness of fit of a regression equation. If the dependent variable is perfectly estimated by the linear function of explanatory variables, then $R^2 = 1$; if there is no correlation, then $R^2 = 0$.

In equation (1), the B.A. ratio is related to the median B.A. income ($B) and to federal aid for students in higher education in the previous year $(SA)_{i-1}$, both adjusted for price changes by dividing by the Consumers Price Index. In this equation, $B has a much greater impact on BA/P than does SA as measured by the standard partial regression coefficients.

Graduate enrollment equation:

$$(2)\quad EN1FTL_i/B_{i-1} = 0.13 + 1.67 \times 10^{-4} SAGE_{i-1} + 3.94(PD)_i \;; \quad R^2 = 0.94$$
$$\qquad\qquad\qquad\qquad (0.89) \qquad\qquad (0.26)$$

where $EN1FTL_i/B_{i-1}$ = (Ratio of graduate Enrollment to Baccalaureate degrees). First year full-time graduate enrollments in all fields relative to number of B.A.'s awarded in preceding year.[9]

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[9]The symbols used here for enrollments are intended to have mnemonic characteristics. First-year graduate enrollments were disaggregated into full-time, part-time, and total. A six-character symbol was used to represent these first-year enrollment variables within each field and total over all fields. The six characters have the following interpretation:

1st and 2nd characters:	EN = Enrollments
3rd character:	1 = first year
4th character:	F, P, or T = full-time, part-time, or total
5th and 6th characters:	TL = total graduate enrollments
	BI = bioscience graduate enrollments
	PE = physical science and engineering graduate enrollments

Thus the symbol EN1FTL stands for first-year, full-time graduate enrollments in all fields.

Total graduate enrollment including first year is represented by a

SAGE = (Student Aid, Graduate Education). Real total federal aid to students in graduate education. Includes all traineeships and fellowships plus 10% of VA direct benefit payments to students in higher education: ($millions, deflated by the CPI).

PD = (Probability of being drafted). Probability of being inducted into military service—computed as the ratio of the number of inductions to the number of classified registrants each year.

Equation (2) shows the results for first-year full-time graduate enrollments relative to the number of B.A.'s awarded in the preceding year (Figure 22b). The student aid variable (SAGE), lagged one year, seems to have had the greatest influence on relative first-year full-time enrollments, in combination with a variable measuring the probability of being drafted (PD). It should be noted that available data do not permit construction of an income variable which relates earnings of graduates to earnings of B.A.'s for the entire period under consideration. Such a variable if available would be a logical one to use to test the hypothesis that the number of B.A. degrees is affected by relative incomes.

Equations were also developed for first-year part-time, first-year total, and total graduate enrollments, with the student aid variable, a research funds variable, and an income variable involved (see Appendix B for details).

Ph.D. completion equation:

$$(3)\quad PhDTL_i/\overline{EN}_i = -0.018 + \underset{(1.01)}{3.19 \times 10^{-5} SAGE_{i-7}} + \underset{(0.46)}{0.023(\$C/HS)_{i-4}} + \underset{(0.20)}{0.010(\$C/HS)_{i-7}}\ ; \qquad R^2 = 0.93$$

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four-character symbol defined as follows:

1st and 2nd characters: EN = Enrollments (total graduate enrollments)
3rd and 4th characters: TL = total over all fields
BI = bioscience
PE = physical science and engineering

Thus the symbol ENTL stands for total graduate enrollment over all fields.

where $PhDTL_i/\overline{EN}_i$ = (PhD/Enrollment Ratio). Total number of PhD's in the i^{th} year relative to the average graduate enrollments for the past three years.

$C/HS = (College/High School salary ratio). Average annual income of males 25 years and older with four or more years of college, relative to those with high school only.

(SAGE is defined above.)

The dependent variable in equation (3) is the ratio of the number of Ph.D. degrees awarded annually relative to the average number of graduate students over the last three years ($PhDTL_i/\overline{EN}_i$). Thus it is an indicator of completion rates over time. Here the combination of federal aid of graduate students (SAGE) and the college/high school salary differential ($C/HS) with two different lags provide the best estimates of relative Ph.D. production, with SAGE again predominant.

The general picture that emerges from the equations is that at the graduate level, direct federal student aid has been a potent and perhaps the dominant force acting to increase the proportions of students who continue their education beyond the B.A. A consistent pattern emerges showing that relative graduate enrollments and Ph.D. degrees are closely related to student aid and to salary differentials, but in most cases, the student aid variable has greater impact. At the B.A. level, the reverse seems to be true. Salaries of B.A.'s and student aid are the best predictors, but salaries have the greater influence.

In Figure 22, some of the variables are illustrated to provide graphic evidence of the relationships. Since all the variables used in this analysis were in time series form, strong correlations could occur between the dependent and explanatory variables simply because they both have increased steadily over time. In such a case, one might be tempted to accept a true relationship between the variables when in fact their relationship is due only to the fact that both exhibit strong trends over the time period of the study. To guard against such an error, the correlations among the variables were examined both before and after removing the linear trend component from the time series. If a strong correlation disappeared after removing the trend, the variables were not considered to be truly related. The results of that analysis are presented in Appendix B.

D. DISTRIBUTION BY FIELD OF STUDY

The number of B.A.'s awarded annually has been tabulated by the U. S. Office of Education since 1870, and the Commission on Human Resources of the National Research Council maintains detailed records of the Ph.D. population in its Doctorate Records File back to 1920, but it has only been since 1955 that data on graduate enrollments by field have been available. Only very rough estimates of the amount of student aid to each field are available for this same time period. Yet, even with these approximate data, there is evidence that the distribution of graduate students among the various disciplines seems to have been influenced by the proportionate share of direct student aid (fellowships and traineeships) that is made available to each field. This conclusion seems to hold at least for the fields analyzed in this study: bioscience and the physical sciences including engineering. The amount of support to these fields has varied in magnitude and timing, and these variations are reflected in the behavior of relative graduate enrollments in subsequent years.

1. Bioscience Equations

In most of the bioscience equations, the dependent variables were formed by relating bioscience graduate enrollments and Ph.D.'s awarded to corresponding totals over all fields. Enrollments were again broken out by first-year full-time, first-year part-time, first-year total, and total bioscience graduate enrollments. Only the results for first-year total bioscience enrollments and Ph.D.'s awarded are shown below in equations (4) and (6)—the others are presented in Appendix B. Equation (5) examines an alternative definition of the enrollment variable.

Enrollment equations:

$$(4)\quad (EN1FBI/EN1FTL)_i = 0.016 + \underset{(1.06)}{0.026(NIHTF/SAGE)_{i-3}} - \underset{(-0.42)}{1.52 \times 10^{-6}(MDENR)_i}$$

$$+ \underset{(0.34)}{0.034(R_{1p}/R_t)_i}\ ; \qquad R^2 = 0.85$$

where (EN1FBI/EN1FTL) = (Relative first-year bioscience enrollments). First-year total graduate enrollments in bioscience relative to total first-year graduate enrollments in all fields.

NIHTF/SAGE = (Relative NIH student aid funds). NIH appropriations for training grants and fellowships relative to total federal aid for graduate students.

MDENR = Total enrollments in medical schools.

R_{lp}/R_t = (Relative funds for research in the life and physical sciences). Federal funds for research in the life sciences and physical sciences relative to total federal funds for research in all fields. The physical sciences were combined with the life sciences in this variable in order to develop a broad measure of research support reflecting the degree of overlap in these fields.

In equation (4), 85% of the variation in relative first-year bioscience enrollments (Figure 23) is accounted for by a student aid variable (NIHTF/SAGE), (negatively) by a medical school enrollment variable (MDENR), and by a research funds variable (R_{lp}/R_t). In this equation, the student aid variable has the greatest impact as measured by the standard partial regression coefficients. There are no significant correlations among the explanatory variables in these two equations.

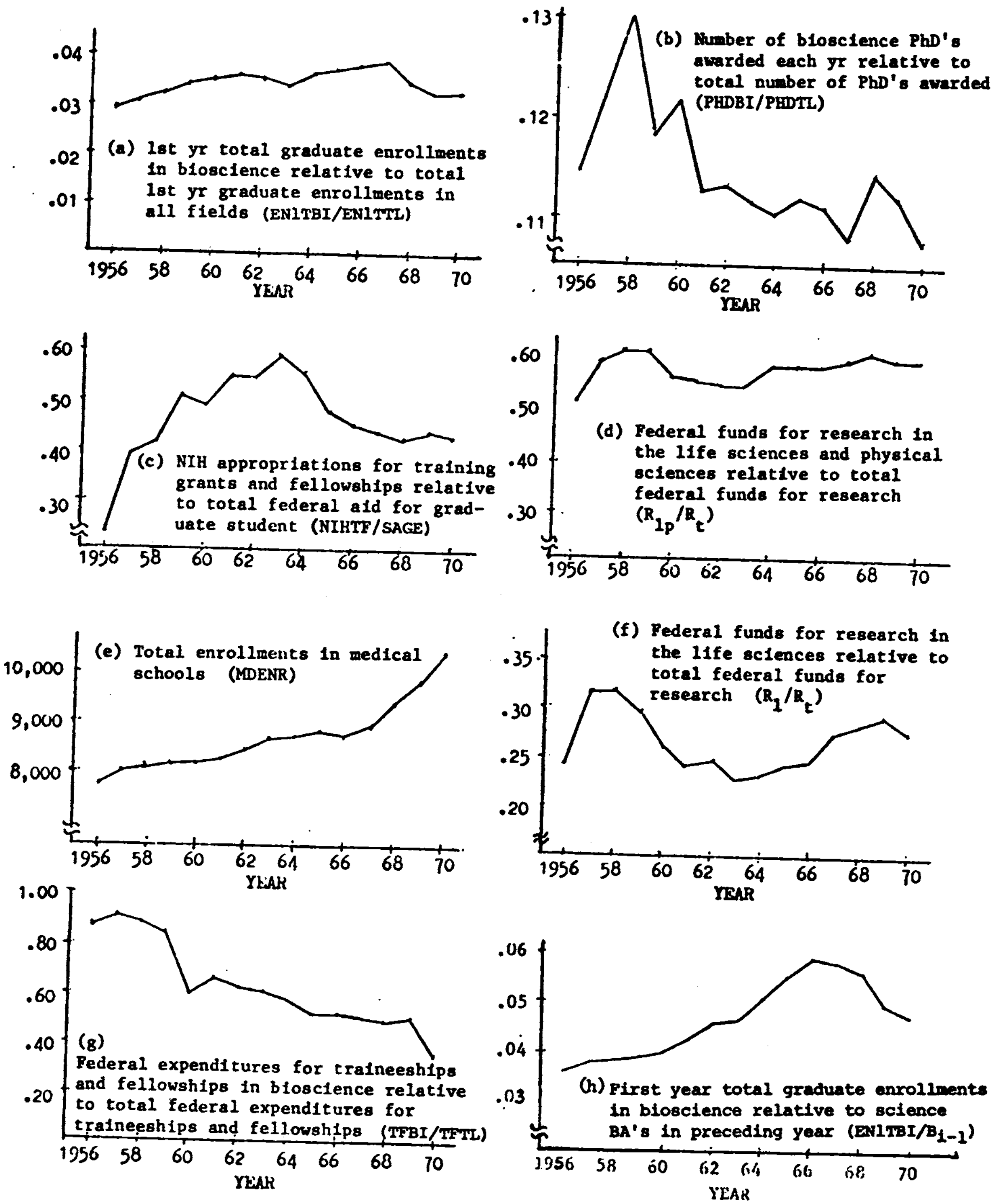
Equation (4) models the behavior of first-year graduate bioscience enrollments in relation to first-year enrollments in all fields of graduate study. An alternative formulation of the problem is presented in equation (5) where the same numerator is related to an estimate of the number of B.A.'s awarded in the previous year in the basic sciences (Figure 23h). This provides a contrasting dependent variable which measures the proportion of those qualified to pursue graduate bioscience study who actually do so.

$$(5)\quad \text{EN1TBI}/B_{i-1} = -0.01 + \underset{(.96)}{0.061(\text{NIHTF/SAGE})_{3,4,5}} + \underset{(.35)}{0.045(\$B/BA)_{3,4,5}}$$

$$- \underset{(-.31)}{3.31 \times 10^{-6}(\text{MDENR})} \; ; \qquad R^2 = 0.99$$

where $\text{EN1TBI}/B_{i-1}$ = (Bioscience Enrollment—BA Ratio). First-year total graduate enrollments in bioscience relative to science B.A.'s in preceding year.

Figure 23 - GRADUATE ENROLLMENTS AND DEGREES IN BIOSCIENCE AND SOME "EXPLANATORY" VARIABLES



$(\$B/BA)_{3,4,5}$ = (Salaries of bioscience PhD's relative to bioscience BA's). Median salary of Ph.D.'s in bioscience relative to the median salary of those with B.A.'s in bioscience, averaged over the years i-3, i-4, i-5.

$(NIHTF/SAGE)_{3,4,5}$ = (Relative NIH student aid funds). NIH appropriations for training grants and fellowships relative to total federal aid for graduate students, averaged over the years i-3, i-4, i-5.

Relative federal aid, although here measured as a three-year lagged average, remains the most important explanatory variable, and medical school enrollments continue to have a significant negative influence. The major feature in equation (5) is that the relative salary variable (median bioscience Ph.D. salaries relative to median salaries for bioscience B.A.'s), is both positive and significant, but still weaker than the student aid variable. Thus, when we look at the variations in the transition ratio between undergraduate and graduate study in bioscience, relative salaries do appear to have some influence in the expected direction.

Ph.D. completion equation:

$$(6)\quad (PHDBI/PHDTL)_i = 0.077 + \underset{(.68)}{0.026(TFBI/TFTL)_{i-1}} + \underset{(.37)}{0.075(R_l/R_t)_i}\ ;\ R^2=0.77$$

where PHDBI/PHDTL = (Relative bioscience PhD production). Number of bioscience Ph.D.'s awarded relative to the total number of Ph.D.'s awarded in the i^{th} year.

TFBI/TFTL = (Relative federal expenditures for bioscience traineeships and fellowships). Federal expenditures for traineeships and fellowships in bioscience relative to total federal expenditures for traineeships and fellowships in all fields.

R_l/R_t = (Relative federal funds for research in life sciences). Federal funds for research in the life sciences relative to total federal funds for research in the i^{th} fiscal year.

In equation (6), the annual number of bioscience Ph.D.'s relative to total Ph.D.'s $(PHDBI/PHDTL)_i$ is dependent on a broad measure of support (TFBI/TFTL), which represents the percentage of all federal traineeship and fellowship support allocated to bioscience, and on federal research in the life sciences relative to the total, (R_1/R_t). Some training grant and fellowship support to the biosciences has come from agencies other than NIH, such as the Consumer Protection and Environmental Health Agency of the Public Health Service and the Social and Rehabilitation Service of HEW. This is reflected in the variable TFBI. Note that TFBI represents federal expenditures whereas NIHTF, used in equation (4), represents appropriations of NIH. Although these two variables have been roughly parallel for most of the period between 1956 and 1970, they appear to diverge considerably starting in 1968, with federal expenditures dropping sharply while NIH appropriations for training grants and fellowships remained relatively constant.

Thus the statistical analysis indicates that federal-government student support, as exemplified by the NIH research training programs, has been an important factor in attracting students to graduate study in bioscience. Medical school enrollments and federal funds for research also appear to be important factors. Medical school is an attractive alternative to bioscience graduate study for many students, and it is understandable that medical school enrollment appears in the equations with a negative coefficient indicating that bioscience graduate enrollments react inversely to it.

The relationship of relative salaries of Ph.D. bioscientists to graduate enrollments and Ph.D. degrees in bioscience appears to be somewhat tenuous. The salary variable becomes a viable "explanatory" variable only in equation (5), and does not provide any help at all in explaining relative bioscience Ph.D. production. However, the influence of earnings on bioscience enrollments is complicated by the relation of medical school to bioscience Ph.D. programs. Salaries of physicians are known to be higher than those of bioscience Ph.D.'s, but admission to medical schools is severely limited by the number of available places. Many students deciding between medical school and a bioscience Ph.D. program choose bioscience because they cannot obtain a place in a medical school. Marginal changes in relative bioscience earnings will not lead them to alter their preferences; instead the portion of these students entering bioscience will depend on the number of medical school places available. At the same time, the second choice of these students is so solidly for bioscience that marginal changes in bioscience salaries will not affect the number of new entrants.

The failure to detect a strong and clearly defined earnings effect on bioscience enrollment despite controlling for medical school enrollments is extremely significant and may warrant some speculation on probable causes. If the preceding argument is correct this finding indicates that the income gap between medicine and bioscience is far too great for marginal increases in the earnings of bioscientists to offset the attractiveness of a career in medicine. At the same time with respect to students who are not considering medicine, the finding suggests that the same marginal changes do not significantly shift them into or away from graduate bioscience. The effect of these conclusions is that a policy of reliance on market forces to adjust relative incomes would have an uncertain impact on student flows into bioscience. Instead, the results of the regression analysis point to the significant and substantial influence of fellowships, training grants, and research funding on bioscience enrollments and Ph.D. degrees.

From a quantitative perspective, equation (4) estimates that a change of 10% in the share of federal student assistance going to bioscience—which would mean a shift of about $60 million on the average—would change the percentage of graduate students entering bioscience by 2 to 3%. A similar percentage change in research funding for bioscience—which would mean a shift of roughly $600 million on the average—would change this percentage by 3 to 4%.

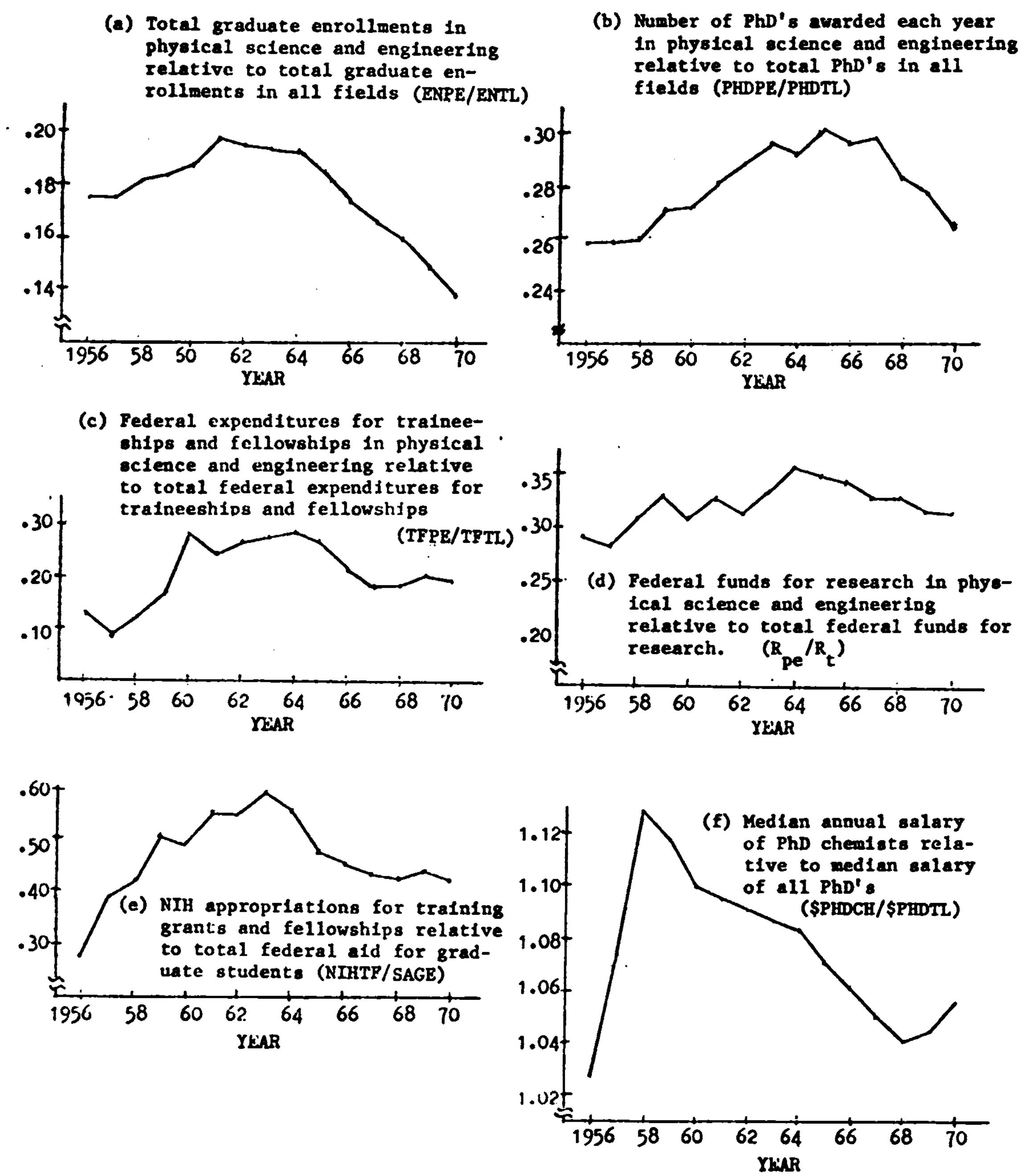
Although there is not much empirical evidence that relative salaries of Ph.D.'s in bioscience have had any strong influence upon bioscience graduate enrollments and degrees, one cannot conclude that bioscience is totally immune to changes in relative salaries. It is probable that if salaries of bioscientists were suddenly to show large increases over salaries in other fields, then one might expect relative graduate enrollments and Ph.D. degrees in bioscience to increase eventually in response to this stimulus. The proper interpretation of the results of this study is that the range of variation of relative salaries in bioscience over the 1956-70 period does not provide much help in explaining the behavior of relative bioscience enrollments and degrees during the same period. Any strong impact that such forces may have had on bioscience has either occurred indirectly through the attraction of, but limited access to, medical school, or has been largely overshadowed by the influence of direct support programs.

Figure 24 displays the variables in the bioscience equations in time series form.

2. Physical Science and Engineering Equations

The structure of the dependent variables in the equations for physical science and engineering is identical to that in the bioscience model, i.e., ratios of enrollments and Ph.D. degrees in the field relative to totals over all fields (Figure 24a,b). Some results for the total enrollment and the Ph.D. ratios are presented in equations (7) and (8). Additional equations for relative first-year enrollments are shown in Appendix B.

Figure 24 - GRADUATE ENROLLMENTS AND DEGREES IN PHYSICAL SCIENCE AND ENGINEERING AND SOME "EXPLANATORY" VARIABLES



Enrollment equation:

$$(7)\quad (ENPE/ENTL)_i = -0.11 + \underset{(0.35)}{0.21(\$PHDCH/\$PHDTL)_i} + \underset{(0.26)}{0.16(R_{pe}/R_t)_i}$$

$$- \underset{(-0.60)}{3.6 \times 10^{-6}(MEDAPP)_i} + \underset{(0.35)}{0.09(TFPE/TFTL)_{i-1}} \; ; \; R^2=0.99$$

where (ENPE/ENTL) = (Relative graduate enrollments in physical science and engineering). Total graduate enrollments in physical science and engineering relative to total graduate enrollments in all fields.

$PHDCH/$PHDTL = (Relative salaries of PhD chemists). Median annual salary of Ph.D. chemists relative to median salary of all Ph.D.'s.

R_{pe}/R_t = (Relative federal funds for research in physical science and engineering). Federal funds for research in physical science and engineering relative to total federal funds for research.

MEDAPP = Number of applications for medical school.

TFPE/TFTL = (Relative federal expenditures for traineeships and fellowships in physical science and engineering). Federal expenditures for traineeships and fellowships in physical science and engineering relative to total federal expenditures for traineeships and fellowships in all fields.

Equation (7) shows that the behavior of relative graduate enrollments in physical science and engineering can be accounted for by a set of variables which includes a salary variable $PHDCH/$PHDTL, a research funds variable (R_{pe}/R_t), a student-aid variable (TFPE/TFTL), and the medical school variable (MEDAPP) (Figure 24c-f). The salary variable and the student-aid variable have equal impact on relative total graduate enrollments in this equation. Because of data limitations it was not possible to introduce research funds or salaries of chemists with time lags.

As in the biosciences, medical school appears to be a prime competitor for graduate students in the physical sciences and engineering.

The variable which seems to have the greatest impact on the proportion of graduate students enrolling in physical science and engineering is the number of applicants for medical school each year (MEDAPP). This explanatory variable has the highest standard partial regression coefficient in equation (7) (in absolute value), and also in other enrollment equations shown in Appendix B, indicating that it has the highest relative importance of all variables in the set. The regression coefficient of MEDAPP is negative, reflecting the fact that an increasing number of medical school applicants tends to draw down the pool of graduate students available to the physical sciences and engineering, even though one might imagine that such individuals have different aptitudes and interests.

There are no significant intercorrelations among the explanatory variables in equation (7), so the standard partial coefficients are fairly reliable indicators of the relative importance of the variables.

The similarities of the physical science equations for enrollments with those for bioscience are striking. The influence of medical school variables and federal funds for research are roughly the same. Student aid is highly significant in both fields but more so in bioscience. Bioscience enrollments are most responsive to NIH fellowships and training grants while in the physical sciences the best variable reflecting the impact of student aid is total federal support for training in the physical sciences.

One can only speculate about the reasons why the effect of salaries emerged more clearly in the physical science equations than in the bioscience ones. The most likely explanation involves the very close and complex relation between graduate bioscience and medical school discussed above.

<u>Ph.D. completion equation</u>:

$$(8)\quad (PHDPE/PHDTL)_i = 0.02 + \underset{(.65)}{0.11(NIHTF/SAGE)_{i-1}} + \underset{(.45)}{0.09(TFPE/TFTL)_{i-3}}$$

$$+ \underset{(.27)}{0.02(\$F/TL)_i}\ ; \qquad R^2 = 0.92$$

where PHDPE/PHDTL = (Relative physical science and engineering PhD production). Number of Ph.D.'s in physical science and engineering relative to total Ph.D.'s in all fields.

TFPE/TFTL = (Relative federal expenditures for traineeships and fellowships in physical science and engineering). Federal expenditures for traineeships and fellowships in physical science and engineering relative to total federal expenditures for traineeships and fellowships in all fields.

NIHTF/SAGE = (Relative NIH student aid funds). NIH appropriations for training grants and fellowships relative to total federal aid for graduate students.

$F/TL = (Relative faculty salaries). An index of faculty salaries prepared by the American Association of University Professors, relative to the median annual salary of all scientific and technical personnel measured in thousands of dollars.

In the Ph.D. equation (8), the ratio of faculty salaries to the median income of all professionals ($F/$TL), helps to explain the behavior of relative Ph.D. production, but the student-aid variables (NIHTF/SAGE) and (TFPE/TFTL) (Figure 24c, e) provide most of the "explanatory" power.

E. SUMMARY AND CONCLUSIONS

Population and economic growth undoubtedly account for much of the steady increase in enrollments and degrees in higher education that has been occurring for many years in practically all fields and at all levels. Yet when the variables in higher education are examined in relative terms, variations in the rates of growth emerge which are more susceptible to analyses of the effects of relative salaries and federal research and education programs. Market forces, federal research activity, and federal support programs for students all seem to have played a role in regulating the flow of students through graduate education.

An empirical analysis of the flow, at several levels and in several fields, yields evidence of a strong correlational relationship between relative enrollments and degrees on the one hand and federal programs for student support on the other. As with cigarette smoking and lung cancer, correlation does not prove causation, but repeated and consistent relationships at different levels and in different fields suggest a causal relationship.

Market forces, as reflected in salaries of college graduates, seem to act especially strongly at the B.A. level. The effect of this variable on graduate enrollments does not seem to be quite as strong as direct student support and it generally seems to take more time for its influence to be felt in graduate education. Apparently the impact of market forces varies from field to field. In the physical sciences and engineering, salary differentials seem to play a larger role than they do in the biosciences where there is very little clear-cut evidence of direct influence of salaries during the 1956-70 period.

APPENDICES

Appendix A - Tables

A1 Number of Persons Trained in the Research Training Programs of NIH by Program Type, Year of Training, Academic Level at First Award, and Full-time/Part-time Status

A2 Number of Persons Trained in the Research Training Programs of NIH by Institute, Specialty Field, and Full-time/Part-time Status

A3 Average Length of NIH Support at Each Academic Level by Year of First Award, Full-time/Part-time Status

A4 Ph.D. Attainment Rates for Supported and Non-supported Groups, for B.A. Years 1941-1955

A5 Median Time Lapse from Degree to First Appointment by Specialty Field at First Appointment and Academic Level

A6 Primary Work Activity and Type of Employer during 1968-1970, by Cohort and Training Pathway

Appendix B — The Methodology Used in Developing the Equations for Chapter 5

Appendix C — Data Used in Chapter 5

Appendix D — Specialty List Used in the Doctorate Records File

Appendix E — Bibliography

APPENDIX A

ADDITIONAL TABLES

TABLE A 1 NUMBER OF PERSONS TRAINED IN THE RESEARCH TRAINING PROGRAMS OF NIH BY PROGRAM TYPE, YEAR OF TRAINING, ACADEMIC LEVEL AT FIRST AWARD, AND FULL-TIME/PART-TIME STATUS, 1938-72

YEAR TRAINING STARTED	ACADEMIC LEVEL AT FIRST AWARD	PROGRAM TYPE											
		TRAINEES				FELLOWS				TOTAL INCLUDING UNKNOWN PROGRAM			
		FT	PT	UNK	TOTAL	FT	PT	UNK	TOTAL	FT	PT	UNK	TOTAL
1938-45	PRE-PHD	---	---	---	---	---	---	---	---	---	---	---	---
	POST-PHD	---	---	---	---	20	---	---	20	20	---	---	20
	PRE-MD	---	---	---	---	---	---	---	---	---	---	---	---
	POST-MD	---	---	---	---	10	2	---	12	10	2	---	12
	POST-MD/PHD	---	---	---	---	---	---	---	---	---	---	---	---
	POST-MD/PRE-PHD	---	---	---	---	---	---	---	---	---	---	---	---
	OTHER	---	---	---	---	---	---	---	---	---	---	---	---
	UNKNOWN	---	---	---	---	89	7	1	97	89	7	1	97
	TOTAL	---	---	---	---	119	9	1	129	119	9	1	129
1946-50	PRE-PHD	---	---	---	---	---	---	---	(a)	---	---	---	---
	POST-PHD	7	---	---	7	115	11	---	126	122	11	---	133
	PRE-MD	---	---	---	---	---	---	---	---	---	---	---	---
	POST-MD	2	---	---	2	314	13	---	327	316	13	---	329
	POST-MD/PHD	---	---	---	---	13	1	---	14	13	1	---	14
	POST-MD/PRE-PHD	---	---	---	---	---	---	---	---	---	---	---	---
	OTHER	---	---	---	---	---	---	---	---	---	---	---	---
	UNKNOWN	---	---	---	---	583	32	1	616	583	32	1	616
	TOTAL	9	---	---	9	1025	57	1	1083	1034	57	1	1092
1951-55	PRE-PHD	---	---	---	---	---	---	---	(a)	---	---	---	---
	POST-PHD	19	1	---	20	280	13	---	293	299	14	---	313
	PRE-MD	---	---	---	---	---	---	---	---	---	---	---	---
	POST-MD	20	1	2	23	374	16	---	390	394	17	2	413
	POST-MD/PHD	---	---	---	---	9	1	---	10	9	1	---	10
	POST-MD/PRE-PHD	---	---	---	---	---	---	---	---	---	---	---	---
	OTHER	---	---	---	---	---	---	---	---	---	---	---	---
	UNKNOWN	15	3	1	19	1303	72	2	1377	1318	75	3	1396
	TOTAL	54	5	3	62	1966	102	2	2070	2020	107	5	2132
1956-60	PRE-PHD	732	146	3	881	86	4	---	90	818	150	3	971
	POST-PHD	283	137	---	420	448	35	1	484	731	172	1	904
	PRE-MD	250	248	---	498	---	---	---	---	250	248	---	498
	POST-MD	2011	374	3	2388	736	20	---	756	2748	395	3	3146
	POST-MD/PHD	55	13	---	68	35	1	---	36	90	14	---	104
	POST-MD/PRE-PHD	45	3	---	48	2	---	---	2	47	3	---	50
	OTHER	86	89	---	175	---	---	---	---	86	89	---	175
	UNKNOWN	850	851	1	1702	2335	318	4	2657	3190	1178	5	4373
	TOTAL	4312	1861	7	6180	3642	378	5	4025	7960	2249	12	10221

FT = Full-time (equivalent of one academic year of training)
PT = Part-time

TABLE A 1 Continued

YEAR TRAINING STARTED	ACADEMIC LEVEL AT FIRST AWARD	PROGRAM TYPE: TRAINEES FT	TRAINEES PT	TRAINEES UNK	TRAINEES TOTAL	FELLOWS FT	FELLOWS PT	FELLOWS UNK	FELLOWS TOTAL	TOTAL INCLUDING UNKNOWN PROGRAM[b] FT	PT	UNK	TOTAL
1961-65	PRE-PHD	7662	1489	40	9191	1438	42	2	1482	9107	1539	42	10668
	POST-PHD	890	332	3	1225	824	42	3	869	1714	374	6	2094
	PRE-MD	2188	3938	3	6129	1	—	—	1	2193	3942	3	6138
	POST-MD	6984	997	13	7994	1387	32	2	1421	8380	1033	15	9428
	POST-MD/PHD	214	38	—	252	75	1	—	76	290	39	—	329
	POST-MD/PRE-PHD	465	41	1	507	114	4	1	119	579	45	2	626
	OTHER	906	1399	—	2305	219	4	—	223	1125	1403	—	2528
	UNKNOWN	320	248	—	568	532	17	1	550	856	271	1	1128
	TOTAL	19629	8482	60	28171	4590	142	9	4741	2424	8646	69	32959
1966-72	PRE-PHD	15483	2062	—	17545	1421	14	2	1437	16904	2076	2	18982
	POST-PHD	1708	389	—	2097	1555	82	9	1646	3263	471	9	3743
	PRE-MD	1627	6166	—	7793	2	—	—	2	1629	6166	—	7795
	POST-MD	9262	1270	8	10540	1011	23	8	1042	10273	1293	16	11582
	POST-MD/PHD	132	12	—	144	49	3	—	52	181	15	—	196
	POST-MD/PRE-PHD	701	58	—	759	139	7	1	147	840	65	1	906
	OTHER	584	2008	—	2592	3	—	—	3	587	2008	—	2595
	UNKNOWN	—	—	—	—	1080	21	2	1103	1080	21	2	1103
	TOTAL	29497	11965	8	41470	5260	150	22	5432	34757	12115	30	46902
UNKNOWN	PRE-PHD	2	1	4	7	6	29	31	66	8	30	35	73
	POST-PHD	—	1	2	3	—	7	35	42	—	8	37	45
	PRE-MD	2	1	3	6	—	—	—	—	2	1	3	6
	POST-MD	1	4	48	53	—	2	15	17	1	6	63	70
	POST-MD/PHD	—	—	1	1	—	—	1	1	—	—	2	2
	POST-MD/PRE-PHD	—	—	—	—	—	—	2	2	—	—	2	2
	OTHER	—	1	—	1	—	1	1	2	—	2	1	3
	UNKNOWN	7	16	70	93	1	3	4	8	8	19	74	101
	TOTAL	12	24	128	164	7	42	89	138	19	66	217	302
ALL YEARS, 1938-72	PRE-PHD	23879	3698	47	27624	2951	89	35	3075	26837	3795	82	30714
	POST-PHD	2907	860	5	3772	3242	190	48	3480	6149	1050	53	7252
	PRE-MD	4067	10353	6	14426	3	—	—	3	4074	10357	6	14437
	POST-MD	18280	2646	74	21000	3832	108	25	3965	22122	2759	99	24980
	POST-MD/PHD	401	63	1	465	181	7	1	189	583	70	2	655
	POST-MD/PRE-PHD	1211	102	1	1314	255	11	4	270	1466	113	5	1584
	OTHER	1576	3497	—	5073	222	5	1	228	1798	3502	1	5301
	UNKNOWN	1192	1118	72	2382	5923	470	15	6408	7124	1603	87	8814
	TOTAL	53513	22337	206	76056	16609	880	129	17618	70153	23249	335	93737

Source: NIH Roster of Trainees and Fellows, 1938-72, Summary File B, Commission on Human Resources, NAS/NRC, August 5, 1975.

[a] A few predoctoral fellowships were awarded beginning in 1946. The records of these fellows had to be reconstructed from scanty data so it was not possible in all cases to identify the academic levels. Most of the early predoctoral awardees are counted in the "other and unknown" academic level category.

[b] 63 individuals with unknown program types are included in the total.

Table A2 - NUMBER OF PERSONS TRAINED IN THE RESEARCH TRAINING PROGRAMS OF NIH BY INSTITUTE AND SPECIALTY FIELD

SPECIALTY FIELD AT FIRST AWARD	INSTITUTE										
	NIAID	NIAMD	NCI	NICHD	NIDR	NIEHS	NEI	NIGMS	NHLI	NINDS	TOTAL
BIOMEDICAL SCIENCES, TOTAL	4517	1165	4327	1590	1648	1130	21	26816	6353	1371	48938
ANATOMY	7	59	100	74	330	2	2	1773	236	122	2705
BIOCHEMISTRY	63	346	819	127	181	19	1	5633	516	101	7806
BIOMATHEMATICS	—	—	1	1	—	2	—	84	—	—	88
BIOMEDICAL ENGINEERING	—	6	1	—	192	1	1	824	513	11	1549
BIOPHYSICS	16	24	104	4	27	3	2	2080	169	20	2449
CYTOLOGY	2	2	28	6	5	—	—	32	10	4	89
GENETICS	33	36	302	127	59	8	—	2049	79	5	2698
IMMUNOLOGY	967	69	82	10	14	1	—	71	32	6	1252
MICROBIOLOGY/BACTERIOLOGY	2269	36	229	11	142	32	—	2467	39	15	5240
MOLECULAR BIOLOGY	14	11	28	35	—	1	1	1	8	1	100
PARASITOLOGY	510	—	—	—	—	3	—	—	—	—	513

Table A2 - continued

SPECIALTY FIELD AT FIRST AWARD	INSTITUTE										
	NIAID	NIAMD	NCI	NICHD	NIDR	NIEHS	NEI	NIGMS	NHLI	NINDS	TOTAL
BIOMEDICAL SCIENCES (continued)											
PATHOLOGY	107	47	864	7	105	6	1	2748	405	200	4490
PHARMACOLOGY	7	96	189	8	91	68	—	2394	569	101	3523
PHYSIOLOGY	34	176	173	339	162	70	10	2646	2304	397	6311
BIOMEDICAL SCIENCES, OTHER	110	213	1190	742	293	41	3	3146	1211	364	7313
BOTANY	17	1	47	13	1	19	—	13	6	2	119
ECOLOGY	12	—	—	3	1	46	—	—	1	—	63
ENTOMOLOGY	282	—	2	1	1	64	—	4	2	1	357
ENVIRONMENTAL SCIENCES	2	—	2	1	—	705	—	201	32	—	943
FOOD SCIENCES/NUTRITION	—	34	2	5	34	3	—	564	154	2	798
HYDROBIOLOGY	1	—	—	1	2	14	—	—	29	—	47
PHARMACEUTICAL SCIENCES	—	—	—	—	2	1	—	—	—	—	3
ZOOLOGY	64	9	164	75	6	22	—	86	38	19	482

Table A2 - continued

SPECIALTY FIELD AT FIRST AWARD	INSTITUTE										
	NIAID	NIAMD	NCI	NICHD	NIDR	NIEHS	NEI	NIGMS	NHLI	NINDS	TOTAL
BEHAVIORAL SCIENCES, TOTAL	4	5	11	1342	257	2	7	1158	52	308	3146
CLINICAL PSYCHOLOGY	—	—	—	21	132	—	—	—	2	145	300
DEVELOPMENT/GERONTOLOGICAL	—	—	—	522	3	—	—	—	1	7	533
EDUCATIONAL	—	—	—	15	—	—	—	—	—	4	19
EXPERIMENTAL	—	1	3	170	62	—	3	7	23	82	351
COMPARATIVE	1	—	4	13	1	—	—	—	—	5	24
PHYSIOLOGICAL	—	3	2	42	7	—	4	—	6	50	114
PERSONALITY	—	—	—	13	3	—	—	1150	—	—	1166
PSYCHOMETRICS	—	—	—	2	—	—	—	—	—	—	2
SOCIAL PSYCHOLOGY	—	—	—	13	2	1	—	—	2	5	23
PSYCHOLOGY, GENERAL	—	—	1	8	5	—	—	—	1	1	16
ANTHROPOLOGY	3	1	—	91	35	1	—	—	3	6	140
BEHAVIOR/ETHOLOGY	—	—	—	121	—	—	—	—	4	1	126
MENTAL HEALTH	—	—	—	13	—	—	—	—	2	—	15
SOCIAL STATISTICS/DEMOG	—	—	—	99	—	—	—	1	—	—	100
SOCIOLOGY	—	—	1	199	7	—	—	—	8	2	217

Table A2 - continued

SPECIALTY FIELD AT FIRST AWARD	INSTITUTE										
	NIAID	NIAMD	NCI	NICHD	NIDR	NIEHS	NEI	NIGMS	NHLI	NINDS	TOTAL
CLINICAL SCIENCES, TOTAL	1436	6617	3865	745	962	15	286	5656	5855	5711	31148
DENTISTRY	3	2	93	—	915	—	—	2	13	—	1028
MEDICINE & SURGERY, SUBTOTAL	1363	6566	1855	717	44	14	280	1162	5620	4915	22536
ALLERGY	156	10	—	—	—	—	—	—	4	—	170
ANESTHESIOLOGY	—	—	1	—	1	—	—	527	23	3	555
GERIATRICS	—	—	—	1	—	—	—	—	3	—	4
INTERNAL MEDICINE, SUBTOTAL	1033	5752	398	23	3	8	1	139	3658	11	11026
CARDIOVASCULAR DISEASES	1	3	2	5	—	—	—	—	2577	3	2591
CLINICAL NUTRITION	—	157	—	—	—	—	—	—	4	—	161
CONNECTIVE TISSUE DIS.	3	613	—	—	1	—	—	—	2	—	619
DERMATOLOGY	9	483	14	—	—	—	—	7	4	—	517
DIABETES	1	507	—	—	—	—	—	—	1	—	509
ENDOCRINOLOGY	—	671	30	4	2	—	—	117	17	1	842
GASTROENTEROLOGY	—	614	16	—	—	1	—	4	13	2	650
HEMATOLOGY	5	627	128	—	—	—	—	10	170	1	941
INFECTIOUS DISEASES	495	3	—	1	—	2	—	—	10	—	511
LIVER DISEASES	2	60	2	—	—	—	—	—	3	—	65
METABOLIC DISEASES	3	355	1	2	—	—	—	—	12	—	373
NUCLEAR MEDICINE	—	—	5	—	—	—	—	—	3	—	8
ONCOLOGY	1	1	154	—	—	1	—	—	2	—	159
PULMONARY DISEASES	45	2	2	—	—	1	—	—	311	1	362
RENAL DISEASES	1	152	1	—	—	—	—	—	300	—	454
TROPICAL MEDICINE	402	—	—	—	—	—	—	1	3	—	406
OTHER	65	1504	45	11	—	3	1	—	226	3	1858

Table A2 - continued

SPECIALTY FIELD AT FIRST AWARD	INSTITUTE										
	NIAID	NIAMD	NCI	NICHD	NIDR	NIEHS	NEI	NIGMS	NHLI	NINDS	TOTAL
CLINICAL SCIENCES (continued)											
MEDICINE & SURGERY (continued)											
NEUROLOGY	---	2	5	---	1	---	---	2	27	2214	2251
NEUROPSYCHIATRY	---	---	---	---	---	---	---	---	---	9	9
OBSTETRICS/GYNECOLOGY	---	37	97	151	---	---	---	4	43	---	332
OPHTHALMOLOGY/OPTOMETRY	1	6	1	---	---	---	277	---	5	1111	1402
OTORHINOLARYNGOLOGY	---	2	2	---	3	---	---	---	---	1171	1178
PEDIATRICS	121	316	54	532	1	1	---	15	532	21	1593
PREVENTIVE MEDICINE	46	---	---	---	---	5	---	---	9	---	60
PSYCHIATRY	---	---	2	5	1	---	---	---	5	13	24
RADIOLOGY	2	6	830	2	16	---	---	219	131	110	1316
SURGERY	4	435	465	3	18	---	2	256	1180	253	2616
VETERINARY MEDICINE	62	15	24	19	2	1	---	3	39	14	179
CLINICAL SCIENCES, OTHER	8	34	1893	9	1	---	6	4489	183	782	7405

Table A2 - continued

SPECIALTY FIELD AT FIRST AWARD	INSTITUTE										
	NIAID	NIAMD	NCI	NICHD	NIDR	NIEHS	NEI	NIGMS	NHLI	NINDS	TOTAL
HEALTH RESEARCH, TOTAL	83	6	86	54	37	198	---	2790	66	2	3322
BIOSTATISTICS/BIOMETRICS	1	1	24	3	2	6	---	1816	24	---	1877
EPIDEMIOLOGY	71	1	17	19	30	8	---	904	24	1	1075
HOSPITAL ADMINISTRATION	7	4	3	23	1	---	---	4	12	---	54
PUBLIC HEALTH	4	---	42	9	4	184	---	66	6	1	316
CHEMISTRY	50	65	319	5	169	18	2	2136	192	24	2980
ENGINEERING, OTHER	4	2	1	---	3	26	---	9	17	4	66
MATHEMATICS	---	---	2	1	---	---	---	---	3	---	5
PHYSICS	1	5	45	---	28	---	---	12	20	2	113
OTHER	4	3	14	77	9	14	---	85	257	7	470
UNKNOWN	15	388	1593	2	5	---	1	556	630	447	3637
ALL FIELDS	6114	8256	10263	3816	3118	1403	317	39218	13444	7876	93825

Source: NIH Roster of Trainees and Fellows, 1938-72, Summary File B, Commission on Human Resources, NAS/NRC, Washington, D. C., August 5, 1975.

Table A3 - AVERAGE LENGTH OF NIH SUPPORT AT EACH ACADEMIC LEVEL

		FULL TIME		PART TIME		TOTAL	
YEAR OF AWARD	ACADEMIC LEVEL	Mean length of support (months)	# of trainees per level	Mean length of support (months)	# of trainees per level	Mean length of support (months)	# of trainees per level
1938-45	Post-PhD	28.7	22	----	----	28.7	22
	Post-MD	30.2	11		(a)	24.6	14
	Other & Unknown	20.0	91		(a)	18.9	98
1946-50(b)	Post-PhD	18.2	137	5.2	13	17.0	150
	Post-MD	15.5	318	3.8	14	15.0	332
	Post-MD/PhD	15.7	13		(a)	14.7	14
	Post-MD/Pre-PhD		(a)	----	----		(a)
	Other & Unknown	17.5	571	4.6	41	16.6	612
1951-55	Post-PhD	16.9	419	4.5	29	16.1	448
	Post-MD	17.3	426	5.1	22	16.7	448
	Post-MD/PhD	16.9	10		(a)	15.5	11
	Other & Unknown	16.2	1366	4.8	91	15.5	1457
1956-60	Pre-PhD	27.8	798	3.8	224	22.5	1022
	Post-PhD	20.2	916	4.0	215	17.1	1131
	Pre-MD	17.4	132	3.2	388	6.8	520
	Post-MD	19.4	2844	4.4	469	17.2	3313
	Post-MD/PhD	19.1	122	4.2	23	16.7	145
	Post-MD/Pre-PhD	28.3	48	3.9	20	21.1	68
	Other & Unknown	16.6	3426	3.3	1555	12.5	4981
1961-65	Pre-PhD	28.0	9796	3.8	2024	23.8	11820
	Post-PhD	19.6	2668	3.6	509	17.0	3177
	Pre-MD	15.3	770	3.3	5798	4.7	6568
	Post-MD	20.3	8894	4.0	1194	18.4	10088
	Post-MD/PhD	16.6	438	3.4	90	14.3	528
	Post-MD/Pre-PhD	25.4	977	4.3	128	23.0	1105
	Other & Unknown	13.5	1976	2.7	2539	7.4	4515
1966-70	Pre-PhD	27.2	13482	3.8	1928	24.3	15410
	Post-PhD	18.7	4514	3.8	676	16.8	5190
	Pre-MD	23.3	749	2.3	5785	4.7	6534
	Post-MD	19.5	9317	4.3	1014	18.0	10331
	Post-MD/PhD	19.7	273	4.1	32	18.1	305
	Post-MD/Pre-PhD	25.9	1064	4.1	97	24.1	1161
	Other & Unknown	13.8	2832	2.5	2118	9.0	4950
TOTAL ALL YEARS 1938-70	Pre-PhD	27.5	24076	3.8	4176	24.0	28252
	Post-PhD	19.1	8676	3.9	1442	16.9	10118
	Pre-MD	19.1	1651	2.8	11971	4.8	13622
	Post-MD	20.0	21810	4.2	2713	18.0	24526
	Post-MD/PhD	17.9	856	3.7	145	15.8	1003
	Post-MD/Pre-PhD	25.7	2089	4.2	245	23.5	2334
	Other & Uknown	15.3	10262	2.8	6344	10.5	16613

Source: NIH Roster of Trainees and Fellows, 1938-72, Summary File B, Commission on Human Resources, NAS/NRC, Washington, D. C. July 28, 1974.

(a) Less than 10 observations.

(b) Pre-Ph.D. fellows were supported as early as 1946 according to the NIH Grants and Awards Report for that year, but difficulties in determining the academic level from early NIH records prevented them from being identified in the data base. For this reason, the early pre-Ph.D.'s fall into the "Other and Unknown" academic level in this table.

Table A4 - PHD ATTAINMENT RATES FOR SUPPORTED AND NON-SUPPORTED GROUPS IN THE BIOLOGICAL SCIENCES, FOR BA YEARS 1941-1955

Year of BA	Source of Pre-PhD Support			Received PhD by 1973 #	Received PhD by 1973 % of Total	Did Not Receive PhD by 1973 #	Did Not Receive PhD by 1973 % of Total	Total #
1941-45	NIH	Trainees	Full-time	26	56.5	20	43.5	46
			Part-time	6	66.7	3	33.3	9
			Total	33	58.9	23	41.1	56
		Fellows	Full-time	13	81.3	3	18.8	16
			Part-time	-	-	-	-	-
			Total	13	81.3	3	18.8	16
		Total	Full-time	39	62.9	23	37.1	62
			Part-time	6	66.7	3	33.3	9
			Total	46	63.9	26	36.1	72
	NDEA(b)			4	80.0	1	20.0	5
	Woodrow Wilson Fellows			-	-	-	-	-
	NSF	Trainees		-	-	-	-	-
		Fellows		6	85.7	1	14.3	7
		Total		6	85.7	1	14.3	7
	Total with Known Support(a)			68	67.3	33	32.7	101
	No trainee or fellowship suppt.			46	41.4	65	58.5	111
1946-50	NIH	Trainees	Full-time	174	69.9	75	30.1	249
			Part-time	30	60.0	20	40.0	50
			Total	207	68.1	97	31.9	304
		Fellows	Full-time	44	88.0	6	12.0	50
			Part-time	4	66.7	2	33.3	6
			Total	48	85.7	8	14.3	56
		Total	Full-time	218	72.9	81	27.1	299
			Part-time	34	60.7	22	39.3	56
			Total	255	70.8	105	29.2	360
	NDEA(b)			11	68.8	5	31.3	16
	Woodrow Wilson Fellows			-	-	-	-	-
	NSF	Trainees		-	-	-	-	-
		Fellows		11	78.6	3	21.4	14
		Total		11	78.6	3	21.4	14
	Total with Known Support(a)			302	71.7	119	28.3	421
	No trainee or fellowship suppt.			425	57.9	309	42.1	734
1951-55	NIH	Trainees	Full-time	478	80.7	114	19.3	592
			Part-time	108	76.6	33	23.4	141
			Total	596	79.7	152	20.3	748
		Fellows	Full-time	169	91.8	15	8.2	184
			Part-time	14	100.0	-	-	14
			Total	187	92.6	15	7.4	202
		Total	Full-time	647	83.4	129	16.6	776
			Part-time	122	78.7	33	21.3	155
			Total	783	82.4	167	17.6	950
	NDEA(b)			24	64.9	13	35.1	37
	Woodrow Wilson Fellows			-	-	-	-	-
	NSF	Trainees		1	50.0	1	50.0	2
		Fellows		46	92.0	4	8.0	50
		Total		47	90.4	5	9.6	52
	Total with Known Support(a)			930	81.0	218	19.0	1148
	No trainee or fellowship suppt.			493	54.7	408	45.3	901

Sources: NIH Roster of Trainees and Fellows, 1938-72, Comprehensive File of Doctoral Scientists and Engineers, 1935-73, Cumulative Index of NSF Trainees and Fellows, 1952-71, Commission on Human Resources, NAS/NRC, Washington, D. C.

NDEA Fellows, 1959-72, Office of Education, U. S. Department of Health, Education and Welfare, Washington, D. C.

Woodrow Wilson Fellows, 1958-69, Woodrow Wilson National Fellowship Foundation, Princeton, N. J.

[a] The total with known support is less than the total from all sources of support because some people had multiple sources of support and are counted in each one, but are counted only once in the total.

[b] The NDEA program is operationally equivalent to a traineeship even though it is called a fellowship program. For this analysis, the NDEA people are considered to be trainees rather than fellows.

Table A5 - MEDIAN TIME LAPSE FROM DEGREE TO FIRST APPOINTMENT
by specialty field at first appointment
and academic level

BA TO FIRST PRE-PHD APPOINTMENT
(Months of Elapsed Time)

Year of First Award

Specialty Field at First Appointment	1956-60 Time Lapse	1956-60 Number Suppt.	1961-65 Time Lapse	1961-65 Number Suppt.	1966-70 Time Lapse	1966-70 Number Suppt.	1971-72 Time Lapse	1971-72 Number Suppt.	Total, All Yrs. Time Lapse	Total, All Yrs. Number Suppt.
GENERAL BIOLOGICAL SCIENCES SUBTOTAL	30.6	233	17.8	7197	16.2	9993	15.7	2019	16.8	19442
Biochemistry	18.3	53	11.0	1574	6.8	1968	10.5	373	9.2	3968
Microbiology	53.5	49	24.3	1400	22.5	1710	23.3	407	24.1	3566
Physiology	28.5	16	22.8	1000	24.8	1102	20.3	205	24.3	2323
Pathology	44.5	10	27.9	180	22.8	204	14.1	52	25.2	446
Pharmacology	18.9	28	16.3	555	14.4	811	14.0	200	15.0	1594
Anatomy	17.5	19	17.2	483	15.5	635	16.4	103	16.1	1240
Genetics	40.5	22	18.9	453	16.3	679	15.5	120	18.1	1274
Biophysics	(a)	3	17.0	564	14.4	637	14.9	141	15.5	1345
Biology	(a)	7	26.7	215	34.2	736	24.5	96	28.5	1054
Multidisciplinary	--	--	20.2	121	18.3	256	6.7	64	17.1	441
Other	40.5	26	19.9	652	25.0	1255	23.2	258	24.0	2191
CLINICAL MEDICINE AND DENTISTRY	50.5	14	28.7	351	26.2	383	28.9	79	27.5	827
MISC. HEALTH FIELDS	34.5	31	25.7	851	27.3	1831	28.4	321	27.0	3034
BEHAVIORAL SCIENCE AND PSYCHOLOGY	--	--	25.2	400	24.8	1521	27.1	332	25.2	2253
EMP, OTHER	32.5	10	21.2	462	27.4	799	27.4	64	26.1	1335
UNKNOWN FIELD	--	--	(a)	5	--	--	--	--	(a)	5
GRAND TOTAL	31.0	288	19.0	9266	21.5	14527	20.2	2815	20.1	26896

Sources: NIH Roster of Trainees and Fellows, 1938-72, Doctorate Records File, 1935-72, Commission on Human Resources, NAS/NRC, Washington, D.C.

(a) Less than 10 observations.

Table A5 (Cont.) - MEDIAN TIME LAPSE FROM DEGREE TO FIRST APPOINTMENT
by specialty field at first appointment

PHD TO FIRST PHD APPOINTMENT
(Months of Elapsed Time)

Year of First Award

Specialty Field at First Appointment	1956-60		1961-65		1966-70		1971-72		Total, All Yrs.	
	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.
GENERAL BIOLOGICAL SCIENCES SUBTOTAL	14.3	630	10.0	1906	5.6	2604	7.1	1075	8.0	6482
Biochemistry	12.6	165	9.4	479	7.6	571	10.6	238	9.1	1543
Microbiology	11.1	71	8.5	304	4.4	388	4.7	141	6.2	934
Physiology	38.5	99	11.7	216	4.6	331	4.7	151	8.8	819
Pathology	25.2	33	16.1	41	3.7	52	5.5	38	8.2	169
Pharmacology	11.2	34	6.0	110	3.6	142	5.8	87	4.9	387
Anatomy	4.5	32	9.2	109	4.3	126	3.2	54	6.0	333
Genetics	30.5	32	9.7	175	4.5	224	7.6	76	8.0	515
Biophysics	13.0	19	13.5	187	9.3	152	15.2	50	12.8	413
Biology	9.8	66	14.9	120	6.3	368	5.4	165	7.0	764
Multidisciplinary	28.5	14	4.3	23	7.8	39	24.5	10	8.5	86
Other	13.9	65	11.9	142	6.9	211	7.8	65	9.9	519
CLINICAL MEDICINE AND DENTISTRY	30.9	60	27.8	96	10.7	190	7.4	102	15.5	469
MISC. HEALTH FIELDS	30.5	20	27.0	95	30.5	164	19.0	81	25.8	364
BEHAVIORAL SCIENCE AND PSYCHOLOGY	(a)	4	17.3	82	11.0	225	7.5	51	12.2	362
EMP, OTHER	10.8	89	7.4	154	4.3	301	11.2	154	7.3	750
UNKNOWN FIELD	(a)	8	(a)	3	--	--	--	--	14.8	41
GRAND TOTAL	14.9	811	10.7	2336	6.2	3484	7.8	1463	8.5	8468

Sources: NIH Roster of Trainees and Fellows, 1938-72, Doctorate Records File, 1935-72, Commission on Human Resources, NAS/NRC, Washington, D. C.

(a) Less than 10 observations.

Table A5 (Cont.) - MEDIAN TIME LAPSE FROM DEGREE TO FIRST APPOINTMENT
by specialty field at first appointment

MD TO FIRST MD APPOINTMENT
(Months of Elapsed Time)

Year of First Award

Specialty Field at First Appointment	1956-60		1961-65		1966-70		1971-72		Total, All Yrs.	
	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.
GENERAL MEDICAL AND BIOLOGICAL SCIENCES SUBTOTAL	44.2	804	49.5	3457	42.0	1871	50.5	336	48.8	6513
Biochemistry	41.2	71	53.6	284	49.8	138	40.5	20	50.6	519
Microbiology	63.9	66	54.3	342	50.8	183	62.2	35	53.1	627
Pathology	40.0	266	41.8	1183	28.0	592	40.3	109	39.3	2155
Physiology	51.9	101	51.5	651	51.8	328	63.0	46	51.7	1129
CLINICAL MEDICINE SUBTOTAL	43.4	1682	51.6	6350	50.5	8415	51.4	2015	50.7	18473
Internal Medicine	50.8	724	52.5	3053	52.0	3515	61.0	845	52.2	8140
Pediatrics	52.5	48	67.6	460	65.5	588	52.5	138	65.0	1237
Radiology	60.5	10	63.6	239	53.1	562	57.3	192	57.8	1003
Surgery	50.0	126	62.5	649	49.4	1060	51.4	226	51.2	2065
Ophthalmology	37.0	169	39.7	510	39.4	630	49.3	123	39.4	1432
Neurology	36.8	402	37.4	743	37.4	836	37.1	187	37.2	2169
Other	50.5	203	52.0	696	50.5	1224	50.5	304	50.8	2427
CLINICAL DENTISTRY	39.9	145	39.7	370	37.3	206	16.5	32	38.2	753
MISC. HEALTH FIELDS	71.7	86	67.0	429	50.6	285	51.8	45	62.8	845
BEHAVIORAL SCIENCE AND PSYCHOLOGY	(a)	2	70.4	25	32.5	42	(a)	4	40.2	73
EMP, OTHER	(a)	9	43.5	23	38.5	12	(a)	1	37.2	47
UNKNOWN FIELD	(a)	1	(a)	2	—	--	—	--	(a)	8
GRAND TOTAL	44.3	2729	51.1	10656	50.1	10831	51.1	2433	50.3	26712

Sources: NIH Roster of Trainees and Fellows, 1938-72, Doctorate Records File, 1935-72, Commission on Human Resources, NAS/NRC, Washington, D. C.

(a) Less than 10 observations.

Table A5 (Cont.) - MEDIAN TIME LAPSE FROM DEGREE TO FIRST APPOINTMENT
by specialty field at first appointment

PHD TO FIRST MD/PHD APPOINTMENT
(Months of Elapsed Time)

Year of First Award

Specialty Field at First Appointment	1956-60		1961-65		1966-70		1971-72		Total, All Yrs.	
	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.	Time Lapse	Number Suppt.
GENERAL MEDICAL AND BIOLOGICAL SCIENCES SUBTOTAL	49.5	43	42.5	108	20.8	85	27.2	30	30.5	274
Biochemistry	(a)	6	10.5	10	11.5	13	(a)	3	12.5	32
Microbiology	(a)	4	14.5	15	15.5	11	(a)	2	16.5	32
Pathology	46.5	10	58.5	23	26.5	18	(a)	2	41.5	53
Physiology	50.5	10	63.5	19	(a)	9	(a)	5	28.5	46
CLINICAL MEDICINE SUBTOTAL	34.5	28	57.5	43	37.3	63	49.8	32	39.8	168
Internal Medicine	(a)	7	38.5	18	37.8	20	44.5	16	49.8	62
Pediatrics	(a)	2	(a)	3	(a)	6	(a)	2	34.5	13
Radiology	--	--	(a)	3	(a)	3	(a)	1	(a)	7
Surgery	(a)	3	(a)	1	14.5	11	(a)	3	16.2	19
Ophthalmology	--	--	(a)	4	(a)	4	(a)	1	70.4	10
Neurology	18.5	11	(a)	9	38.5	13	(a)	6	39.8	39
Other	(a)	4	(a)	5	(a)	6	(a)	3	40.5	18
CLINICAL DENTISTRY	--	--	(a)	3	--	--	(a)	2	(a)	5
MISC. HEALTH FIELDS	(a)	5	(a)	8	16.0	11	--	--	34.5	25
BEHAVIORAL SCIENCE AND PSYCHOLOGY	(a)	1	--	--	(a)	1	(a)	1	(a)	2
EMP, OTHER	--	--	(a)	1	(a)	4	(a)	1	(a)	8
UNKNOWN FIELD	--	--	--	--	--	--	--	--	--	--
GRAND TOTAL	46.5	77	46.5	163	26.0	164	38.7	66	35.2	482

Sources: NIH Roster of Trainees and Fellows, 1938-72, Doctorate Records File, 1935-72, Commission on Human Resources, NAS/NRC, Washington, D. C.

(a) Less than 10 observations.

Table A6 - PRIMARY WORK ACTIVITY AND TYPE OF EMPLOYER DURING 1968-70, BY COHORT AND TRAINING PATHWAY

Yr of BA[a]	Training Pathway[b]	PRIMARY WORK ACTIVITY							TYPE OF EMPLOYER							
		MGT/ ADMIN	RES/ DEV	TEACH-ING	PROF. SERVICES to INDIV.	TOTAL KNOWN		UN-KNOWN	BUS/ INDUS	MED SCH/ UNIV	SELF	OTHER	TOTAL KNOWN		UN-KNOWN	TOTAL in PATHWAY
	Non-MD's	%	%	%	%	%	No.		%	%	%	%	%	No.		
1925-1935	1. No pre-PhD support → no PhD	12.2	4.8	82.5	0.5	100.0	189	793	1.6	69.8	3.1	25.6	100.0	129	853	982
	2. All with pre-PhD suppt. → no PhD	--	--	100.0	--	100.0	10	21	--	63.6	--	36.4	100.0	11	20	31
	3. Total--non-PhD's	11.6	4.5	83.4	0.5	100.0	199	814	1.4	69.3	2.9	26.4	100.0	140	873	1013
	4. No pre-PhD → PhD → no post PhD	33.8	21.6	40.9	3.7	100.0	8150	10223	20.4	60.9	3.6	15.1	100.0	8665	9708	18373
	5. NIH pre-PhD → PhD → no post PhD	60.0	20.0	20.0	--	100.0	5	5	--	80.0	--	20.0	100.0	5	5	10
	6. Non-NIH pre-PhD → PhD → no post PhD	18.2	18.2	63.6	--	100.0	11	11	--	91.7	--	8.3	100.0	12	10	22
	7. Total--PhD's with pre-PhD support	31.3	18.8	50.0	--	100.0	16	16	--	88.2	--	11.8	100.0	17	15	32
	8. PhD's with NIH post-PhD support	18.8	43.5	37.7	--	100.0	69	38	1.4	81.9	--	16.7	100.0	72	35	107
	9. PhD's with non-NIH post-PhD support	14.2	17.0	68.9	--	100.0	106	57	1.8	96.5	--	1.8	100.0	114	49	163
	10. Total--PhD's with post-PhD suppt.	16.0	27.4	56.6	--	100.0	175	95	1.6	90.9	--	7.5	100.0	186	84	270
	MD's															
	11. NIH pre-MD → no post-MD → no PhD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	12. No NIH pre-MD → no post-MD → no PhD	6.7	1.9	1.3	90.1	100.0	4243	533	0.2	4.8	79.4	15.7	100.0	4378	398	4776
	13. Total--MD's with no further suppt.	6.7	1.9	1.3	90.1	100.0	4243	533	0.2	4.8	79.4	15.7	100.0	4378	398	4776
	14. NIH pre-MD → NIH post-MD → no PhD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	15. No NIH pre-MD → NIH post-MD → no PhD	13.0	23.9	21.7	41.3	100.0	46	15	--	44.7	29.8	25.5	100.0	47	14	61
	16. Total--MD's with NIH post-MD, no PhD	13.0	23.9	21.7	41.3	100.0	46	15	--	44.7	29.8	25.5	100.0	47	14	61
	17. NIH pre-MD → no NIH post-MD → PhD	100.0	--	--	--	100.0	1	--	--	100.0	--	--	100.0	1	--	1
	18. No NIH pre-MD → no NIH post-Md → PhD	22.2	24.4	6.7	46.7	100.0	45	4	10.0	37.5	27.5	25.0	100.0	40	9	49
	19. NIH pre-MD → NIH post-MD → PhD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	20. No NIH pre-MD → NIH post-MD → PhD	60.0	--	20.0	20.0	100.0	5	7	--	50.0	16.7	33.3	100.0	6	6	12
	21. Total--MD's with PhD, no further support	27.5	21.6	7.8	43.1	100.0	51	11	8.5	40.4	25.5	25.5	100.0	47	15	62
	22. No NIH pre-MD → no NIH post-MD → PhD → NIH post MD/PhD	33.3	33.3	33.3	--	100.0	9	2	9.1	72.7	--	18.2	100.0	11	--	11
	23. No NIH pre-MD → NIH post-MD → PhD → NIH post-MD/PhD	--	--	--	100.0	100.0	1	--	--	--	--	100.0	100.0	1	--	1
	24. Total--MD's with NIH post MD/PhD support	30.0	30.0	30.0	10.0	100.0	10	2	8.3	66.7	--	25.0	100.0	12	--	12
	TOTAL						12890	11709						13492	11107	24599

[a]For M.D.'s without a B.A., year of B.A. was approximated by subtracting four from year of M.D.

[b]In this table NIH support is defined as full-time support at an academic level.

Table A6 (continued) - PRIMARY WORK ACTIVITY AND TYPE OF EMPLOYER DURING 1968-70, BY COHORT AND TRAINING PATHWAY

Yr of BA[a]	Training Pathway[b]	PRIMARY WORK ACTIVITY: MGT/ADMIN	RES/DEV	TEACHING	PROF. SERVICES to INDIV.	TOTAL KNOWN		UNKNOWN	TYPE OF EMPLOYER: BUS/INDUS	MED SCH/UNIV	SELF	OTHER	TOTAL KNOWN		UNKNOWN	TOTAL in PATHWAY
	Non-MD's	%	%	%	%	%	No.		%	%	%	%	%	No.		
	1. No pre-PhD support → no PhD	11.6	8.1	80.3	--	100.0	406	1712	5.5	66.3	1.0	27.2	100.0	309	1809	2118
	2. All with pre-PhD suppt. → no PhD	18.0	3.3	75.4	3.3	100.0	61	170	4.5	77.3	1.5	16.7	100.0	66	165	231
	3. Total--non-PhD's	12.4	7.5	79.7	0.4	100.0	467	1882	5.3	68.3	1.1	25.3	100.0	375	1974	2349
	4. No pre-PhD → PhD → no post PhD	36.1	26.7	33.7	3.5	100.0	19339	17404	26.6	56.4	2.6	14.5	100.0	20120	16623	36743
	5. NIH pre-PhD → PhD → no post PhD	23.1	46.2	30.8	--	100.0	39	46	2.3	65.1	--	32.6	100.0	43	42	85
	6. Non-NIH pre-PhD → PhD → no post PhD	17.0	19.6	62.5	0.9	100.0	112	189	10.0	80.0	--	10.0	100.0	120	181	301
	7. Total--PhD's with pre-PhD support	18.5	26.5	54.3	0.7	100.0	151	235	8.0	76.1	--	16.0	100.0	163	223	386
	8. PhD's with NIH post-PhD support	11.9	52.6	34.8	0.7	100.0	293	143	4.5	81.0	--	14.5	100.0	310	126	436
	9. PhD's with non-NIH post-PhD support	16.8	29.0	54.2	--	100.0	465	196	1.4	95.0	--	3.5	100.0	483	178	661
	10. Total--PhD's with post-PhD suppt.	14.9	38.1	46.7	0.3	100.0	758	339	2.6	89.5	--	7.8	100.0	793	304	1097
	MD's															
	11. NIH pre-MD → no post-MD → no PhD	--	--	50.0	50.0	100.0	2	--	--	50.0	--	50.0	100.0	2	--	2
1936–1945	12. No NIH pre-MD → no post-MD → no PhD	5.9	1.5	2.0	90.6	100.0	5810	222	0.2	6.5	79.1	14.1	100.0	5763	269	6032
	13. Total--MD's with no further suppt.	5.9	1.5	2.0	90.6	100.0	5812	222	0.2	6.6	79.1	14.2	100.0	5765	269	6034
	14. NIH pre-MD → NIH post-MD → no PhD	--	--	--	100.0	100.0	1	--	--	--	100.0	--	100.0	1	--	1
	15. No NIH pre-MD → NIH post-MD → no PhD	11.9	25.8	19.5	42.9	100.0	555	179	0.2	53.9	24.4	21.5	100.0	553	181	734
	16. Total--MD's with NIH post-MD, no PhD	11.9	25.7	19.4	43.0	100.0	556	179	0.2	53.8	24.5	21.5	100.0	554	181	735
	17. NIH pre-MD → no NIH post-MD → PhD	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	18. No NIH pre-MD → no NIH post-Md → PhD	20.5	28.2	9.0	42.3	100.0	78	2	11.8	36.8	30.3	21.1	100.0	76	4	80
	19. NIH pre-MD → NIH post-MD → PhD	--	--	100.0	--	100.0	1	--	--	100.0	--	--	100.0	1	--	1
	20. No NIH pre-MD → NIH post-MD → PhD	20.5	36.1	25.3	18.1	100.0	83	15	2.3	69.0	8.0	20.7	100.0	87	11	98
	21. Total--MD's with PhD, no further support	20.4	32.1	17.9	29.6	100.0	162	17	6.7	54.3	18.3	20.7	100.0	164	15	179
	22. No NIH pre-MD → no NIH post-MD → PhD → NIH post MD/PhD	14.0	55.8	18.6	11.6	100.0	43	10	2.3	76.7	4.7	16.3	100.0	43	10	53
	23. No NIH pre-MD → NIH post-MD → PhD → NIH post-MD/PhD	--	--	50.0	50.0	100.0	2	2	--	100.0	--	--	100.0	2	2	4
	24. Total--MD's with NIH post MD/PhD support	13.3	53.3	20.0	13.3	100.0	45	12	2.2	77.8	4.4	15.6	100.0	45	12	57
	TOTAL						27290	20290						27979	19601	47580

[a]For M.D.'s without a B.A., year of B.A. was approximated by subtracting four from year of M.D.

[b]In this table NIH support is defined as full-time support at an academic level.

Table A6 (continued) - PRIMARY WORK ACTIVITY AND TYPE OF EMPLOYER DURING 1968-70, BY COHORT AND TRAINING PATHWAY

Yr of BA[a]	Training Pathway[b]	PRIMARY WORK ACTIVITY: MGT/ADMIN	RES/DEV	TEACH-ING	PROF. SERVICES to INDIV.	TOTAL KNOWN		UN-KNOWN	TYPE OF EMPLOYER: BUS/INDUS	MED SCH/UNIV	SELF	OTHER	TOTAL KNOWN		UN-KNOWN	TOTAL in PATHWAY
	Non-MD's	%	%	%	%	%	No.		%	%	%	%	%	No.		
1946–1955	1. No pre-PhD support → no PhD	20.5	20.3	58.4	0.7	100.0	1653	6957	28.8	41.2	1.7	28.3	100.0	1516	7094	8610
	2. All with pre-PhD suppt. → no PhD	13.8	28.8	57.2	0.3	100.0	320	1165	17.8	59.5	1.8	21.0	100.0	338	1147	1485
	3. Total--non-PhD's	19.4	21.7	58.2	0.7	100.0	1973	8122	26.8	44.5	1.7	27.0	100.0	1854	8421	10095
	4. No pre-PhD → PhD → no post PhD	26.8	33.7	35.0	4.5	100.0	40197	34244	23.4	59.3	2.4	14.9	100.0	41337	33104	74441
	5. NIH pre-PhD → PhD → no post PhD	16.2	44.2	37.5	2.1	100.0	437	465	15.9	67.9	0.6	15.5	100.0	483	419	902
	6. Non-NIH pre-PhD → PhD → no post PhD	18.1	35.4	46.2	0.3	100.0	1808	1584	21.3	69.5	0.6	8.6	100.0	1839	1553	3392
	7. Total--PhD's with pre-PhD support	17.8	37.1	44.5	0.6	100.0	2245	2049	20.2	69.2	0.6	10.0	100.0	2322	1972	4294
	8. PhD's with NIH post-PhD support	9.5	57.5	32.7	0.3	100.0	1237	690	6.0	82.5	0.2	11.4	100.0	1303	624	1927
	9. PhD's with non-NIH post-PhD support	10.7	39.5	49.6	0.1	100.0	1080	432	5.0	89.9	0.3	4.8	100.0	1110	402	1512
	10. Total--PhD's with post-PhD suppt.	10.1	49.1	40.6	0.2	100.0	2317	1122	5.6	85.9	0.2	8.3	100.0	2413	1026	3439
	MD's															
	11. NIH pre-MD → no post-MD → no PhD	2.3	2.3	2.3	93.0	100.0	43	4	--	15.6	62.2	22.2	100.0	45	2	47
	12. No NIH pre-MD → no post-MD → no PhD	4.0	2.6	2.5	90.8	100.0	7268	401	0.2	7.7	73.4	18.7	100.0	7368	301	7669
	13. Total--MD's with no further suppt	4.0	2.6	2.5	90.8	100.0	7311	405	0.2	7.7	73.4	18.7	100.0	7413	303	7716
	14. NIH pre-MD → NIH post-MD → no PhD	8.3	25.0	8.3	58.3	100.0	36	4	--	47.2	30.6	22.2	100.0	36	4	40
	15. No NIH pre-MD → NIH post-MD → no PhD	5.6	19.1	11.6	63.7	100.0	6019	1662	0.3	42.5	41.5	15.7	100.0	6108	1573	7681
	16. Total--MD's with NIH post-MD, no PhD	5.7	19.1	11.5	63.7	100.0	6055	1666	0.3	42.5	41.5	15.8	100.0	6144	1577	7721
	17. NIH pre-MD → no NIH post-MD → PhD	--	75.0	25.0	--	100.0	4	2	--	60.0	20.0	20.0	100.0	5	1	6
	18. No NIH pre-MD → no NIH post-Md → PhD	8.0	38.7	12.0	41.3	100.0	75	7	3.8	43.6	25.6	26.9	100.0	78	4	82
	19. NIH pre-MD → NIH post-MD → PhD	--	66.7	33.3	--	100.0	3	1	--	100.0	--	--	100.0	3	1	4
	20. No NIH pre-MD → NIH post-MD → PhD	13.8	52.5	18.3	15.4	100.0	240	68	3.6	75.7	7.3	13.4	100.0	247	61	308
	21. Total--MD's with PhD, no further support	12.1	49.7	17.1	21.1	100.0	322	78	3.6	68.2	11.7	16.5	100.0	333	67	400
	22. No NIH pre-MD → no NIH post-MD → PhD → NIH post MD/PhD	8.7	50.4	12.2	28.7	100.0	115	30	3.4	67.2	11.8	17.6	100.0	119	26	145
	23. No NIH pre-MD → NIH post-MD → PhD → NIH post-MD/PhD	10.6	55.3	8.5	25.5	100.0	47	21	--	63.0	10.9	26.1	100.0	46	22	68
	24. Total--MD's with NIH post MD/PhD support	9.3	51.9	11.1	27.8	100.0	162	51	2.4	66.1	11.5	20.0	100.0	165	48	213
	TOTAL						60582	47737						61981	46338	108319

[a]For M.D.'s without a B.A., year of B.A. was approximated by subtracting four from year of M.D.

[b]In this table NIH support is defined as full-time support at an academic level.

Table A6 (continued) - PRIMARY WORK ACTIVITY AND TYPE OF EMPLOYER DURING 1968-70, BY COHORT AND TRAINING PATHWAY

Yr of BA[a]	Training Pathway[b]	PRIMARY WORK ACTIVITY							TYPE OF EMPLOYER							
		MGT/ ADMIN	RES/ DEV	TEACH- ING	PROF. SERVICES to INDIV.	TOTAL KNOWN		UN- KNOWN	BUS/ INDUS	MED SCH/ UNIV	SELF	OTHER	TOTAL KNOWN		UN- KNOWN	TOTAL in PATHWAY
	Non-MD's	%	%	%	%	%	No.		%	%	%	%	%	No.		
1956-1960	1. No pre-PhD support → no PhD	18.3	31.8	49.6	0.3	100.0	1896	6799	36.3	37.5	1.0	25.2	100.0	1910	6785	8695
	2. All with pre-PhD suppt. → no PhD	18.0	39.1	42.4	0.6	100.0	517	3494	29.7	49.7	0.9	19.7	100.0	579	3432	4011
	3. Total--non-PhD's	18.2	33.4	48.0	0.4	100.0	2413	10293	34.8	40.3	1.0	23.9	100.0	2489	10217	12706
	4. No pre-PhD → PhD → no post PhD	12.2	44.1	40.1	3.7	100.0	22753	22858	21.3	64.6	1.0	13.1	100.0	23463	22148	45611
	5. NIH pre-PhD → PhD → no post PhD	8.7	56.1	34.8	0.4	100.0	1105	918	15.8	73.0	0.2	11.0	100.0	1222	801	2023
	6. Non-NIH pre-PhD → PhD → no post PhD	8.6	45.0	46.1	0.4	100.0	2968	3271	20.0	72.4	0.5	7.1	100.0	3047	3192	6239
	7. Total--PhD's with pre-PhD support	8.6	48.0	43.0	0.4	100.0	4073	4189	18.8	72.6	0.4	8.2	100.0	4269	3993	8262
	8. PhD's with NIH post-PhD support	3.8	68.7	27.2	0.3	100.0	1126	690	7.9	82.2	0.1	9.8	100.0	1190	626	1816
	9. PhD's with non-NIH post-PhD support	3.8	54.4	41.9	--	100.0	559	191	9.4	86.7	--	3.9	100.0	563	187	750
	10. Total--PhD's with post-PhD suppt.	3.8	64.0	32.0	0.2	100.0	1685	881	8.4	83.6	0.1	7.9	100.0	1753	813	2566
	MD's															
	11. NIH pre-MD → no post-MD → no PhD	3.7	9.2	2.3	84.8	100.0	574	131	0.2	17.2	48.7	34.0	100.0	647	58	705
	12. No NIH pre-MD → no post-MD → no PhD	2.5	3.9	2.0	91.6	100.0	3447	759	0.2	9.4	56.4	34.1	100.0	3859	347	4206
	13. Total--MD's with no further suppt.	2.7	4.7	2.0	90.6	100.0	4021	890	0.2	10.5	55.3	34.1	100.0	4506	405	4911
	14. NIH pre-MD → NIH post-MD → no PhD	1.8	28.8	6.1	63.3	100.0	605	114	0.2	39.2	27.7	33.0	100.0	658	61	719
	15. No NIH pre-MD → NIH post-MD → no PhD	2.5	19.9	9.1	68.5	100.0	5856	1377	0.1	38.4	39.4	22.2	100.0	6238	995	7233
	16. Total--MD's with NIH post-MD, no PhD	2.4	20.8	8.8	68.0	100.0	6461	1491	0.1	38.5	38.2	23.2	100.0	6896	1056	7952
	17. NIH pre-MD → no NIH post-MD → PhD	--	73.7	10.5	15.8	100.0	19	3	4.5	40.9	--	54.5	100.0	22	--	22
	18. No NIH pre-MD → no NIH post-Md → PhD	12.0	44.0	20.0	24.0	100.0	25	4	17.9	46.4	14.3	21.4	100.0	28	1	29
	19. NIH pre-MD → NIH post-MD → PhD	14.3	52.4	9.5	23.8	100.0	21	5	--	42.9	4.8	52.4	100.0	21	5	26
	20. No NIH pre-MD → NIH post-MD → PhD	9.9	54.5	20.7	14.9	100.0	121	59	5.7	65.0	4.9	24.4	100.0	123	57	180
	21. Total--MD's with PhD, no further support	9.7	54.8	18.3	17.2	100.0	186	71	6.7	57.2	5.7	30.4	100.0	194	63	257
	22. No NIH pre-MD → no NIH post-MD → PhD → NIH post MD/PhD	--	66.7	11.1	22.2	100.0	27	13	3.1	62.5	3.1	31.3	100.0	32	8	40
	23. No NIH pre-MD → NIH post-MD → PhD → NIH post-MD/PhD	8.3	41.7	8.3	41.7	100.0	12	10	--	64.3	14.3	21.4	100.0	14	8	22
	24. Total--MD's with NIH post MD/PhD support	2.6	59.0	10.3	28.2	100.0	39	23	2.2	63.0	6.5	28.3	100.0	46	16	62
	TOTAL						41631	40696						43616	38711	82327

[a]For M.D.'s without a B.A., year of B.A. was approximated by subtracting four from year of M.D.

[b]In this table NIH support is defined as full-time support at an academic level.

Table A6 (continued) - PRIMARY WORK ACTIVITY AND TYPE OF EMPLOYER DURING 1968-70, BY COHORT AND TRAINING PATHWAY

Yr of BA[a]	Training Pathway[b]	PRIMARY WORK ACTIVITY							TYPE OF EMPLOYER							
		MGT/ ADMIN	RES/ DEV	TEACH- ING	PROF. SERVICES to INDIV.	TOTAL KNOWN		UN- KNOWN	BUS/ INDUS	MED SCH/ UNIV	SELF	OTHER	TOTAL KNOWN		UN- KNOWN	TOTAL in PATHWAY
	Non-MD's	%	%	%	%	%	No.		%	%	%	%	%	No.		
Total, 1925–1960	1. No pre-PhD support→no PhD	18.2	23.7	57.6	0.5	100.0	4144	16261	29.7	42.3	1.3	26.6	100.0	3864	16541	20405
	2. All with pre-PhD suppt.→no PhD	16.3	32.6	50.4	0.7	100.0	908	4850	23.6	55.0	1.2	20.1	100.0	994	4764	5758
	3. Total--non-PhD's	17.9	25.3	56.3	0.5	100.0	5052	21111	28.5	44.9	1.3	25.3	100.0	4858	21305	26163
	4. No pre-PhD→PhD→no post PhD	25.7	33.7	36.5	4.0	100.0	90439	84729	23.3	60.2	2.2	14.4	100.0	93585	81583	175168
	5. NIH pre-PhD→PhD→no post PhD	11.3	52.5	35.4	0.8	100.0	1586	1434	15.5	71.4	0.3	12.8	100.0	1753	1267	3020
	6. Non-NIH pre-PhD→PhD→no post PhD	12.3	40.8	46.5	0.4	100.0	4899	5055	20.2	71.6	0.5	7.7	100.0	5018	4936	9954
	7. Total--PhD's with pre-PhD support	12.1	43.7	43.8	0.5	100.0	6485	6489	19.0	71.6	0.5	9.0	100.0	6771	6203	12974
	8. PhD's with NIH post-PhD support	7.6	61.2	30.8	0.3	100.0	2725	1561	6.5	82.2	0.1	11.2	100.0	2875	1411	4286
	9. PhD's with non-NIH post-PhD support	10.4	40.0	49.5	--	100.0	2210	876	5.2	90.5	0.1	4.1	100.0	2270	816	3086
	10. Total--PhD's with post-PhD suppt.	8.9	51.7	39.2	0.2	100.0	4935	2437	5.9	85.9	0.1	8.1	100.0	5145	2227	7372
	MD's															
	11. NIH pre-MD→no post-MD→no PhD	3.6	8.7	2.4	85.3	100.0	619	135	0.1	17.1	49.4	33.3	100.0	694	60	754
	12. No NIH pre-MD→no post-MD→ no PhD	4.8	2.4	2.0	90.7	100.0	20768	1915	0.2	7.1	73.1	19.6	100.0	21368	1315	22683
	13. Total--MD's with no further suppt.	4.8	2.6	2.0	90.6	100.0	21387	2050	0.2	7.4	72.4	20.1	100.0	22062	1375	23437
	14. NIH pre-MD→NIH post-MD→no PhD	2.2	28.5	6.2	63.1	100.0	642	118	0.1	39.6	27.9	32.4	100.0	695	65	760
	15. No NIH pre-MD→NIH post-MD→ no PhD	4.5	19.8	10.8	65.0	100.0	12476	3233	0.2	41.0	39.7	19.1	100.0	12946	2763	15709
	16. Total--MD's with NIH post-MD, no PhD	4.4	20.2	10.6	64.9	100.0	13118	3351	0.2	40.9	39.1	19.8	100.0	13641	2828	16469
	17. NIH pre-MD→no NIH post-MD→PhD	4.2	70.8	12.5	12.5	100.0	24	5	3.6	46.4	3.6	46.4	100.0	28	1	29
	18. No NIH pre-MD→no NIH post-Md→ PhD	15.7	32.7	10.8	40.8	100.0	223	17	9.5	40.5	26.1	23.9	100.0	222	18	240
	19. NIH pre-MD→NIH post-MD→PhD	12.0	52.0	16.0	20.0	100.0	25	6	--	52.0	4.0	44.0	100.0	25	6	31
	20. No NIH pre-MD→NIH post-MD→PhD	14.5	49.4	20.3	15.8	100.0	449	149	3.9	71.3	6.9	17.9	100.0	463	135	598
	21. Total--MD's with PhD, no further support	14.4	45.1	16.9	23.6	100.0	721	177	5.4	60.4	12.5	21.7	100.0	738	160	898
	22. No NIH pre-MD→no NIH post-MD→ PhD→NIH post MD/PhD	9.8	53.1	14.4	22.7	100.0	194	55	3.4	68.8	8.3	19.5	100.0	205	44	249
	23. No NIH pre-MD→NIH post-MD→ PhD→NIH post-MD/PhD	9.7	50.0	9.7	30.6	100.0	62	33	--	63.5	11.1	25.4	100.0	63	32	95
	24. Total--MD's with NIH post MD/PhD support	9.8	52.3	13.3	24.6	100.0	256	88	2.6	67.5	9.0	20.9	100.0	268	76	344
	TOTAL						142393	120432						147068	115757	262825

Sources: NIH Roster of Trainees and Fellows, 1938-72, Comprehensive Roster of Doctoral Scientists and Engineers, 1935-73, Cumulative Index, 1952-71, CHR, NAS/NRC; National Register of Scientific and Technical Personnel, 1954-70, NSF; Register of Licensed Physicians in the United States, 1971, AMA; Medical School Faculty Roster, 1971, AAMC; NDEA Fellows, 1959-72, Office of Education, USDHEW; Woodrow Wilson Fellows, 1958-69, Woodrow Wilson National Fellowship Foundation; Dental School Faculty Roster, 1971-72, AADS.

[a]For M.D.'s without a B.A., year of B.A. was approximated by subtracting four from year of M.D.

[b]In this table NIH support is defined as full-time support at an academic level.

APPENDIX B

THE METHODOLOGY USED IN DEVELOPING THE EQUATIONS FOR CHAPTER 5

A. METHODOLOGY

The equations in Chapter 5 were developed from a regression analysis in which variables measuring the flow of students through higher education (hereafter called the dependent variables) were correlated with more than 50 variables measuring economic and demographic factors (the "explanatory" variables). The data were in the form of annual values, i.e., time series for the period 1956-1970.

Using the correlation matrix as a starting point, the estimating equations were developed from a stepwise regression procedure, adding the "best" explanatory variable at each step until no significant explanatory variables remain. The "best" variable is defined as that which makes the maximum contribution towards explaining the residual variation in the dependent variable. Variables which are non-significant in the original correlation matrix may become significant at a later stage in the procedure and be included in the final equation. Conversely, variables which are significant originally may become non-significant as additional explanatory variables are added to the equation. The stepwise procedure does not guarantee that the final set of explanatory variables selected for the equation is the "best" of all possible sets. This can only be guaranteed if all possible combinations of explanatory variables are tested. While the stepwise method is a powerful tool for developing empirical relationships, a certain amount of subjectivity is necessarily involved in developing the final equations. In some cases the explanatory variable chosen for inclusion in the equation was not the "best" one in the sense of making the greatest contribution towards explaining the residual variation. Exceptions from this rule occurred when the "best" variable was highly correlated with other explanatory variables in the equation, or when the coefficient of the "best" variable was negative when a positive effect was to be expected. As is usual with time series data, the correlations among all the variables tend to be higher than would ordinarily occur with cross-sectional data. This is partly due to the fact that each point in a time series tends to be related to previous points (autocorrelation), and partly due to trends in the series being compared. It is not uncommon to find several variables to be significantly correlated over time even though there is no apparent connection between them. Thus, correlations alone cannot be relied upon to determine if a true relationship exists between two time series. In developing the equations for this model, an attempt has been made to insure that the explanatory variables not only have statistically significant correlations with the dependent variable, but also have logical cause and effect relations, and have logical algebraic signs.

This admittedly empirical approach can be contrasted with results obtained by taking a more conceptual approach to the problem. In the bioscience equations, an attempt was made to test several a priori hypotheses about the determinants of bioscience graduate enrollments and Ph.D. degrees. The results of those tests are reported below in the section on Alternative Models in the Biosciences. For the most part these alternative models failed to produce results as satisfactory as the empirical approach.

The predictive power of a regression equation is usually measured by R^2, the proportion of the variation in the dependent variable accounted for by its association with the explanatory variables. The time series data used to develop the equations in the model result in R^2 values which are quite high; generally in the range of 0.8 to 0.9. One should not place too much emphasis on the value of R^2 in weighing the merits of any single equation—in many cases it merely serves to indicate nothing more than that a good fit to the observed data has been achieved by the linear combination of explanatory variables. Other criteria are equally important in judging the adequacy of an equation which attempts to explain the behavior of a phenomenon. From a purely statistical point of view, the specification error[1] is quite important and its avoidance tends to enlarge the number of explanatory variables used in any equation. From a philosophical point of view, the principle of parsimony tends to minimize the number of explanatory variables used. Steering a course between this Scylla and Charybdis has been an important element of the methodology.

In the equations that follow, the standard partial regression coefficients, which under certain rather stringent conditions discussed on page 85, measure the relative importance of each explanatory variable, are shown in parentheses under each variable. In general, the higher the standard partial regression coefficient (in absolute value), the greater is the relative importance of the variable.

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[1]Specification error covers the many different ways in which the function of explanatory variables specified in an equation might fail to represent the true relationship between the dependent and explanatory variables. Variables omitted from the equation contribute to specification error if they actually do affect the dependent variable, as do variables whose form is not specified properly. For more complete explanation of specification error see J. Johnston, Econometric Methods, McGraw-Hill, New York, 1963.

Aggregate Equations (All Fields Combined)

Values in parentheses under each variable are the standard partial regression coefficients.

B.A.'s relative to the 20-24 year old population:

(1) $(BA/P)_i = -0.01 + \underset{(0.99)}{0.00433\ \$B_i} + \underset{(0.35)}{8.20 \times 10^{-6} SA_{i-1}}$; $R^2 = .95$

Graduate enrollments relative to B.A.'s in the preceding year:

First-year full-time:

(2) $EN1FTL_i/B_{i-1} = 0.133 + \underset{(0.88)}{1.66 \times 10^{-4} SAGE_{i-1}} + \underset{(0.27)}{3.94(PD)}$; $R^2 = .94$

First-year part-time:

(3) $EN1PTL_i/B_{i-1} = 0.224 + \underset{(.97)}{1.17 \times 10^{-5} FRDSC}$; $R^2 = .94$

First-year total:

(4) $EN1TTL_i/B_{i-1} = 0.15 + \underset{(.99)}{4.42 \times 10^{-4} SAGE_{i-1}} + \underset{(.10)}{0.179(\$C/HS)_{i-5}}$; $R^2 = .98$

Total graduate enrollments:

(5) $ENTL_i/B_{i-1} = 0.732 + \underset{(.97)}{5.19 \times 10^{-4} SAGE_{i-1}}$; $R^2 = .95$

Ph.D.'s relative to average graduate enrollments for the last three years:

(6) $PHDTL_i/\overline{EN}_i = -0.018 + \underset{(1.01)}{3.19 \times 10^{-5} SAGE_{i-7}} + \underset{(.46)}{0.0230(\$C/HS)_{i-4}} + \underset{(.20)}{0.010(\$C/HS)_{i-7}}$;

$R^2 = .93$

B. AGGREGATE EQUATIONS

Table B1 shows dependent variables for the aggregate equations and the explanatory variables that were used. Table B2 shows the correlation matrix for some of these variables. Since all the data were in the form of time series for the 1956-70 period, high correlations could result from strong trend components in the series rather than from the variations around the trend, which is really the vital factor in trying to specify cause and effect relationships. Therefore, Table B2 shows the correlations both with and without the linear trend component in the data. The correlations which fail to remain significant after the trend is removed are considered to be spurious. Of course those that remain significant could also be spurious, it being well recognized that correlation does not imply causation. But substantial and consistent correlations provide supportive empirical evidence to a hypothesized causal relationship.

1. Conclusions from the Aggregate Equations

It is evident from the correlation matrix that relative salaries alone cannot adequately explain the variation in relative degrees and enrollments. For example, the ratio of annual incomes of individuals with four or more years of college to incomes of high school graduates ($C/HS), is available from periodic surveys of the Census Bureau beginning in 1939. This ratio would seem to be a logical candidate for explaining the behavior of the annual number of B.A.'s relative to the college age population. Yet as seen from Table B2 in no case was the correlation between these variables significant before removing the trend, and only with $\$C/HS_{i-10}$ was it significant after removing the trend. Absolute salaries, at least in the case of the ratio BA/P give much higher correlations. In the case of Ph.D.'s, no salary variable has a significant and positive correlation with $PHDTL/\overline{EN}$ after the trend is removed, indicating that the variation in relative Ph.D. production cannot be due solely to market forces as reflected by incomes.

The standard partial regression coefficients may be used as measures of relative importance of the explanatory variables in the above equations with some confidence since the equations are relatively free of multicollinear effects. In no case is the correlation among the explanatory variables significant; the highest observed correlation is 0.39 between $B and SA_{i-1} in equation (1).

Table B1 - DEFINITION OF VARIABLES INVOLVED IN THE AGGREGATE EQUATIONS

DEPENDENT VARIABLES	DESCRIPTION	MEAN 1956-70	STANDARD DEVIATION
$(BA/P)_i$	Total number of BA's awarded in the i^{th} year relative to the U.S. Population 20-24 yrs. old	0.0378	0.00516
$EN1FTL_i/B_{i-1}$	First year, full-time graduate enrollments relative to BA's in the preceding year	0.212	0.0382
$EN1PTL_i/B_{i-1}$	First year, part-time graduate enrollments relative to BA's in the preceding year	0.362	0.0555
$EN1TTL_i/B_{i-1}$	First year total graduate enrollments relative to BA's in the preceding year	0.574	0.0898
$ENTL_i/B_{i-1}$	Total graduate enrollments relative to BA's in preceding year	0.898	0.107
$PHDTL_i/\overline{EN}_i$	Total number of Ph.D.'s awarded in the i^{th} year relative to the average graduate enrollments for the last 3 years	0.0377	0.00246
EXPLANATORY VARIABLES			
$\$B_i$	Real median salary of all professional and technical personnel whose highest degree is a BA: (thousands, deflated by the CPI)	10.39	1.18
SA_{i-1}	Real total federal aid to higher education. Includes all traineeships and fellowships plus VA benefits for higher education; ($millions, deflated by CPI)	744.5	221.2
$SAGE_{i-1}$ $SAGE_{i-7}$	Real total federal aid for students in graduate education. Includes all traineeships and fellowships plus 10% of VA direct benefit payments to students in higher education (10% is the estimated amount allocated to graduate education); ($millions, deflated by CPI)	318.5 125.2	201.4 77.7
$\$C/HS_{i-4}$ $\$C/HS_{i-5}$ $\$C/HS_{i-7}$	Average annual income of males, 25 years and older with 4 or more years of college relative to those with high school only	1.58 1.59 1.59	0.0497 0.0498 0.0489
FRDSC	Real federal funds for research and development in science, and for R+D plant; ($ millions, deflated by CPI)	11.764	4581.7
PD	Probability of obtaining an educational deferment from military service	0.00642	0.00261

Table B2 - CORRELATION MATRIX FOR THE DEPENDENT VARIABLES OF THE AGGREGATE EQUATIONS AND SOME SELECTED "EXPLANATORY" VARIABLES

	Dependent Variables											
	Ratio BA's to population (BA/P20-24)$_i$		Relative 1st-yr full-time grad. enrollments ($EN1FTL_i/BA_{i-1}$)		Relative 1st-yr part-time grad. enrollments ($EN1PTL_i/BA_{i-1}$)		Relative 1st-yr total grad. enrollments ($EN1TTL_i/BA_{i-1}$)		Relative total grad. enrollments ($ENTL_i/BA_{i-1}$)		Relative PhD production $PHDTL_i/\overline{EN}_i$	
Explanatory Variables	unadj	w/o trend	unadj	w/o trend	unadj	w/o trend	unadj	w/o trend	unadj	w/o trend	unadj	w/o trend
Ratio of annual incomes: 4 or more years college/high school												
\$C/HS i	-.04	.53	-.29	-.19	-.40	-.54	-.37	-.47	-.32	-.31	-.63	-.63
\$C/HS i-1	-.01	.24	-.35	-.51	-.29	-.55	-.33	-.68	-.32	-.63	-.61	-.67
\$C/HS i-2	-.08	-.09	-.40	-.67	-.13	-.21	-.25	-.57	-.27	-.57	-.44	-.49
\$C/HS i-3	-.15	-.24	-.41	-.65	.00	.21	-.17	-.28	-.22	-.40	-.19	-.18
\$C/HS i-4	-.13	-.27	-.30	-.48	.15	.53	-.03	.03	-.11	-.17	.04	.08
\$C/HS i-5	-.23	-.46	-.12	-.09	.15	**.61**	.04	.34	-.04	.09	.11	.19
\$C/HS i-7	-.18	-.39	.39	**.83**	.13	.48	.25	**.84**	.25	**.79**	.16	.23
\$C/HS i-10	.52	**.70**	.19	-.16	.05	-.70	.11	-.55	.20	-.26	.02	-.20
Median PhD/Median BA income \$PHDTL/\$BATL	**.62**	-.77	**.72**	.09	**.91**	**.73**	**.87**	.53	**.83**	.36	.45	.00
Median MA/Median BA income \$MATL/\$BATL	-.09	-.02	-.11	-.06	-.04	.11	-.07	.04	-.04	.13	-.13	-.09
Faculty salaries/Median Professional salaries \$F/\$TL	-.56	-.66	-.03	**.59**	-.13	**.66**	-.09	**.80**	-.13	**.64**	-.20	.01
Real median professional income, all levels \$TL	**.88**	-.78	**.84**	-.27	**.90**	**.72**	**.92**	.29	**.91**	.01	**.59**	-.39
Real median PhD income \$PHDTL	**.88**	-.78	**.85**	-.12	**.90**	**.66**	**.92**	.35	**.92**	.15	**.58**	-.51
Real median MA income \$MATL	**.88**	-.13	**.82**	-.26	**.86**	.13	**.88**	-.08	**.89**	-.06	**.55**	-.51
Real median BA income \$BATL	**.91**	-.12	**.83**	-.35	**.86**	.01	**.88**	-.21	**.90**	-.29	**.56**	-.68
Real disposable income ($RDSPIN_{i-4}$)	**.98**	**.81**	**.84**	.04	**.86**	-.75	**.89**	-.45	**.90**	-.17	**.60**	.37
Real federal R & D in science FRDSC	**.76**	-.81	**.84**	-.07	**.97**	**.79**	**.96**	.47	**.93**	.20	.52	-.29
Real student aid to graduate education												
SAGE i	**.79**	-.84	**.91**	.46	**.95**	**.67**	**.97**	**.72**	**.96**	**.52**	**.57**	-.07
SAGE i-1	**.86**	-.65	**.94**	**.82**	**.93**	**.58**	**.97**	**.90**	**.97**	**.83**	**.64**	.27
SAGE i-5	**.91**	.35	**.89**	**.69**	**.77**	-.31	**.86**	.24	**.88**	.39	**.76**	**.80**
SAGE i-7	**.74**	.41	**.82**	**.66**	**.58**	-.35	**.71**	.19	**.76**	.39	**.84**	**.81**

Circled values indicate significant and positive correlations

The subscript i is used to denote the value of the variable in the ith year

C. DISCUSSION OF BIOSCIENCE EQUATIONS

In equations (7) through (10) bioscience graduate enrollments relative to total graduate enrollments are dependent primarily on the NIH training and fellowship programs, medical school enrollments, and federal research in the life sciences and physical sciences.

Table B4 shows the correlations between the dependent variables in the bioscience model and some selected explanatory variables. These correlations were computed from the data with and without a linear trend component in order to detect those relationships due mainly to the trend.

For the biosciences, a longer than normal series of income data is available because of a special survey of bioscientists conducted by the National Science Foundation in 1951.[2] With these data it becomes possible to test hypotheses about the influence of bioscientists' income ratios with various time lags on relative graduate enrollments and Ph.D. production in the biosciences. The income variables used are ratios of median annual income of bioscience Ph.D.'s relative to all Ph.D.'s ($PHDBI/$PHDTL); and ratios of annual incomes of bioscience Ph.D.'s relative to bioscience B.A.'s ($PHDBI/$BABI). In Table B4 these income ratios are seen to have some weak but significant correlations with the dependent variables using the unadjusted data. After removing the trend, however, all but one of these become non-significant, indicating that the original correlations resulted more from the trend component than from the inherent variation in the two series. Relative federal aid to bioscience students (NIHTF/SAGE) exhibits much higher correlations, most of which remain strong after trend is removed. This evidence supports the hypothesis that relative bioscience graduate enrollments and Ph.D. production react primarily to student aid variables. Further evidence is obtained from equations (7) to (11) where the explanatory variables represent the best set that could be found in this study to account for the behavior of the dependent variables. Among this set, relative student aid to bioscience consistently explains the major portion of the variation in relative enrollments and Ph.D. degrees.

The standard partial regression coefficients are fairly reliable indicators of the relative importance of each explanatory variable in all the bioscience equations except (7), where the significant correlation between $(NIHTF/SAGE)_{i-1}$ and $(NIHTF/SAGE)_{i-3}$, $(r = 0.73)$, suggests

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[2]*Manpower Resources in the Biological Sciences*, National Science Foundation, Washington, D. C., 1955.

Bioscience Equations

Values in parentheses under each variable are the standard partial regression coefficients.

Graduate enrollments in bioscience relative to total graduate enrollments:

First-year full-time:

(7) $(EN1FBI/EN1FTL)_i = 0.0469 + \underset{(.70)}{0.0361(NIHTF/SAGE)_{i-1}} - \underset{(-0.65)}{4.25 \times 10^{-6}(MDENR)}$

$+ \underset{(.48)}{0.0210(NIHTF/SAGE)_{i-3}} + \underset{(.23)}{0.0408(R_{1p}/R_t)_i}$; $R^2 = .97$

First-year part-time:

(8) $(EN1PBI/EN1PTL)_i = 0.00637 + \underset{(.78)}{0.0186(NIHTF/SAGE)_{i-3}} + \underset{(.28)}{0.0123(NIHTG/SAGE)_i}$; $R^2 = .87$

First-year total:

(9) $(EN1TBI/EN1TTL)_i = 0.0156 + \underset{(1.06)}{0.0264(NIHTF/SAGE)_{i-3}} - \underset{(-0.42)}{1.52 \times 10^{-6}(MDENR)_i}$

$+ \underset{(.34)}{0.0343(R_{1p}/R_t)_i}$; $R^2 = .85$

Total graduate enrollments in bioscience:

(10) $(ENBI/ENTL)_i = 0.0344 + \underset{(.94)}{0.0278(NIHTF/SAGE)_{i-3}}$; $R^2 = .89$

Ph.D.'s in bioscience relative to all Ph.D.'s:

(11) $(PHDBI/PHDTL)_i = 0.0774 + \underset{(.68)}{0.0257(TFBI/TFTL)_{i-1}} + \underset{(.37)}{0.0749(R_1/R_t)_i}$; $R^2 = .77$

Table B3 - DEFINITION OF VARIABLES INVOLVED IN THE BIOSCIENCE EQUATIONS

DEPENDENT VARIABLES	DESCRIPTION	MEAN 1956-70	STANDARD DEVIATION
$(EN1FBI/EN1FTL)_i$	First year full-time graduate enrollments in bioscience relative to total first year full-time enrollments	0.0599	0.00482
$(EN1PBI/EN1PTL)_i$	First year part-time graduate enrollments in bioscience relative to total first year part-time enrollments	0.0194	0.00259
$(EN1TBI/EN1TTL)_i$	First year graduate enrollments in bioscience relative to total first year enrollments in all fields	0.0342	0.00269
$(ENTL)_i$	Total graduate enrollments in bioscience relative to total graduate enrollments in all fields	0.0466	0.00323
$(PHDBI/PHDTL)_i$	Number of bioscience PhD's relative to total number of PhD's produced in the school year ending in year i	0.115	0.00605
EXPLANATORY VARIABLES			
$(NIHTF/SAGE)_{i-1}$ $(NIHTF/SAGE)_{i-3}$	NIH appropriations for training grants and fellowships relative to total federal aid for graduate students in the i^{th} fiscal year; ($/$)	0.457 0.439	0.0939 0.110
$(NIHTG/SAGE)_i$	NIH appropriation for training grants relative to total federal aid for graduate students in the i^{th} fiscal year; ($/$)	0.393	0.0603
$MDENR_i$	Enrollments in medical schools in the school year ending in year i	8703.2	742.6
$(R_{lp}/R_t)_i$	Federal funds for research in the life sciences and physical sciences relative to total federal funds for research in fiscal year i; ($/$)	0.592	0.0272
$(R_l/R_t)_i$	Federal funds for research in the life sciences relative to total federal funds for research in fiscal year i; ($/$)	0.267	0.0298
$TFBI/TFTL_{i-1}$	Federal expenditures for traineeships and fellowships in bioscience relative to total federal expenditures for traineeships and fellowships in all fields; ($/$)	0.667	0.161

Table B4 - CORRELATION MATRIX FOR THE DEPENDENT VARIABLES OF THE BIOSCIENCE EQUATIONS AND SOME SELECTED "EXPLANATORY" VARIABLES

Explanatory Variables		Dependent Variables: Relative 1st-yr full-time grad. enrollments in Bioscience $(EN1FBI/EN1FTL)_i$ unadj	w/o trend	Relative 1st-yr part-time grad. enrollments in Bioscience $(EN1PBI/EN1PTL)_i$ unadj	w/o trend	Relative 1st-yr total grad. enrollments in Bioscience $(EN1TBI/EN1TTL)_i$ unadj	w/o trend	Relative total grad. enrollments in Biosci. $(ENBI/ENTL)_i$ unadj	w/o trend	Relative PhD production in Bioscience $(PHDBI/PHDTL)_i$ unadj	w/o trend
Median Bioscience PhD income relative to median income of all PhD's ($PHDBI/$PHDTL)	i	-.11	-.38	.47	-.35	.30	-.31	.66	.16	-.82	-.59
	i-1	-.48	-.61	.02	-.53	-.10	-.47	.40	.09	-.48	-.24
	i-2	-.72	-.75	-.36	-.69	-.43	-.61	.01	-.15	-.07	.05
	i-3	-.80	-.80	-.62	-.82	-.62	-.69	-.41	-.51	.38	.45
	i-4	-.73	-.72	-.66	-.71	-.63	-.60	-.67	-.71	.54	.51
	i-5	-.63	-.66	-.68	-.55	-.63	-.50	-.81	-.76	.60	.41
Median Bioscience PhD income relative to median bioscience BA income ($PHDBI/$BABI)	i	.17	.13	.68	.08	.47	-.04	.78	.44	-.77	-.45
	i-1	.10	.03	.59	.23	.39	-.26	.70	.16	-.69	-.19
	i-2	.08	-.06	.58	-.17	.43	-.09	.70	.19	-.67	-.16
	i-3	.02	-.15	.57	-.08	.49	.11	.69	.24	-.63	-.14
	i-4	-.21	-.44	.37	-.33	.30	-.15	.54	.03	-.44	-.13
	i-5	-.53	-.78	.08	-.70	-.04	-.56	.27	-.32	-.32	.20
NIH Traineeship and Fellowship appropriations relative to total student aid to graduate education (NIHTF/SAGE)	i	.52	.54	.65	.46	.48	.28	.38	-.01	-.40	-.05
	i-1	.86	.90	.80	.79	.77	.70	.62	.48	-.43	-.19
	i-2	.77	.86	.87	.80	.83	.75	.84	.74	-.72	-.54
	i-3	.64	.81	.90	.78	.84	.79	.94	.88	-.74	-.46
	i-4	.47	.70	.86	.65	.78	.72	.92	.84	-.65	-.16
	i-5	.36	.64	.80	.48	.69	.60	.82	.58	-.61	.14
Fed. funds for research in life sci. relative to total federal research FRLS/FRTOT		-.58	-.58	-.44	-.54	-.44	-.46	-.53	-.66	.60	.74
Fed. traineeship & fellowship expenditures in Biosci. relative to total fed. train. & fel. expend. (TFBI/TFTL)	i	-.27	-.41	-.81	-.52	-.63	-.44	-.87	-.76	.80	.60
	i-1	-.13	-.03	-.69	-.02	-.50	.00	-.81	-.52	.74	.34
	i-2	.03	-.35	-.52	.51	-.35	.41	-.69	-.12	.69	.18

Circled values indicate significant and positive correlations

The subscript i is used to denote the value of the variable in the ith year caution. None of the other equations had any significant correlations among the explanatory variables so the regression coefficients are generally stable, and the standard partials are more reliable measures of relative importance.

The influence of the NIH training grant and fellowship programs appears to be spread over at least three years from the time the funds are appropriated, and a more sophisticated handling of the lag problem than was attempted here could be devised to show the impact of each year's NIH training funds on graduate enrollments. Further development of the model would include such refinements to this distributed lag problem, but these would require more time and resources than are available at present.

Although $(NIHTL/SAGE)_{i-2}$ is not included in equation (1), the implications in the data are that $(NIHTL/SAGE)_{i-1}$, $(NIHTF/SAGE)_{i-2}$, and $(NIHTF/SAGE)_{i-3}$ all share in this influence.[3] This seems reasonable in view of the fact that a fellowship award from NIH has usually meant a three-year commitment of support. And since an NIH awardee is allowed one year before activating his fellowship award, it is not unreasonable to expect at least a one-year lag between the funding variable and its effect on enrollments. On the other hand, training-grant support alone (NIHTG/SAGE) seems to have an immediate impact which shows up mainly in first-year, part-time enrollments.

The effect of medical school enrollments in reducing the number of bioscience graduate students is especially noticeable with first-year enrollments.

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[3] Since $(NIHTF/SAGE)_{i-2}$ is highly correlated with $(NIHTF/SAGE)_{i-3}$, and also with $(NIHTF/SAGE)_{i-1}$, the inclusion of all three explanatory variables in the same equation causes statistical problems. In this case $(NIHTF/SAGE)_{i-2}$ is not statistically significant when included with the other two, which is the same as saying that the inclusion of $(NIHTF/SAGE)_{i-2}$ adds no information beyond that contained in $(NIHTF/SAGE)_{i-1}$ and $(NIHTF/SAGE)_{i-3}$. Fortunately, the correlation between $(NIHTF/SAGE)_{i-1}$ and $(NIHTF/SAGE)_{i-3}$, although significant, is not high enough to prevent their joint use in the same equation. This is a problem in distributed lags, and perhaps a better means of handling it than attempted here could and should be devised. (See for example J. Johnston, _op. cit._, chapter 10.)

D. ALTERNATIVE MODELS FOR THE BIOSCIENCES

The five bioscience equations were generated under the hypothesis that graduate enrollments and degrees were related to that combination of explanatory variables which explained the maximum amount of the variance in the dependent variables while providing logical relationships, with appropriate algebraic signs, and avoiding multicollinearity where possible. Of course many other hypotheses could have been used, and a comparison of the equations developed under alternative hypotheses with those in the model provides some insight into results obtained from taking other approaches to these data. The five bioscience equations were developed under eight other hypotheses about the behavior of bioscience enrollments and degrees and the results are summarized in Table B5.

Alternative hypotheses A1 and A2 assume that relative bioscience enrollments and degrees are dependent only on relative salaries of bioscience Ph.D.'s. Under A1, the single best salary variable was used in each equation, and under A2, the best combination of salary variable was used. A very unsatisfactory model results in either case. The salary variables alone, although statistically significant, do not explain much of the variation in bioscience enrollments and Ph.D. degrees. Furthermore, most of the salary variables have negative coefficients which would imply that a reduction in relative salaries of bioscience Ph.D.'s tends to increase relative bioscience enrollments and Ph.D.'s.

In hypotheses A3 and A4, the dependent variables in bioscience are assumed to depend only on research funds, and these do a fair job of explaining the behavior of the dependent variables. Hypothesis A3 generates the second highest R^2 per variable, but one equation contains an illogical sign.

Under hypotheses A5 and A6, student aid variables alone do a better job than either salaries or research funds alone. Hypothesis A5 gives the highest R^2 per variable, with no illogical signs.

In hypothesis A7, relative salaries, research funds, and medical school enrollment variables explain a respectable 80% of the variation with nine explanatory variables, but two of these have illogical signs (i.e., relative bioscience Ph.D. salaries, and federal research and development funds relative to total federal research funds, have negative coefficients, indicating that these variables are inversely related to bioscience enrollments). Adding student aid variables to the explanatory set, as in hypothesis A8, improves the fit to 91% of the variation, but requires 16 explanatory variables, six of which have illogical signs. Three of the variables with illogical signs are

TABLE B5 - SUMMARY OF VARIOUS HYPOTHESES TESTED IN BIOSCIENCE

Hypothesis A. Relative Bioscience Graduate Enrollments and PhD Degrees are Dependent on:	Average R^2 for the 5 equations (R^2 measures the goodness-of-fit to the observed data)	Total number of explanatory variables in the 5 equations	R^2 per variable	Number of nonsignificant variables	Number of variables with illogical signs
A1. Relative salaries of bioscience PhD's (using the single best salary variable in each equation)	0.57	5	.11	0	5
A2. Relative salaries of bioscience PhD's (using the best combination in each equation)	0.67	9	.07	0	7
A3. Federal funds for research (using the single best research variable in each equation)	0.67	5	.13	0	1
A4. Federal funds for research (using the best combination in each equation)	0.76	8	.09	0	2
A5. Student aid variables (using the single best student aid variable in each equation)	0.76	5	.15	0	0
A6. Student aid variables (using the best combination in each equation)	0.85	11	.08	0	5
A7. Relative salaries of bioscience PhD's, research funds and medical school enrollments	0.80	9	.09	0	2
A8. Relative salaries of PhD's, research funds, medical school enrollments and relative student aid to bioscience	0.91	16	.06	0	6
A9. The best combination of explanatory variables, rejecting those with illogical signs, and avoiding multicollinearity where possible. (This is the methodology used to generate the equations in the model.)	0.87	12	.07	0	0

salary variables, one is a student aid variable, and two are research variables.

Hypothesis A9 is the one under which the equations in the model were developed. The explanatory variables were added sequentially starting with the one that generally had the highest correlation with the dependent variable. Other explanatory variables were added which contributed significantly to R^2, which were logically related to the dependent variable with the proper sign, and which were not too highly correlated with other explanatory variables already selected for the equation. This procedure gave equations which explain an average of 87% of the variation in the dependent variables with a total of 12 explanatory variables, all of which are statistically significant and have the logically correct signs. These equations, even though they do not give the highest R^2, appear to be the most satisfactory set from the standpoint of their overall statistical and rational properties.

E. DISCUSSION OF PHYSICAL SCIENCE AND ENGINEERING EQUATIONS

The complete set of equations for enrollments and Ph.D. degrees in physical science and engineering are presented in equations (12) through (16).

Relative first-year full-time and total graduate enrollments in physical science and engineering behave very similarly, and appropriately are explained by the same set of variables. These include a salary variable ($PHDCH/$PHDTL), a research funds variable (R_p/R_t), a student-aid variable (TFPE/TFTL), and the medical school variable (MEDAPP). The salary variable ranks ahead of the student-aid variable in terms of its impact on first-year full-time enrollments, but they are about equal in impact on total graduate enrollments.

The highest correlation among the explanatory variables in equations (12) through (16) is -0.66 between $(\text{MEDAPP})_1$ and $(\text{TFBI/TFTL})_{i-1}$ in equation (13). There are no other significant correlations among this explanatory set.

The physical sciences and engineering are influenced to a certain extent by the proportionate amount of traineeship and fellowship money available to these fields (TFPE/TFTL), but some additional influence is seen to come from what are normally considered to be bioscience funds, (NIHTF/SAGE) and (TFBI/TFL). This is an interesting result because it lends empirical evidence to the interrelationship between the biological and physical sciences. While bioscience training funds seem to affect physical science and engineering enrollments, the relationship does not

Physical Science and Engineering Equations

Values in parentheses under each variable are the standard partial regression coefficients.

Graduate enrollments in physical science and engineering relative to total graduate enrollments:

First-year full-time:

(12) $$(EN1FPE/EN1FTL)_i = 0.332 + \underset{(.49)}{0.420(\$PHDCH/\$PHDTL)_i} + \underset{(.19)}{0.164(R_p/R_t)_i} - \underset{(-0.51)}{4.53 \times 10^{-6}(MEDAPP)_i} + \underset{(.38)}{0.133(TFPE/TFTL)_{i-1}} ; \quad R^2 = .99$$

First-year part-time:

(13) $$(EN1PPE/EN1PTL)_i = 0.0182 + \underset{(.05)}{0.0564(TFBI/TFTL)_{i-1}} + \underset{(.29)}{0.181(R_p/R_t)_i} - \underset{(-0.42)}{2.67 \times 10^{-6}(MEDAPP)_i} ; \quad R^2 = .96$$

First-year total:

(14) $$(EN1TPE/EN1TTL)_i = -0.155 + \underset{(.34)}{0.213(\$PHDCH/\$PHDTL)_i} + \underset{(.33)}{0.212(R_p/R_t)_i} - \underset{(-0.62)}{3.90 \times 10^{-6}(MEDAPP)_i} ; \quad R^2 = .97$$

Total graduate enrollments in physical science and engineering:

(15) $$(ENPE/ENTL)_i = -0.108 + \underset{(.35)}{0.210(\$PHDCH/\$PHDTL)_i} + \underset{(.26)}{0.158(R_p/R_t)_i} - \underset{(-0.60)}{3.60 \times 10^{-6}(MEDAPP)_i} + \underset{(.35)}{0.0865(TFPE/TFTL)_{i-1}} ; \quad R^2 = .99$$

Ph.D.'s in physical science and engineering relative to all Ph.D.'s:

(16) $$(PHDPE/PHDTL)_i = 0.0176 + \underset{(.65)}{0.107(NIHTF/SAGE)_{i-1}} + \underset{(.45)}{0.0942(TFPE/TFTL)_{i-3}} + \underset{(.27)}{0.0160(\$F/\$TL)_i} ; \quad R^2 = .92$$

Table B6 - DEFINITION OF VARIABLES INVOLVED IN THE PHYSICAL SCIENCE AND ENGINEERING EQUATIONS

DEPENDENT VARIABLES	DESCRIPTION	MEAN 1956-70	STANDARD DEVIATION
$(EN1FPE/EN1FTL)_i$	First year full-time graduate enrollments in physical science and engineering relative to total first year full-time enrollments	0.175	0.0251
$(EN1PPE/EN1PTL)_i$	First year full-time graduate enrollments in physical science and engineering relative to total part-time graduate enrollments	0.127	0.0183
$(EN1TPE/EN1TTL)_i$	First year graduate enrollments in physical science and engineering relative to total first year graduate enrollments in all fields	0.145	0.0184
$(ENPE/ENTL)_i$	Total graduate enrollments in physical science and engineering relative to total graduate enrollments in all fields	0.177	0.0174
$(PHDPE/PHDTL)_i$	Number of PhD's in physical science and engineering relative to total PhD's in all fields produced in the school year ending in year i.	0.281	0.0155
EXPLANATORY VARIABLES			
$(\$PHDCH/\$PHDTL)_i$	Median annual salary of PhD chemists relative to median salary of all PhDs; ($/$)	1.075	0.0293
$(NIHTF/SAGE)_{i-1}$	NIH appropriations for training grants and fellowships relative to total federal aid for graduate students in the i^{th} fiscal year; ($/$)	0.457	0.939
$MEDAPP_i$	Number of applicants for medical school in school year ending in year i	17299.1	2844.96
$(TFPE/TFTL)_{i-1}$ $(TFPE/TFTL)_{i-3}$	Federal expenditures for traineeships and fellowships in physical science and engineering relative to total federal expenditures for traineeships and fellowships in all fields; ($/$)	0.208 0.202	0.0712 0.0739
$(TFBI/TFTL)_{i-1}$	Federal expenditures for traineeships and fellowships in bioscience relative to total federal expenditures for traineeships and fellowships in all fields; ($/$)	0.667	0.161
$(\$F/\$TL)_i$	An index of faculty salaries, prepared by the American Association of University Professors, relative to the median annual salary of all scientific and technical personnel measured in $ thousands	12.21	0.260
$(R_{pe}/R_e)_i$	Federal funds for research in physical science and engineering relative to total federal funds for research in fiscal years; ($/$)	0.651	0.0290

seem to be reciprocal. These data provide no evidence that physical science and engineering training funds have any impact on bioscience enrollments, although there is evidence that research in the physical sciences does provide some support for bioscience graduate students.

Table B7 shows how the dependent variables correlate individually with some of the explanatory variables.

F. FURTHER TESTS OF THE MODEL AND SOME OF ITS LIMITATIONS

As a further check on the validity of the equations in the model, some additional tests of the bioscience and physical science equations were run. Hypotheses were set up to see if the bioscience explanatory variables used in the model could provide as good a fit to the physical science and engineering dependent variables, and conversely, if the explanatory variables in physical science and engineering provide an equally good fit to the bioscience dependent variables. If this interchange of explanatory variables were to provide satisfactory relationships in both cases, then one would suspect that the explanatory variables in the model do not really represent the causal factors for the effects they are attempting to explain, since they work equally well for a different set of effects. However, as the results show, when the variables are interchanged, their explanatory power deteriorates significantly. Under hypothesis I (that the bioscience explanatory variables could explain the behavior of the physical science enrollments and degrees), the average R^2 for the physical science equations drops from 0.96 in the model to 0.55, with seven non-significant variables and seven illogical signs. Under hypothesis II (that the physical science explanatory variables could explain the bioscience enrollments and degrees) the average R^2 for the bioscience equations drops from 0.87 in the model to 0.73, with twelve non-significant variables and six with illogical signs.

In summary, it would appear that the methodology used to generate the equations in the model gives results which are at least as defensible as any of the alternatives examined here. This certainly does not mean that no better explanations for the behavior of the dependent variables can be found. There are always problems with the accuracy and consistency of the data; certainly some of the variables were estimated very crudely. Perhaps important variables were not included in the analysis, or the variables should have been structured differently. The fact that the analysis deals with time series data leads to problems of autocorrelation, for which no correction was made, and the handling of the lagged variables could certainly be improved upon. Verification of the results should be attempted with cross-sectional data. If the model were to be developed further, these problems would have to be

Table B7 - CORRELATION MATRIX FOR THE DEPENDENT VARIABLES OF THE PHYSICAL SCIENCE AND ENGINEERING EQUATIONS AND SOME SELECTED "EXPLANATORY" VARIABLES

Explanatory Variables		Dependent Variables: Relative 1st-yr full-time grad. enrollments in Physical Sci. & Engineering $(EN1FPE/EN1FTL)_i$ unadj	Relative 1st-yr full-time grad. enrollments in Physical Sci. & Engineering $(EN1FPE/EN1FTL)_i$ w/o trend	Relative 1st-yr part-time grad. enrollments in Physical Sci. & Engineering $(EN1PPE/EN1PTL)_i$ unadj	Relative 1st-yr part-time grad. enrollments in Physical Sci. & Engineering $(EN1PPE/EN1PTL)_i$ w/o trend	Relative 1st-yr total grad. enrollments in Physical Sci. & Engineering $(EN1TPE/EN1TTL)_i$ unadj	Relative 1st-yr total grad. enrollments in Physical Sci. & Engineering $(EN1TPE/EN1TTL)_i$ w/o trend	Relative total grad. enrollments in Phys. Sci. & Engin. $(ENPE/ENTL)_i$ unadj	Relative total grad. enrollments in Phys. Sci. & Engin. $(ENPE/ENTL)_i$ w/o trend	Relative PhD production in Physical Sci. & Engineering $(PHDPE/PHDTL)_i$ unadj	Relative PhD production in Physical Sci. & Engineering $(PHDPE/PHDTL)_i$ w/o trend
Median incomes of Chemists	TOTAL ($TLCH)	.21	-.12	.36	-.54	.35	-.25	.12	-.28	-.59	-.43
	PhD'S ($PHDCH)	.72	.62	.48	.10	.63	.50	.61	.47	-.12	.18
	MA'S ($MACH)	-.16	.31	-.59	.06	-.46	.23	-.19	.30	.44	.16
	BA'S ($BACH)	.05	-.68	.58	-.71	.40	-.77	.04	-.76	-.76	-.83
Median income of Chemists relative to overall median income	TOTAL ($CH/$TL)	.21	-.12	.36	-.54	.35	-.25	.12	-.28	-.59	-.43
	PhD'S ($PHDCH/$PHDTL)	.72	.61	.48	.10	.63	.50	.61	.47	.12	.18
	MA'S ($MACH/$MATL)	-.16	.31	-.59	.07	-.46	.23	-.19	.30	.44	.16
	BA'S ($BACH/$BATL)	.05	-.68	.58	-.71	.40	-.77	.05	-.76	-.87	-.83
Median income of PhD & MA Chemists relative to BA Chemists	PhD's relative to BA's ($PHDCH/$BACH)	.53	.79	-.06	.46	.19	.76	.45	.74	.59	.58
	MA's relative to BA's ($MACH/$BACH)	-.14	.52	-.66	.35	-.49	.50	-.16	.56	.66	.47
Faculty salaries relative to median professional income	($F/$TL)	.20	-.01	.50	.49	.42	.20	.40	.23	.27	.60
NIH Traineeship and Fellowship appropriations relative to total student aid to graduate education (NIHTF/SAGE)	i	.28	.82	-.46	.17	-.19	.64	.12	.64	.48	.28
	i-1	.46	.95	-.25	.65	.03	.93	.40	.93	.78	.72
	i-2	.24	.84	-.36	.82	-.14	.91	.25	.93	.92	.89
	i-3	-.04	.67	-.53	.86	-.37	.80	.00	.80	.90	.89
	i-4	-.24	.54	-.70	.74	-.56	.68	-.22	.70	.83	.85
	i-5	-.38	.43	-.83	.49	-.70	.51	-.39	.55	.71	.66
Federal traineeship and fellowship expenditures in physical science and engineering relative to total federal traineeship & fellowship expenditure (TFPE/TFTL)	i-1	.34	.79	-.22	.77	-.01	.86	.34	.84	.78	.71
	i-2	.08	.54	-.33	.71	-.20	.64	.14	.68	.83	.76
	i-3	-.22	.19	-.45	.57	-.40	.34	-.14	.36	.76	.65
Federal traineeship and fellowship expenditures in bioscience relative to total federal traineeship & fellowship expenditures (TFBI/TFTL)	i-1	.38	-.47	.83	-.56	.71	-.54	.38	-.59	-.68	-.59
	i-2	.52	-.01	.86	-.29	.80	-.08	.52	-.14	-.59	-.30
	i-3	.64	.39	.86	-.11	.88	.26	.63	.26	-.49	-.01
Federal funds for research in the physical sciences relative to total federal research	(FRPH/FRTOT)	.13	.69	-.38	.77	-.19	.80	.14	.76	.79	.70
Medical school applicants	(MEDAPP)	-.79	-.71	-.85	-.32	-.90	-.65	-.82	-.74	.13	-.69
Total federal funds for research	(FRTOT)	-.47	.45	-.88	.88	-.79	.63	-.49	.62	.66	.76
NIH training grants relative to total student aid to graduate education	$(NIHTG/SAGE)_{i-1}$	.74	.81	.21	.28	.46	.69	.60	.66	.26	.40

Circled values indicate significant correlations with the logically correct sign.

The subscript i is used to denote the value of the variable in the ith year.

considered. However at this stage, the model serves its main purpose which is to find a set of variables which are closely correlated with graduate enrollments and Ph.D. degrees and conceivably could represent factors having a causal influence on them. There is substantial statistical evidence to support the hypothesis that federal student-aid programs had a significant impact on graduate enrollments and Ph.D. degrees during the 1956-70 period, especially in the biosciences. The evidence is found in the fact that we can adequately "explain" the behavior of the dependent variables by relationships primarily involving student aid variables which have good statistical properties, are consistent in different fields, seem to be logical and rational, and are generally more satisfactory than alternative explanations using different sets of variables.

APPENDIX C

DATA USED IN CHAPTER 5

Table C1 - RELATIVE NUMBERS OF BACHELOR DEGREES, GRADUATE ENROLLMENTS AND PHD DEGREES, 1956-70

Year	BA's Relative to Population 20-24 Years Old	First Year Graduate Enrollments Relative to BA's Awarded in the Previous Year			Total Grad Enrollments Relative to BA's in the Previous Year	PhD's Awarded Relative to Average Grad Enrollments for the Last 3 Years
		Full-time	Part-time	Total		
1956	0.029	0.192	0.285	0.477	0.780	0.040
1957	0.032	0.186	0.293	0.479	0.806	0.038
1958	0.034	0.179	0.295	0.474	0.784	0.036
1959	0.035	0.174	0.300	0.474	0.790	0.034
1960	0.036	0.172	0.309	0.481	0.796	0.034
1961	0.035	0.175	0.325	0.499	0.796	0.034
1962	0.035	0.181	0.361	0.541	0.844	0.036
1963	0.036	0.191	0.381	0.572	0.889	0.037
1964	0.038	0.201	0.400	0.601	0.917	0.038
1965	0.039	0.227	0.406	0.633	0.951	0.039
1966	0.040	0.245	0.421	0.666	0.993	0.038
1967	0.039	0.268	0.400	0.667	0.999	0.039
1968	0.043	0.279	0.441	0.720	1.092	0.040
1969	0.047	0.260	0.423	0.683	1.048	0.040
1970	0.049	0.245	0.397	0.642	0.983	0.042
Average	0.038	0.212	0.362	0.574	0.898	0.038
Std. Dev.	0.005	0.038	0.056	0.090	0.107	0.003

Sources: Current Population Reports, U. S. Bureau of the Census, Population Estimates, series P-25, nos. 311 (1965), 314 (1965), 385 (1968), 441 (1970).

Doctorate Records File, maintained by the National Academy of Sciences/National Research Council, Washington, D. C., June, 1972. From 1936 through 1957, DRF data were recorded on a calendar year basis. Since 1958, a fiscal year basis has been used. The 1957 figure for Ph.D.'s awarded was obtained by interpolation between 1956 and 1958 to avoid the effects on the time series of changing from a calendar basis to fiscal year basis.

Graduate Student Enrollment and Support in American Universities and Colleges, National Science Foundation, Washington, D. C., 1954.

Students Enrolled for Advanced Degrees, National Center for Educational Statistics, Office of Education, U. S. Department of Health, Education and Welfare, annual editions, 1959-70.

Table C2 - RELATIVE GRADUATE ENROLLMENTS AND PHD PRODUCTION IN THE BIOSCIENCES AND PHYSICAL SCIENCES AND ENGINEERING, 1956-70

Year	BIOSCIENCES: First Year Graduate Enrollments in Bioscience Relative to All Fields			BIOSCIENCES: Total Grad Enrollments in Bioscience Relative to Total All Fields	BIOSCIENCES: Ph.D.'s Awarded in Bioscience Relative to All Fields	PHYSICAL SCIENCES AND ENGINEERING: First Year Graduate Enrollments in Phys. Sci. & Eng. Relative to All Flds			PHYSICAL SCIENCES AND ENGINEERING: Total Grad Enrollments in Phys. Sci. & Eng. Relative to Total All Fields	PHYSICAL SCIENCES AND ENGINEERING: Ph.D.'s Awarded in Phys. Sci. & Eng Relative to All Fields
	Full-time	Part-time	Total			Full-time	Part-time	Total		
1956	0.051	0.014	0.029	0.043	0.115	0.162	0.153	0.157	0.176	0.259
1957	0.054	0.015	0.031	0.042	0.122	0.172	0.148	0.157	0.175	0.259
1958	0.057	0.017	0.032	0.043	0.130	0.180	0.143	0.157	0.181	0.260
1959	0.060	0.018	0.033	0.042	0.118	0.188	0.139	0.157	0.183	0.271
1960	0.062	0.019	0.034	0.043	0.121	0.196	0.136	0.157	0.187	0.273
1961	0.063	0.021	0.036	0.047	0.113	0.209	0.138	0.163	0.198	0.282
1962	0.064	0.021	0.035	0.048	0.113	0.203	0.131	0.155	0.195	0.288
1963	0.063	0.019	0.034	0.048	0.111	0.204	0.130	0.155	0.194	0.297
1964	0.066	0.021	0.036	0.050	0.110	0.197	0.134	0.155	0.193	0.293
1965	0.065	0.022	0.037	0.050	0.112	0.180	0.127	0.146	0.185	0.302
1966	0.064	0.023	0.038	0.051	0.111	0.166	0.121	0.137	0.176	0.298
1967	0.063	0.022	0.038	0.051	0.108	0.156	0.115	0.132	0.167	0.300
1968	0.058	0.020	0.035	0.049	0.114	0.146	0.102	0.119	0.159	0.284
1969	0.054	0.019	0.033	0.047	0.112	0.138	0.096	0.112	0.149	0.278
1970	0.053	0.020	0.033	0.046	0.108	0.130	0.094	0.108	0.139	0.266
Average	0.060	0.019	0.034	0.047	0.115	0.175	0.127	0.145	0.177	0.281
Std. Dev.	0.005	0.003	0.003	0.003	0.006	0.025	0.018	0.018	0.017	0.016

Sources: Doctorate Records File, maintained by the National Academy of Sciences/National Research Council, Washington, D. C., June, 1972. From 1936 through 1957, DRF data were recorded on a calendar year basis. Since 1958, a fiscal year basis has been used. The 1957 figure for Ph.D.'s awarded was obtained by interpolation between 1956 and 1958 to avoid the effects on the time series of changing from a calendar basis to fiscal year basis.

Graduate Student Enrollment and Support in American Universities and Colleges, National Science Foundation, Washington, D. C., 1954.

Students Enrolled for Advanced Degrees, National Center for Educational Statistics, Office of Education, U. S. Department of Health, Education and Welfare, annual editions, 1959-70.

Table C3 - FEDERAL FUNDS FOR TRAINING GRANTS, FELLOWSHIPS, AND OTHER STUDENT AID PROGRAMS, 1949-70

Year	Federal Funds for Traineeships & Fellowships by Field			NIH Training & Fellowship Funds Relative to Total Federal Student Aid to Graduate Education	Total Federal Student Aid to Graduate Education (million $)
	Bioscience Relative to Total	Physical Science and Engineering Relative to Total	Total All Fields (million $)		
1949				0.043	115.0
1950				0.072	108.5
1951				0.109	75.4
1952				0.189	48.7
1953				0.276	37.0
1954				0.319	40.4
1955				0.269	50.5
1956	0.870	0.130	18.0	0.283	61.2
1957	0.906	0.094	40.0	0.392	85.5
1958	0.879	0.121	51.4	0.421	93.5
1959	0.834	0.166	84.4	0.506	119.2
1960	0.604	0.334	159.5	0.491	182.8
1961	0.656	0.246	227.2	0.546	241.8
1962	0.618	0.267	258.8	0.553	267.1
1963	0.614	0.280	327.9	0.589	332.4
1964	0.590	0.283	389.3	0.557	391.8
1965	0.524	0.267	471.4[a]	0.483	470.4
1966	0.515	0.220	577.2	0.459	577.2
1967	0.497	0.185	631.9	0.441	653.5
1968	0.494	0.185	573.6	0.502	607.1
1969	0.512	0.209	569.3	0.516	612.5
1970	0.363	0.198	502.5	0.558	569.0
1956-70					
Average	0.632	0.212	325.5	0.486	351.0
Standard Deviation	0.167	0.089	221.3	0.079	217.4

Sources: Merriam, Ida C. and Skonik, Alfred M., Social Welfare Expenditures under Public Programs in the U. S., 1929-66, U. S. Department of Health, Education and Welfare, Social Security Administration, Office of Research and Statistics, Research Report No. 25, Washington, D. C., 1968.

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[a]Source of data for 1965-70 were unpublished data provided by Alfred Skolnik, SSA, HEW. Certain items mainly pertaining to loan programs of the Bureau of Health Manpower Education, NIH, were excluded from Mr. Skolnik's data to obtain the figures shown here and to make them consistent with prior years.

Table C4 - FEDERAL OBLIGATIONS FOR CONDUCT OF RESEARCH BY FIELD, 1956-70

Year	Life Sciences Relative to Total	Physical Sciences Relative to Total	Life & Physical Sciences Relative to Total	Total All Fields (million $)
1956	0.244	0.289	0.533	852
1957	0.316	0.284	0.600	925
1958	0.317	0.310	0.627	1079
1959	0.297	0.331	0.628	1403
1960	0.263	0.313	0.577	1941
1961	0.240	0.328	0.568	2620
1962	0.248	0.314	0.562	3273
1963	0.228	0.331	0.560	4041
1964	0.234	0.359	0.593	4464
1965	0.240	0.351	0.592	4854
1966	0.247	0.347	0.594	5271
1967	0.275	0.331	0.606	5273
1968	0.287	0.334	0.621	5365
1969	0.293	0.317	0.610	5447
1970	0.280	0.325	0.605	6112
Average	0.267	0.324	0.592	3528
Standard Deviation	0.030	0.021	0.027	1901

Source: Federal Funds for Research, Development and Other Scientific Activities, National Science Foundation, Washington, D. C., Vol. XVIII.

Table C5 - RELATIVE MEDIAN SALARIES OF BIOSCIENTISTS, 1956-70

Year	All Biosciences Relative to Total All Fields	Bioscience PhD's Relative to All PhD's	Bioscience MA's Relative to All MA's	Bioscience MA's Relative to Bioscience BA's	Bioscience PhD's Relative to Bioscience BA's
1951[a]		0.97			1.35
1952[a]		0.95			1.33
1953[a]		0.96			1.31
1954[a]		0.97			1.29
1955		0.97			1.28
1956[a]	0.91	0.93	0.82	0.94	1.29
1957[a]	0.88	0.90	0.81	0.96	1.28
1958	0.87	0.86	0.77	0.98	1.28
1959[a]	0.88	0.88	0.78	1.00	1.28
1960	0.89	0.90	0.78	1.00	1.28
1961[a]	0.95	0.90	0.78	1.00	1.36
1962	1.00	0.91	0.78	1.00	1.43
1963[a]	0.99	0.92	0.79	1.01	1.43
1964	0.97	0.93	0.80	1.04	1.45
1965[a]	0.99	0.94	0.82	1.01	1.40
1966	1.00	0.95	0.84	1.00	1.39
1967[a]	0.99	0.95	0.83	1.02	1.44
1968	0.98	0.95	0.83	1.04	1.48
1969[a]	0.99	0.96	0.83	1.04	1.48
1970	1.00	0.97	0.84	1.05	1.48
1956-70					
Average	0.95	0.92	0.81	1.01	1.38
Standard Deviation	0.05	0.03	0.04	0.03	0.08

Source: American Science Manpower, National Science Foundation, Washington, D. C., biennial editions, 1955-70.

[a]Data obtained by interpolation.

Table C6 - MEDIAN ANNUAL SALARIES OF SCIENTIFIC AND TECHNICAL PERSONNEL

($ THOUSANDS)

Year	BIOLOGICAL SCIENCE				CHEMISTRY				ALL FIELDS			
	Total	PhD	MA	BA	Total	PhD	MA	BA	Total	PhD	MA	BA
1951[a]	5.4	6.2	4.8	4.6						6.6		
1956[b]	6.4	7.1	5.2	5.5	7.1	7.8	6.4	7.1	7.0	7.6	6.3	6.8
1957[b]	6.6	7.3	5.5	5.7	7.9	8.7	7.2	7.6	7.5	8.1	6.8	7.2
1958	6.9	7.4	5.7	5.8	8.7	9.7	8.1	8.0	7.9	8.6	7.4	7.7
1959[b]	7.4	8.2	6.4	6.4	9.4	10.4	8.6	8.5	8.4	9.3	8.2	8.4
1960	8.0	9.0	7.0	7.0	10.0	11.0	9.0	9.0	9.0	10.0	9.0	9.0
1961[b]	9.0	9.5	7.0	7.0	10.0	11.5	9.5	9.0	9.5	10.5	9.0	9.0
1962	10.0	10.0	7.0	7.0	10.0	12.0	10.0	9.0	10.0	11.0	9.0	9.0
1963[b]	10.4	10.6	7.5	7.4	10.5	12.5	10.3	9.4	10.5	11.5	9.5	9.5
1964	10.7	11.2	8.0	7.7	11.0	13.0	10.6	9.9	11.0	12.0	10.0	10.0
1965[b]	11.4	11.8	8.5	8.4	11.5	13.5	11.1	10.2	11.5	12.6	10.4	10.5
1966	12.0	12.5	9.0	9.0	12.0	14.0	11.6	10.5	12.0	13.2	10.7	11.0
1967[b]	12.5	13.4	9.5	9.3	12.8	14.8	12.3	11.2	12.6	14.1	11.4	11.5
1968	13.0	14.2	10.0	9.6	13.5	15.6	13.0	12.0	13.2	15.0	12.0	12.0
1969[b]	14.0	15.1	10.6	10.2	14.4	16.5	14.0	12.9	14.1	15.8	12.8	13.0
1970	15.0	16.0	11.3	10.8	15.3	17.4	15.0	13.8	15.0	16.5	13.5	13.9
1956-70												
Average	10.2	10.9	7.0	7.8	10.9	12.6	10.4	9.9	10.6	11.7	9.8	0.9
Standard Dev.	2.8	2.9	1.9	1.7	2.3	2.8	2.5	1.9	2.5	2.8	2.0	2.1

Source: American Science Manpower, National Science Foundation, Washington, D. C., biennial editions, 1955-70.

Science and Public Policy: Manpower for Research (The Steelman Report), The President's Scientific Research Board, vol. 4, 1947, p. 39.

[a]Values obtained by interpolation from the data given in the second source above.

[b]Data obtained by interpolation.

Table C7 - MISCELLANEOUS EXPLANATORY VARIABLES

Year	VA Funds for Higher Education Benefits (million $)	Aggregate Real Disposable Income (billion $)	Probability of Being Drafted (# inductions/ # classified registrants)	Medical School		Ratio of Annual Incomes: 4 or More Yrs. of College Relative to 4 Yrs. H.S.
				Appli- cants	En- roll- ments	
1950	993			24434	7042	1.61[a]
1951	661			22279	7177	1.60[a]
1952	366	300.25		19920	7436	1.58[a]
1953	249	315.23		16763	7425	1.57[a]
1954	252	319.13		14678	7449	1.55[a]
1955	344	342.14		14538	7576	1.54[a]
1956	432	356.88	0.0082	14937	7686	1.52
1957	455	361.92	0.0101	15917	8014	1.58[a]
1958	422	367.09	0.0067	15791	8030	1.64
1959	348	386.37	0.0056	15170	8128	1.65[a]
1960	233	395.03	0.0043	14952	8173	1.65[a]
1961	146	406.70	0.0023	14397	8298	1.65
1962	83	425.28	0.0066	14381	8483	1.57[a]
1963	45	440.35	0.0029	15847	8642	1.50
1964	25	469.11	0.0054	17668	8772	1.53
1965	8	500.74	0.0034	19168	8856	1.55[a]
1966	0	526.65	0.0106	18703	8759	1.57
1967	216	546.30	0.0087	18250	8964	1.56
1968	334	567.37	0.0095	18724	9479	1.59
1969	432	575.23	0.0069	21117	9863	1.59
1970	665	588.82	0.0051	24465	10401	1.57
1956-70						
Average	256	460.92	0.0064	17299	8703	1.58
Std. Dev.	204	83.66	0.0026	2845	743	0.05

Sources: Current Population Reports, U. S. Department of Commerce, series P-60, no. 74.

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[a]Data obtained by interpolation.

APPENDIX D

SPECIALTIES LIST

Doctorate Records File

MATHEMATICS

000 — Algebra
010 — Analysis & Functional Analysis
020 — Geometry
030 — Logic
040 — Number Theory
050 — Probability, Math. Statistics (see also 544, 670, 725, 727, 920)
060 — Topology
080 — Computing Theory & Practice
082 — Operations Research (see also 478)
085 — Applied Mathematics
098 — Mathematics, General
099 — Mathematics, Other*

ASTRONOMY

101 — Astronomy
102 — Astrophysics

PHYSICS

110 — Atomic & Molecular Physics
120 — Electromagnetism
130 — Mechanics
132 — Acoustics
134 — Fluids
135 — Plasma Physics
136 — Optics
138 — Thermal Physics
140 — Elementary Particles
150 — Nuclear Structure
160 — Solid State
198 — Physics, General
199 — Physics, Other*

CHEMISTRY

200 — Analytical
210 — Inorganic
220 — Organic
230 — Nuclear
240 — Physical
250 — Theoretical
260 — Agricultural & Food
270 — Pharmaceutical
275 — Polymer Chemistry
298 — Chemistry, General
299 — Chemistry, Other*

EARTH SCIENCES

301 — Mineralogy, Petrology
305 — Geochemistry
310 — Stratigraphy, Sedimentation
320 — Paleontology
330 — Structural Geology
340 — Geophysics (Solid Earth & Atmospheric)
350 — Geomorph., Glacial Geology
360 — Hydrology
370 — Oceanography
380 — Meteorology
391 — Applied Geol., Geol. Engr., Econ. Geol.
395 — Fuel Tech., Petrol. Engr. (see also 479)
398 — Earth Sciences, General
399 — Earth Sciences, Other*

ENGINEERING

400 — Aeronautical & Astronautical
410 — Agricultural
415 — Biomedical Engineering
420 — Civil
430 — Chemical
435 — Ceramic
440 — Electrical
445 — Electronics
450 — Industrial
455 — Nuclear Engineering
460 — Engineering Mechanics
465 — Engineering Physics
470 — Mechanical
475 — Metallurgy & Phys. Met. Engr.
478 — Operations Research (see also 082)
479 — Fuel Tech., Petrol. Engr. (see also 395)
480 — Sanitary
486 — Mining
497 — Materials Science Engr.
498 — Engineering, General
499 — Engineering, Other*

ENVIRONMENTAL SCIENCES

589 — Environmental Sciences*

AGRICULTURAL SCIENCES

500 — Agronomy
501 — Agricultural Economics
502 — Animal Husbandry
503 — Food Science & Technology
504 — Fish & Wildlife
505 — Forestry
506 — Horticulture
507 — Soils & Soil Science
510 — Animal Sciences
511 — Phytopathology
518 — Agriculture, General
519 — Agriculture, Other*

MEDICAL SCIENCES

520 — Medicine & Surgery
522 — Public Health
523 — Veterinary Medicine
524 — Hospital Administration
527 — Parasitology
534 — Pathology
536 — Pharmacology
537 — Pharmacy
538 — Medical Sciences, General
539 — Medical Sciences, Other*

BIOLOGICAL SCIENCES

540 — Biochemistry
542 — Biophysics
544 — Biometrics, Biostatistics (see also 050, 670, 725, 727, 920)
545 — Anatomy
546 — Cytology
547 — Embryology
548 — Immunology
550 — Botany
560 — Ecology
562 — Hydrobiology
564 — Microbiology & Bacteriology
566 — Physiology, Animal
567 — Physiology, Plant
569 — Zoology
570 — Genetics
571 — Entomology
572 — Molecular Biology
578 — Biological Sciences, General
579 — Biological Sciences, Other*

PSYCHOLOGY

600 — Clinical
610 — Counseling & Guidance
620 — Developmental & Gerontological
630 — Educational
635 — School Psychology
641 — Experimental
642 — Comparative
643 — Physiological
650 — Industrial & Personnel
660 — Personality
670 — Psychometrics (see also 050, 544, 725, 727, 920)
680 — Social
698 — Psychology, General
699 — Psychology, Other*

SOCIAL SCIENCES

700 — Anthropology
708 — Communications*
710 — Sociology
720 — Economics (see also 501)
725 — Econometrics (see also 050, 544, 670, 727, 920)
727 — Statistics (see also 050, 544, 670, 725, 920)
740 — Geography
745 — Area Studies*
750 — Political Science, Public Admin.
755 — International Relations
770 — Urban & Reg. Planning
798 — Social Sciences, General
799 — Social Sciences, Other*

ARTS & HUMANITIES

801 — Art, Applied
802 — Art, History & Criticism
804 — History, American
805 — History, European
806 — History, Other*
807 — History & Philosophy of Science
830 — Music
831 — Speech as a Dramatic Art (see also 885)
832 — Archeology
833 — Religion (see also 881)
834 — Philosophy
835 — Linguistics
878 — Arts & Humanities, General
879 — Arts & Humanities, Other*

LANGUAGES & LITERATURE

811 — American
812 — English
821 — German
822 — Russian
823 — French
824 — Spanish & Portuguese
826 — Italian
827 — Classical*
829 — Other Languages*

EDUCATION

900 — Foundations: Social, Philosoph.
910 — Educational Psychology
908 — Elementary Educ., General
909 — Secondary Educ., General
918 — Higher Education
919 — Adult Educ. & Extension Educ.
920 — Educ. Meas. & Stat.
929 — Curriculum & Instruction
930 — Educ. Admin. & Superv.
940 — Guid., Couns., & Student Pers.
950 — Special Education (Speech, Gifted, Handicapped, etc.)
960 — Audio-Visual Media

TEACHING FIELDS

970 — Agriculture
972 — Art
974 — Business
976 — English
978 — Foreign Languages
980 — Home Economics
982 — Industrial Arts
984 — Mathematics
986 — Music
988 — Phys. Ed., Health, & Recreation
990 — Science Educ.
992 — Social Science Educ.
994 — Vocational Educ.
996 — Other Teaching Fields*

998 — Education, General
999 — Education, Other*

OTHER PROFESSIONAL FIELDS

881 — Theology (see also 833)
882 — Business Administration
883 — Home Economics
884 — Journalism
885 — Speech & Hearing Sciences
886 — Law, Jurisprudence
887 — Social Work
891 — Library & Archival Science
897 — Professional Field, Other*

899 — OTHER FIELDS*

* Identify the specific field in the space provided on the questionnaire.

APPENDIX E

BIBLIOGRAPHY

APPENDIX E

BIBLIOGRAPHY

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