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ABSTRACT
This document describes in detail a study of postdoctoral training in biomedical sciences. Highlights of the study indicate: (1) During the 1958-70 period, 8,685 postdoctorals, equally divided between MD's and PD's, were supported by the National Institute of General Medical Sciences (NIGMS), at a total cost of $86.5 million. (2) Directors of the nation's leading biomedical research laboratories, the postdoctorals now in training there, and former NIGMS postdoctorals, presented strong testimony to the effect that training at this level is essential to the continued improvement of medical science and the delivery of advanced techniques for the diagnosis, care, and treatment of disease. (3) The study indicates that the objectives of the postdoctoral research training have been met by those supported by the following data: (a) Both post-M.D.'s and post-Ph.D.'s are found on followup to be employed by the nation's medical schools in numbers far beyond those of M.D.'s and Ph.D.'s without training, and having advanced faster up the academic ladder than have comparable groups without postdoctoral training. (b) Post-M.D.'s and post-Ph.D.'s are much more frequently employed by the more research-oriented medical schools than by those less research-oriented and in much greater proportions than are Ph.D.'s and M.D.'s without postdoctoral training. Additional findings are included. (MJM)

Postdoctoral Training in the Biomedical Sciences

An Evaluation of NIGMS Postdoctoral Traineeship and Fellowship Programs

Advisory Committee on the Study of
NIGMS Postdoctoral Fellowships and
Traineeships in the Biomedical Sciences

Commission on Human Resources

National Research Council

NATIONAL ACADEMY OF SCIENCES

December 1974

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 asp-cts 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 reported herein was sponsored by the National Institute of General Medical Sciences under Contract PH 43-64-44, Task Order 26.

ADVISORY COMMITTEE ON THE STUDY OF NIGMS POSTDOCTORAL FELLOWSHIPS AND TRAINEESHIPS IN THE BIOMEDICAL SCIENCES

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HIGHLIGHTS

- During the 1958-1970 period, 8,685 postdoctorals, equally divided between MD's and PhD's, were supported by the NIGMS, at a total cost of $86.5 million. The purpose of the study reported here was a review and evaluation of the career impacts of this program of postdoctoral support.

- Directors of the nation's leading biomedical research laboratories, the postdoctorals now in training there, and former NIGMS postdoctorals, presented strong testimony to the effect that training at this level is essential to the continued improvement of medical science and the delivery of advanced techniques for the diagnosis, care, and treatment of disease.

- The study indicates that the objectives of the postdoctoral research training - to increase both the number and competence of biomedical researchers - have been met by those supported, as shown by the following data:

- Both post-MD's and post-PhD's are found on follow-up to be employed by the nation's medical schools in numbers far beyond those of MD's and PhD's without such training, and have advanced faster up the academic ladder than have comparable groups without postdoctoral training.

- Post-MD's and post-PhD's are much more frequently employed by the more research-oriented medical schools than by those less research-oriented, and in much greater proportion than are PhD's and MD's without postdoctoral training.

- A larger proportion of physicians who have postdoctoral training (as compared with those who do not have such training) publish articles in the scientific literature. Those postdoctorals who do publish, do so more frequently than do those without postdoctoral training, and are far more frequently cited by other scientists. This difference increases as the stage of professional career advances.

- Physicians with postdoctoral training win competitive research awards with a frequency several times that of physicians from the same graduation cohorts who do not have postdoctoral training.

- PhD's with postdoctoral training are more frequently employed by academic institutions, particularly those with the most prestigious graduate schools, than are non-postdoctoral PhD's, and are much more frequently engaged in research as a primary work activity.

- PhD's with postdoctoral training advance to the status of thesis adviser more rapidly and in larger numbers than do PhD's without postdoctoral training.

- PhD's with postdoctoral training win competitive research grants much more frequently than do those without postdoctoral training, and the difference increases as careers mature.

- Postdoctoral PhD's publish more and are cited far more in the scientific literature than are non-postdoctoral PhD's, and these differences persist, with lowered intensity, when controls are introduced for ability, graduate school environment, place of employment, and major work activity.

PREFACE

For over fifty years postdoctoral education has been a part of the higher education scene in the United States, but it is only in the past two decades that it has reached major proportions. Because this growth had gone almost unnoticed, the National Academy of Sciences, in 1966, undertook, with the sponsorship of several agencies and foundations, a major examination of the whole field of postdoctoral education. The results of that study, The Invisible University, published in 1969, made it clear that postdoctoral training has become an important, frequently essential experience for the younger scholar and an opportunity for reinvigoration and new directions for the established investigator.

As the advance of science has increased the trend toward specialization, and has added enormously to the body of knowledge and technical competence required for full qualification as an accomplished scholar, the importance of postdoctoral training has increased. Within these last two decades, postdoctoral study has reached institutional status and may justifiably be referred to as the newest stratum of higher education in this country. The importance of postdoctoral training has been most widely recognized in the biomedical sciences; it is in this field that the largest proportion of PhD's undertake this level of training. For the physician who wishes to pursue a career in research or academic medicine, postdoctoral training has become almost a requirement.

Concomitantly and equally significant, these highly motivated, highly trained young men and women serve as the junior colleagues of the more senior investigators to whom they are apprenticed. As such, they constitute a unique "labor force"; the coupling of their imagination, enthusiasm and energy with the experience of their mentors accounts, in considerable degree, for the enormous productivity of the American biomedical research endeavor.

Philip Handler
President
National Academy of Sciences

FOREWORD

In 1970 the National Institute of General Medical Sciences asked the National Research Council to undertake a study and evaluation of the program of postdoctoral fellowships and traineeships which the NIGMS had been sponsoring since 1958. In an earlier study, the Council, through its Office of Scientific Personnel, had made a study of the effects of NIGMS training programs on predoctoral graduate education in the biomedical sciences. The new study was to include only the postdoctoral level (both post-PhD and post-MD) and was to focus on the effects of postdoctoral training on the careers of individuals, rather than on the effects of the training on the graduate institutions.

An Advisory Committee was chosen to guide the study and to evaluate the results. The members of the Committee were:

Jerome W. Conn, University of Michigan
John A. D. Cooper, Association of American Medical Colleges
Richard B. Curtis, St. George Homes, Berkeley, California
Warren O. Hagstrom, University of Wisconsin
Robert W. Hodge, University of California, Los Angeles
Leon O. Jacobson, University of Chicago (Chairman)
Percy L. Julian, Julian Research Institute
Boris Magasanik, Massachusetts Institute of Technology

The Committee held a number of meetings during the course of 1971, 1972, and 1973, planning the study, reviewing the data collected, and evaluating its significance. The conclusions of the Committee are presented in Chapter VIII, and it recommendations for the guidance of policy decisions in the field of higher education and advanced training are in Chapter IX. The collection and analysis of data for this study, and other staff support for the Committee were provided by the staff of the Office of Scientific Personnel. Interviews in biomedical laboratories were carried out by Dr. Richard B. Curtis.

The Committee acknowledges with warmest thanks the contributions of many individuals and organizations to this project. Credit is due first of all to Dr. Lindsey R. Harmon, project director for the study, who persevered to bring the project to a successful conclusion in spite of interruptions caused by illness. His skill not only in interpreting the directions of the Committee, but also in grasping the significance of the data and relating them to the Committee's task, is largely responsible for any cogency this report may have. Ms. Marilyn Brus, Dr. Harmon's assistant, was indispensable throughout in coordinating the many activities, planning data analyses, recording the minutes of the Committee meetings, and typing and editing the final report. Dr. William C. Kelly, director of the Office of Scientific Personnel, provided general administrative supervision and helpful advice throughout the project.

Because so much of the data collection involved the use of pre-existing data banks, particular thanks are due to the Data Processing Section of the Office of Scientific Personnel, under the able direction of Mr. Herbert Soldz. Ms. Cathy Roberts (now with the Institute of Medicine), Mr. George A. Boyce, Ms. Donna J. Yocum, and Mr. Donald G. Wharton performed the arduous and meticulous computer programming which brought together into a single study several massive data files from quite different sources to make the study possible. Ms. Clarebeth Cunningham assisted with the direction of the study at a crucial stage. Mrs. Norma Melendez deserves recognition for typing the tables as well as a good portion of the text.

Acknowledgement is due to the National Institute of General Medical Sciences, not only for its financial support of the project, but also for the assistance of Dr. Solomon Schneyer, the first NIGMS project officer, and Dr. Elizabeth Frame and Dr. Philip Chen, who served in that capacity during the developmental and later phases of the project. We are very grateful to the National Science Foundation for making available for analysis the 1970 Register of Scientific and Technical Personnel, and data from the Cumulative Index of NSF fellowship-holders. In addition, both the National Science Foundation and the National Institutes of Health made available their data on research grant awardees. The Association of American Medical Colleges contributed by making available to the Committee extensive tabular data from its records.

Thanks are due also to the several laboratories visited in the course of the study, to their staffs and postdoctorals, and also to the former NIGMS postdoctorals who wrote to the Committee regarding their experiences and opinions.

This study was first submitted to NIGMS in July 1973. Following review by NIGMS, the report was published.

It is the hope of the Committee that the findings of this study, which point unmistakably to the value of postdoctoral training for both bioscience PhD's and for research-oriented physicians, will be useful to all those concerned with biomedical education and the nation's health.

December 1974 Leon O. Jacobson, Chairman

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NATIONAL RESEARCH COUNCIL
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OFFICE OF SCIENTIFIC PERSONNEL
RESEARCH DIVISION

27 February 1973

REPORT ON STUDY OF NIGMS POSTDOCTORAL TRAINEESHIPS AND FELLOWSHIPS

CAREER OUTCOMES OF NIGMS POSTDOCTORAL TRAINING

CHAPTER I

INTRODUCTION

The National Institute of General Medical Sciences, one of the NIH Institutes, in 1970 requested the National Research Council to undertake a review of its program of postdoctoral training which had been begun in 1958. In addition to tracing the career patterns of the people who had been trained under this program, the NRC was requested to evaluate its effectiveness in attaining the program goals. These goals, very briefly stated, were (1) to enlarge and improve the pool of manpower available for biomedical research, and (2) to provide for advanced training of researchers in the nation's graduate schools and medical schools. The NRC undertook the task, and appointed an Advisory Committee on the Study of Postdoctoral Fellowship and Traineeship Programs in the Biomedical Sciences, whose members had been engaged in biomedical training and research or were experienced in the techniques of social science research, particularly in the area of advanced training. The first task of the Committee was to review the nature of the problem and to decide on a research strategy for accomplishing its mission.

In orienting itself to its mission, the Committee first took note of the fact that the NIGMS postdoctoral training program did not develop in a vacuum, but in a milieu of many other training programs at the graduate and postdoctoral level, supported not only by other government agencies, but also by such private organizations as the American Cancer Society and the Jane Coffin Childs Foundation. The place of postdoctoral education, furthermore, needed to be considered as it affected both biomedically-trained PhD's, and MD's who had taken up research or academic medicine. Another dimension added to the context in which this training has taken place is what may be very briefly suggested by the term "life sciences revolution." The life sciences have been transformed in many ways during the past two decades, through fundamental discoveries such as the nature of the DNA molecule and through the development of new and highly-refined techniques stemming from the physical sciences, such as electron microscopy, neutron activation analysis, and improved gas chromatography. At the level of clinical application, furthermore, biomedical engineering has made rapid advances, with every indication that this work is still in its infancy.

Postdoctoral education has been one of the most important means for meeting the challenges of this life science revolution, and larger numbers of bioscientists than scientists in other fields have undertaken postdoctoral training. Yet postdoctoral training has not been limited to the life sciences. In the physical sciences, too, there has been manifest a need for further training beyond that afforded by the graduate school, particularly for those intending to enter faculty positions in the better graduate schools. The need for such training is not entirely new; the extent of its development, parallel with the vast expansion in doctorate output in the graduate schools, has been the stimulus to various studies of the extent and nature of postdoctoral education, and efforts to evaluate its impact, its costs, and its continuing importance in the field of higher education. Postdoctoral education in the biomedical sciences must therefore be examined in the context of what has happened in postdoctoral education as a whole.

What is postdoctoral education? Perhaps, as a starting point, the definition developed by an earlier committee of the NAS[1] will be most useful. The following definition of postdoctoral appointments was used, and is quoted from The Invisible University:

> "...appointments of a temporary nature at the postdoctoral level that are intended to offer an opportunity for continued education and experience in research, usually, though not necessarily, under the supervision of a senior mentor. The appointee may have a research doctorate (e.g., PhD, ScD) or professional doctorate (e.g., MD, DVM) or other qualifications which are considered equivalent in the circumstances. A person may have more than one postdoctoral appointment during his career."

[1] The Invisible University: Postdoctoral Education in the United States, (Washington, D.C.: National Academy of Sciences, 1969).

For over half a century postdoctoral training has had a recognized place in the American educational scene, but it is only in the past two decades that the number of postdoctorals has reached proportions that demand systematic study. The study undertaken in 1966 by the National Academy of Sciences,[2] with the sponsorship of a number of public and private agencies indicated that there were, in the late 1960's, approximately 16,000 "postdoctorals" studying in various United States universities, laboratories, and hospitals. Of these, it was estimated that approximately 1,200 were NIH Postdoctoral Fellows, and that another 500 were NIH Special Fellows. Undoubtedly there were many more supported by NIH under such titles as trainees, research associates, and a variety of other titles, working on a variety of research projects supported by NIH grants.

Despite the long history of postdoctoral education, largely dominated by and almost defined by the Rockefeller Foundation-supported National Research Fellowships during the 1920's, and emulated by other agencies in later years, the term has lacked definition, and has grown to encompass a wide variety of situations. Most of the people termed "postdoctorals" are those who have recently completed PhD's, and who seek further research experience under an eminent mentor. Some are MD's, either earlier graduates who seek an updating and enhancement of their clinical capabilities, or those who seek research training that was not provided by their medical school experience. For positions in academic medicine, such training is becoming ever more important, if not essential. Other postdoctorals are people several or many years beyond the doctorate who seek to change their fields of specialization, to become acquainted with new techniques and research methods, or to refurbish research skills that may have become obsolescent.

The settings in which postdoctoral training is undertaken, the titles given to people in such training, the sponsorship, and the kinds of work activity involved, are as varied as the reasons for seeking such training and the backgrounds of those who undertake it. Yet throughout all the variations, the theme of increased competence in research, and the importance of studying under a highly skilled mentor, dominate the activity that goes under the title of postdoctoral education. It was recognition of the need for more highly skilled researchers in the biomedical sciences that led the National Institute of General Medical Sciences to undertake the support of postdoctoral education in 1958, and to continue it since.

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[2] Ibid.

In considering how to evaluate the postdoctoral traineeship and fellowship programs[3] of the NIGMS, the Committee also faced the question of alternatives. What other means were there by which the objectives of the program might be achieved? Was it possible to estimate the effect of turning the resources which hitherto had been devoted to postdoctoral training, into other channels which conceivably might be more effective in attaining the same objectives? With this set of problems as a definition of its mission, the Committee considered how it might proceed to gather evidence that would be relevant to its evaluation, and how it might assess this evidence.

One of the first issues was an operational definition of the program objectives of the NIGMS postdoctoral program--a set of observable and measurable desired consequences of the program, against which the career outcomes and achievements of those who participated in the program might be judged. Highly trained biomedical manpower is needed in many situations. One of these is the medical schools, which increasingly require a professoriate versed not only in clinical medicine, but also in research techniques, and familiar with the new and developing technologies which the medical profession is adopting and will increasingly adopt over the predictable future. These teachers, needing both the clinical and research orientations, are most effective if they are trained together, so that they learn not only from their mentors, but from each other, acquiring not only technical knowledge but mutual orientations and mutual respect. It was known that the medical schools had been increasingly requiring postdoctoral training for appointments to academic positions. Yet some questions remained: Were people with such training advancing more rapidly up the academic ladder than people without postdoctoral training, and thus validating, through their performance, the method of their preparation? Were both post-MD's and post-PhD's being employed on medical school faculties? In what numbers, and by which schools? All of these questions appeared to be answerable.

A somewhat similar set of questions exists with respect to the post-PhD's, but not an entirely similar one, because of the very different orientation with which the PhD approaches postdoctoral training, as compared with the MD. The former has already been trained in research technique; he may need a great deal of improvement in precision, in breadth and depth, and even in orientation as to how research may best be done. Research is his primary orientation, however, as contrasted with the clinical orientation achieved in medical school, internship, and residency, all of which normally precede postdoctoral research training for the MD. The post-PhD normally looks forward to a career of research or teaching

[3] Trainees are locally appointed under terms of a training grant to the university. Fellows win appointments in a national competition; only a minority of candidates win appointments.

in a research-oriented environment. Increasingly, the better graduate schools have been requiring postdoctoral training for appointments to their faculties, just as have the medical schools. Have the NIGMS postdoctorals been winning these appointments? At what schools? Have the numbers of people going along this career route from NIGMS postdoctoral training been consonant with the expenditures for such training? Have they won appointments in the institutions which turn out PhD's, as compared with those awarding degrees at lower levels? Have they been appointed in due proportion in the most prestigious of these graduate schools? Have they made such progress in the academic environment as to validate the time, money, and effort spent on their postdoctoral training?

In addition to those in the academic world, many PhD's, including many with postdoctoral training, are engaged in research in private industry, in governmental agencies, and in non-profit organizations. What proportion of these nonacademic people are engaged primarily in research? How does this compare with the general run of those who have not had postdoctoral training? What evidence can be garnered with respect to the quality of their research? Are there measureable career achievement standards that make possible a comparison of the NIGMS post-PhD's with other postdoctorals, or with the people who have not had such training?

A Three-Pronged Approach

In considering these various questions, and possible answers, the Committee decided on a three-pronged approach. Although the Committee included within its membership people with extensive knowledge of the NIGMS fellowship and traineeship programs and other comparable programs, it was felt that it would be advisable to get the views of a variety of people outside the Committee. For outside views, two groups were to be queried. One consisted of the postdoctorals and mentors in laboratories at the present time. To get their views, a member of the Committee would visit the laboratories and conduct interviews. The second group consisted of former holders of NIGMS postdoctoral fellowships and traineeships, who would be invited to send letters to the Committee, expressing their views, based on actual experience, as to the influence of the postdoctoral training on their lives and careers. They would also be invited to comment on possible alternatives for the funding of research and training. These two sets of data and opinions, it was felt, would help sharpen the questions which might be asked in concrete and quantifiable form and answered by reference to existing data banks. It was felt to be essential to have hard data which might be quantitatively analyzed to provide fully objective judgments of the effects of postdoctoral training. This would be the third avenue of approach.

Organization of the Report

In accordance with this plan, the report is organized to show (1) the evidence from the interviews; (2) the evidence from the letters received; (3) the Committee's further planning for the development of hard data; (4) statistical demographic data on the extent of postdoctoral training in general and of the NIGMS training in particular; and (5) the quantitative data regarding the subsequent careers of the NIGMS postdoctorals and of other groups without such training. Finally, the Committee sums up the evidence and draws its conclusions with respect to the program of NIGMS postdoctoral training. A technical appendix presents further detail on a number of techniques and data sets judged to be too voluminous for the body of the report.

CHAPTER II

SITE VISITS TO POSTDOCTORAL LABORATORIES

In order to obtain a representative sample of the opinions of present mentors and of postdoctorals, it was decided to visit a series of laboratories in the United States, on both coasts and in mid-continent, including some of the most prestigious and some of the lesser-known institutions. Arrangements were therefore made for visits to a total of eight laboratories by a member of the Committee. Laboratory directors, other mentors, trainees, and fellows (both NIGMS and those of other programs) were interviewed. It was discovered that, although the circumstances of postdoctoral training varied widely, a rather consistent set of themes ran through the testimony of those involved with postdoctorals in laboratories large and small, famous and not so famous. These themes had to do with such topics as diffusion of knowledge and the opportunity to change direction from the frequently narrow focus of a PhD thesis, the broadening of outlook through contact with mentors, who were frequently outstanding people in their fields, the development of research skills beyond what had been learned in previous training, and increased confidence in one's research capacity--important for teachers of graduate students in particular.

Diffusion of Knowledge

A subtle but persistent theme throughout the interviews in the postdoctoral laboratories relates to the diffusion of knowledge. Even with all the modern methods of communication, with books and journals, the most effective method of diffusing new knowledge and technique is through moving people. People are the carriers of the culture, whether technological or otherwise. Through contact with people who know different techniques or points of view, or even a different store of factual knowledge, the diffusion of research methods and results takes place in a way which is finally translated into practical results in medical care. This diffusion is regarded as one of the most important results of the postdoctoral program, for it moves people from the institutions in which they have learned one point of view or set of methodologies to another with a different outlook. Here the subtle but important interaction occurs: They learn and they teach, and the result, through a kind of "cultural chemistry" is both the diffusion of knowledge and the creation of new ideas, new research approaches, and new science.

Broadening of Outlook

A major reason cited for postdoctoral training is a broadening of outlook, the acquisition of a different way of approaching the scientific enterprise. This is true even for very able graduates of first-rate graduate departments. One such commented that he thinks he would have been wiser to have gone elsewhere for his postdoctoral so that he could see other styles of research. He has arranged to go elsewhere next year. Another said that overall he is happier than he expected to be and would change nothing about his experience. If there had been no postdoctoral opportunities, his growth would have been slow and his vision narrow. A mentor (although all his postdoctorals assist in research) stressed that the postdoctoral period is important in developing a sense of independence. If there were no postdoctoral opportunities, most people would simply continue to develop their doctoral thesis. A fellow added that by changing institutions one meets many people interested in what one is interested in, but from different backgrounds. He is glad that he has moved around, since he has learned more than he could have at his PhD institution alone, although it is an outstanding one.

A post-doctoral mentor in a laboratory with several NIGMS postdoctorals stressed the importance of experiencing other institutions to remove the parochial view one receives in graduate school. Expanding on this theme a bit, another postdoctoral in a famous laboratory justified his taking a postdoctoral appointment on the grounds that it would take much longer to learn what he has learned if he had been on his own. Journals do not provide the details of techniques, and, even if one knows techniques, there is the question of when to apply them. He explained that he learned most of the techniques, their uses and how to approach a problem, as a graduate student. As a postdoctoral he has an opportunity to explore his own mind and to discover what he is capable of doing. He also finds the clinical opportunities most valuable in his postdoctoral setting. Another had come to the same lab explicitly to work with a particular mentor. When he finished his PhD, he did not feel adequately prepared to do research. His thesis topic was too narrow and he wanted to broaden himself. As a graduate student there was much emphasis on getting results and he didn't take chances. Here there were lots of experts around to ask. He has picked up a different set of priorities and, because of the good rapport in the laboratory, he feels more free to ask for assistance. He is also able to pursue various avenues with respect to his problem without being funneled into a preferred path by his research director; he has more independence.

A mentor described by his colleagues as the most exciting researcher in biology in a famous laboratory described the postdoctoral period as the most vital part of the career of one who wants to do research. In doctoral work one tends to go straight down the line, but the postdoctoral time allows one to get going on an entirely different tack. It also brings the added maturity which allows one to do science in the right way, i.e., one works on solvable problems. Problems have a way of resisting solution until the time is ripe. The postdoctoral period teaches one how to recognize when things are right. In biology, particularly, most work is interdisciplinary. One must have the post-doctoral experience to pick up the other discipline.

Change of Direction - for Individuals and for Science

A change of discipline, or a developing of competence in new multidisciplinary or interdisciplinary fields, is another important aspect of the postdoctoral experience. One postdoctoral at a prominent institution said that his experience has been successful in all ways. He enjoys collaborating and has had good interaction with people in other disciplines. His education would have been very much more difficult without the postdoctoral appointment. He has learned how to ask questions and how to judge what will be important five years from now. He is convinced that his fellow postdoctorals will be the researchers who will set the tone in his field of immuno-pathology in the future. A leading mentor confided his own experience. Over the past ten years he has had a number of very gifted postdoctorals whose doctoral fields ranged from medicine to elementary particle physics. In his laboratory these scientists learned about mammalian cell biology. These ex-postdoctorals (over twenty in all) are still working in this field which started in the mentor's laboratory and they are spread over the United States and abroad. A whole field has been created via the postdoctoral route. Graduate students alone could not have done it, since the crucial aspect of the growth of the field is the knowledge and techniques the postdoctorals brought from other fields to apply to mammalian cell biology. These postdoctorals held all kinds of fellowships from widely different sources. One postdoctoral received his PhD in organic chemistry, so his move to biochemistry represents a change of fields. His motivation was mainly to expand his employment opportunities. Compared to his pre-doctoral experience, the postdoctoral period is one of independence. He has chosen his problem after discussing it with his mentor and is able to pursue it as he sees fit. The director of a leading biomedical laboratory said the major function of postdoctoral work opportunities is for young people to work in new or newly formed areas of science. This is the way science changes and grows. One must take already-trained PhD's and give them these opportunities. There are some areas of science where the basic ideas are pretty well set. These do not need postdoctoral programs since the ideas are already in the undergraduate and graduate programs. Perhaps people in other fields who want to shift their careers, especially M.D.'s, should take postdoctorals in these established fields, but PhD's trained in such fields should not need the postdoctoral experience.

Interaction of MD's and PhD's

The opportunity for M.D.'s and PhD's to be trained together during the postdoctoral period is widely regarded as one of the most valuable aspects of this experience. One M.D. mentor is involved in clinical investigations and all of his people hold M.D.'s but have significant contact with the PhD's of other mentors. He never has many postdoctorals at any one time. In his peak year he had five postdoctorals, all from abroad. They now head laboratories in Israel, Toronto, Tubingen, Australia, and Japan. All who have come through his laboratory have stayed in research. Having himself come to biochemistry through the MD route, he acknowledges that his entire career as a scientist is based upon his postdoctoral experience. He was first exposed to biochemistry during his medical training, and, although he participated in some research during his medical experience, he sought and received a postdoctoral fellowship, where he learned both the field and the sense of research. He does not think that it is necessary for an M.D. to take a PhD subsequently. He even conjectured that the time lapse for the M.D. plus postdoctoral would be less than for the PhD plus postdoctoral. At any rate he did not regret at all the route that he took.

A postdoctoral at another leading lab was an M.D. and has learned all the biochemistry he knows as a postdoctoral. He may still return to clinical medicine, but in an academic setting. He found an advantage in being an M.D. since he knew some of the problems from a clinical point of view. He would have changed his medical training but not his postdoctoral experience. Most of what he is learning is from his fellow postdoctorals. His mentor leaves him alone and he is forced to figure out the problem on his own. In a smaller institution, the director commented that his department is very rich in the variety of backgrounds of people who are associated with it. This is very useful for the predoctoral. The presence of MD's is particularly enriching.

Learning from Other Postdoctorals

The opportunity to learn from other postdoctorals was stressed by many of them. One of them said that he enjoys being around the other postdoctorals. A new PhD needs people to compare himself to. If he could talk only to the laboratory director, he would feel very inferior and inadequate, but after talking with other postdoctorals he gets a better picture of himself at his stage of development. The postdoctorals also feed each other intellectually. One stated that he has learned more from his fellow postdoctorals than from his professors. A third stated that he has obtained a different perspective on science, not only from his mentor but also from his fellow postdoctorals. He now feels re-encouraged about science. The same theme was expressed in negative form by a trainee in a laboratory with no other postdoctorals. He said he misses not having other postdoctorals around and feels very isolated. There had been a post-MD in the department a year ago and it had been pleasant working with him. Now he feels in a state of limbo.

Increased Confidence for Teaching

A great many postdoctorals are aiming at faculty positions in graduate schools. The postdoctoral experience is increasingly regarded as highly important training for this type of position, both from the individual and the institutional point of view. The postdoctorals themselves speak eloquently of their development of confidence in their teaching ability during the postdoctoral years. One expressed the feeling that one comes out of graduate school feeling somewhat insecure. If one is treated as just a pair of hands, then one's self-doubt begins to impair one's ability even to grind out data. It is self-defeating to use people as tools. Another postdoctoral suggested that the primary function of the postdoctoral period was to allow the postdoctoral to find out where things are and to be allowed to make mistakes. He spent just under five years getting his doctorate--the first two years were spent in taking courses. His first three predoctoral years were very discouraging and left him feeling he was making no progress. Even when he received his PhD, he did not feel fully satisfied. He did not think that he could have been able to take on an independent position in a university; he lacked the self-confidence. Anc r, coming to a prominent laboratory from a school without a national reputation, said that confidence building was his mentor's strongest suit. Being new and insecure, he didn't ask questions at first, because h thought it was a sign of weakness. Now he has the confidence to expose his ignorance.

At one of the laboratories visited, acquaintanceship with other scientists was almost impossible--in contrast to most of them where one is in contact with so many people. One postdoctoral here faults himself for not pushing himself enough on other people. When he first arrived he was afraid to make a mistake in front of the lab director. He was even cautious in front of other postdoctorals. On the other hand he knew that he could never succeed as a scientist unless he could spend some time in a laboratory like this one. If he has any regrets about his postdoctoral experience, it is that there is not enough contact with students.

Another postdoctoral in the same laboratory cited another benefit of the postdoctoral period: the opportunity to discover whether one can "make it" in a top laboratory--both scientifically and humanly. He learns not only science from his mentor, but also how to think about sicence. This latter is the most important thing he has learned; techniques can be learned from a book, the attitude only from a man. At another laboratory, a postdoctoral commented that another benefit of being a postdoctoral is that the graduate students are rotated among the postdoctorals every three months. They work directly for the postdoctoral and this gives the postdoctoral the experience of teaching, in a gradual way. The experience is like an apprenticeship to becoming a faculty member. A laboratory director maintained that the postdoctoral experience is a sine qua non for new faculty. The doctoral training is so intense and the demands of the faculty position are so grave that only a genius could go from the PhD to a faculty position. The PhD lacks experience. It is also hard to know from the doctoral dissertation alone whether the work represents the student or his mentor.

One of the few women postdoctorals interviewed said that she felt prepared to do research in the area of her dissertation when she completed her PhD. Her thesis research, however, was in a very narrow subject. Here she has had an opportunity to meet people, to exchange ideas and to learn new techniques. As a graduate student she felt stupid and found it difficult to ask questions. Here there are many people at the same level and her confidence has risen. She can take time to read outside her field now, but she still feels pressure. These are the critical years for a young scientist and one's future career depends upon what is produced during the postdoctoral period. She has produced research satisfactory to her and she thinks she has learned much. Because she wants to work at a university and guide graduate students in their research, she is aware that her own research must be in good order.

Advantages to the Institution

The postdoctoral-mentor relationship is not by any means a one-way street. The postdoctorals bring important values to the institution, also. In a smaller school, the department head said that postdoctorals have been terribly important to his own research. They seem to come just when he needs them to carry out something that has just opened up. They often provide a stimulus for going on with the research. They bring enthusiasm and challenge him to keep alive and not to get set in his ways. He provides them with ideas and ways of thinking. It is an ideal teaching and symbiotic relationship.

The postdoctoral program provides another important service to the universities. In the opinion of the director at one of the large laboratories visited, it is difficult to diagnose in science the man or woman who has only a modest amount of creativity at the doctoral level but whose growth will occur later. In the search for prospective faculty members the postdoctoral period allows the university to see whether the candidate can do research before he is hired. Without post-doctoral programs people would be hired and fired at a great rate and unhappiness would be created on a very high level. This department does not hire anyone at the assistant professor level who does not have a good chance to become a full professor.

At a smaller school, postdoctorals are incorporated into the teaching program. They work with the graduate students and help to train them. They are the heart of the department, just as residents are in the clinical departments. Graduate students spend time in research with several professors before picking one to be their dissertation supervisor. This gives the student several perspectives. Postdoctorals are treated in the same way.

Quality and Quantity of Research

At one of the larger schools, a mentor asserted that the quantity of research in the biological sciences is dependent upon the work of the postdoctorals. They do not have the other responsibilities which are in a professor's life. Postdoctorals are also important to bring new life to the department, since schools are not expanding now. Without postdoctorals the department would tend to stagnate. One postdoctoral feels that he has taught his mentor more techniques than he has learned from him. On the other hand, he has received a perspective on medical research from his mentor and an idea of what is likely to work. Another, at a leading laboratory, contended that most biological research is done by postdoctorals. He believes further that postdoctorals are more innovative than their mentors because they are younger and have more time. He is aware that he will have more obligations ten years from now, but believes his brain is better now than it will be then. A laboratory director agreed that most high-quality research is being done by postdoctorals and suggested that the justification of postdoctoral programs rests on the research that is done. The post-doctoral period is the time when we get the best return for the money spent. At another laboratory the point was made that the postdoctorals serve research in part by helping to create critical sizes for the research groups. Unless a group reaches a critical size, it becomes impossible to keep in touch with other work in the field. The group, by sharing the responsibility, can screen the enormous volume of publications.

Evaluations of the importance of the postdoctoral experience, either by the postdoctorals themselves or by their mentors, are expressed in different ways, often varying according to the particular syle of the mentor or the way in which the relationships are structured within a given laboratory. One senior mentor, some of whose former postdoctorals are now themselves mentors of other postdoctorals, insisted that postdoctorals are absolutely essential to research in the United States--even more so than graduate students. Postdoctorals are the means of doing research and it is obligatory that research money go to the support of postdoctorals.

Flexibility Necessary for Efficiency

Several mentors stressed the importance of a variety of modes of funding and flexibility in arrangements. In addition to competitive fellowships, one mentor said, reliable principal investigators should also have research funds from which they may support other postdoctorals. Such flexibility permits the principal investigator to staff his laboratory adequately. This mentor believes that research panels are concerned whether a principal investigator has produced good students. They look into the question of whether postdoctorals are given finite projects that they can anticipate finishing and whether the laboratory provides the appropriate environment for general and scientific growth.

A student of the above mentor, now himself a postdoctoral mentor, says that he learned from this mentor his style for doing research and his ways of thinking about research. He described him as having stored an enormous amount of information and being able to come out with just that datum which fits the problem. Rather than methodically exhausting the alternatives, he uncannily picks the method that will work and then goes back and cleans up the details. The interviewee's predoctoral mentor was very different--very precise. He has tried to combine the two styles in his own research.

A senior researcher in one of the country's leading laboratories spoke of the relative impact and differing results of different types of research support. He feels that eliminating postdoctoral fellowship or traineeship programs would shift the competition from the junior level among prospective postdoctorals to the senior level where principal investigators would try to obtain sufficient research funds to support the postdoctorals as research associates. It is important to have the competition occur at the junior level. A young man discovers how good he is and where he stands among his peers. The postdoctoral period operates to teach a man to work at the maximum of his capacity. This is not necessarily true at the predoctoral level. There one must try to get the candidate through in a reasonable amount of time. The predoctoral student is like a patient. One cannot test him that deeply; he is not mature enough. Only in the postdoctoral period is a man free from major responsibilities and on his own. Also the pay is enough to live on.

A mentor in a large public university, would continue all three mechanisms of postdoctoral support: traineeships, fellowships and research associateships. If the person a student wants to work with is well established, then it is easier for the student to get a competitive fellowship. A non-established person gets his postdoctorals on training grants. The training grant also allows an established man to have a flexible use of his laboratory. Research grants enable one to support foreigners. This mentor recommends that competitive fellowships permit a third and fourth year at a higher stipend.

A somewhat differing view was expressed by a mentor who stressed that his critical need is for predoctoral support and as a result the major use of his training grant is the support of graduate students. Of the eighteen postdoctorals in the department only two are on the training grant. Eight of the rest are on fellowships, and eight are supported from research grants. He sees the postdoctoral period as a time of apprenticeship and encourages relationship among all groups in the department.

A mentor to several of the postdoctorals whose views have been noted above explained that investigators who are in fields that are overcrowded can afford to sit back and wait for people to come to them. There are not that many people interested initially in pathology, for example, and it becomes necessary to go out and attract people who could make good money elsewhere. He argued that cut-backs in training grant funds would force the department to enlarge its research support and still retain the postdoctorals. In that case, however, the objective would be research and not training. Most research in this country is done by postdoctorals or real research associates. He feels the present stipend forces people to suffer. He gets enough applicants, but he still thinks it awkward to pay so little.

Another postdoctoral mentor with a medical background said that biomedical research is in a phase of development which is unprecedented in its history. This would not be the case if NIH had not been foresighted in the 1950's. If programs are curtailed now, institutions doing biomedical research will not be able to operate effectively in a decade or two. He sees the leading research laboratories as having the responsibility for training the future generations of scientists. To accomplish this the postdoctoral mechanism is essential, since medical school training is too general. We need physicians in research who can ask the human questions.

Conclusions

On examining the results of this series of interviews, it appeared quite clear to the Committee that the postdoctoral fellowships and traineeships were indeed of inestimable value, not only to those who received the stipends, but to the universities and to the development of biomedical science. This evidence pointed to the conclusion that the rate of progress in medicine, and hence future improvement in the health of the populace was importantly dependent upon the retention of these programs, and that the social benefits far outweighed the cost of the programs to the taxpayers. However, this was but the first of the three sources of evidence sought. The testimony of former holders of NIGMS postdoctoral fellowships and traineeships was felt to be important, as would be also the hard statistical data on career outcomes and achievements. We turn now to the substance of letters received by the Committee from the former NIGMS fellows and trainees.

CHAPTER III

TESTIMONY OF FORMER NIGMS POSTDOCTORALS

Another source of information regarding the value of the postdoctoral experience, and reactions to various alternative modes of support of research, was found in letters received by the Committee from former postdoctorals. Such reactions were solicited from a significant number of former NIGMS fellows and trainees who were working in a variety of settings in 1972 and whose career achievements, insofar as they could be judged by publications and citations, were widely varied. The individual replies were not numerous enough to provide any statistical data, but were surprising both in their uniformity of endorsement of postdoctoral training, and in the description of the ways in which the postdoctoral experience had contributed to their own careers.

Typical excerpts from these letters, whose authors must remain anonymous, are grouped under several headings, including opportunities for changing direction of interests, increase in skills, changes in the conditions of awards, and reactions to various proposed alternatives.

Changed Direction of Interest

"The postdoctoral experience made a very great change, because it enabled me to do research at an excellent medical school. Essentially, it introduced me to the research area which I did not feel I had by fulfilling my PhD thesis requirement. After receiving my PhD I had planned to go simply into teaching at the college level, but after my postdoctoral fellowship I felt competent in research and more prepared as a teacher as well." "It helped re-orient my research interests from pure physical chemistry to physical biochemistry by providing the opportunity to work with Dr. ________________." "I became interested in molecular biology instead of classical biochemistry." "Prior to my postdoctoral experience I was concerned with mainly classical areas of biology. The work done while a postdoctoral and thereafter influenced me to the study of plant and insect viruses as well as a variety of biomolecular problems that I was not previously interested in." "It has allowed me to develop some understanding of analysis and to use statistical methods with more than a 'cook-book' approach."

Not all postdoctorals changed their direction of effort. One simply said, "No. The program I participated in was in line with my professional interests." "No change, but it did significantly aid me in updating my knowledge and techniques in protein chemistry and allowed me to initiate a course in biochemistry here with greater confidence and competence." "It did not bring about a change in direction, rather an intensification of certain interests and efforts."

Increase of Skill

"The postdoctoral period allowed me opportunity to develop skills in instrumentation (i.e., gas chromatography, spectrophotometry, etc.) and in other chemical research methods." "In addition to learning electron microscopy, I was able to build a background in X-ray diffraction and polarization microscopy. Concentrating on these techniques provided me with a much broader point of view within my particular area of interest." "As a postdoctoral fellow I was able to acquire many of the 'modern' skills of cell biology particularly, electron microscopy, cell fractionation, spectroscopy, etc." "My graduate training was definitely limited in the area of quantitative genetics. My postdoctoral program enabled me to study statistics and quantitative genetics in depth." "I learned the use of ultracentrifuge and development of techniques for studying homology of base sequence." "I learned the skills of hypothalamic brain stimulation and lesioning techniques; also the preparation of frozen brain sections to check the sites of lesioning and brain stimulation." "I teach in a small school and had been devoting full time to general and organic chemistry. Though my training was in biophysical chemistry I was in need of refurbishing."

Two Year Awards - or One?

Matters of arrangements for postdoctoral fellowship awards--annual renewals and stipends, which have been much discussed in fellowship circles--came in for discussion in the letters received from former NIGMS postdoctorals. There was no unanimity with respect to one-year vs. two-year awards, and some of the writers felt that the stipend level should be increased. Examples of comments on this question were as follows:

"I favor the requirement for yearly renewal (1) if the option exists for termination after one year, and (2) if the fellowship can be transferred from one place to another, should the first position be unsuccessful." "A two-year fellowship would be better because an individual could plan his time." "Yearly renewal provides an automatic opportunity for a reassessing of the overall value of the fellowship." "I would suggest a stipend formula which would place the level of support at one-third to one-half the scale between a typical graduate assistantship and an average starting salary for an assistant professor."

Improvements

Perhaps because they may have felt that it would seem ungrateful "to bite the hand that fed them," few former postdoctorals were critical of the general arrangements as they had experienced them; most had no suggestions for improvements. A few did offer suggestions, such as the following:

"Perhaps one improvement might be to more critically evaluate the methods by which traineeships are granted in individual programs. For example, it might be possible to have an ad hoc outside committeeman oversee the awards so that internal politics play less of an importance." "Better screening of laboratories and the directors who participate." "Speed up the selection process. Better information about your prospects when you apply. But I have no complaints. It's a good program."

Alternative Modes of Support

Letters from former NIGMS postdoctorals were in general quite negative with respect to the idea that postdoctoral funds might be spent in other ways, such as research grants, block grants, etc. Typical reactions were as follows:

"Research grants should not be at the cost of eliminating fellowships. Block grants? No, a good applicant should be able to choose his location. He should not be limited to a place that has a grant." "Negative for using postdoctoral moneys for research grants. I perhaps favor institutional grants since it might insure a more even distribution of awards." "The training grant should not be superseded by research grants as they provide another degree of freedom to the students working under them than would ordinarily be true if the student were working on a research grant. Block or institutional grants are satisfactory, but they should have an appropriate supervisor. Again, perhaps an outside, unbiased committeeman should be involved in the fiscal policies of that grant." "No. Fellowships and traineeships spawn independent thinking and creativity by young investigators." "There should be a separate category for postdoctoral fellowships, as now. I am not in favor of block grants as a substitute." "Research grants are good, but I should not like to see the traineeships program discontinued. Block grants could be used for traineeships." From a university administrator: "Negative for substituting research grants for postdoctorals. I think it is sounder to assign funds to individuals than institutions because this makes it more flexible and because you will have better control of the final distribution of funds." But the dissent was not unanimous. One fellow from the early years, now teaching, comments: "For individuals in the small colleges, research grants have been most beneficial. It is very difficult to keep up in your field without some outside financial support. I like departmental grants, so that several individuals can work together in a small college and have an opportunity to cover research areas very thoroughly."

Two fellows from more recent years enlarged upon their reactions to these ideas of substituting research grant or block grant funds for post-doctoral support as such. They said: "All three are lousy substitutes for training open-ended basic researchers. The unrestricted post-doc lets a top prospect choose where he wants to go and whom he wants to work with. His salary doesn't come out of his professor's grant, so he has freedom to work up his own project. Research and institutional grants are instruments of governmental control over the direction science is to take. Both have their place." "I do not favor institutional grants because there would be too little control on disbursement of funds within the institution and the internal politics in the institution could work to give funds to unworthy investigators and deny funds to worthy investigators. (Of course, external politics could do the same, but this is less probable.)"

Conclusions

The letters of former NIGMS postdoctoral fellows and trainees added further to the weight of testimony from the interviews, giving quite eloquent evidence of the ways in which the postdoctoral training received under NIGMS sponsorship had indeed improved the quality of research performed by the former postdoctorals. They gave further support to the importance of a balanced program, including competitive fellowships, traineeships, and grants-in-aid of research. These subjective opinions, it was felt, needed to be put to the test of objective statistical evidence. Those who had benefited by the programs--or who were currently benefiting--were in favor of the programs, as might well be expected. Actual career achievement data were needed, to be analyzed regarding those who had had such postdoctoral training, and those who had not. The examination of such statistical data, to confirm or refute the opinions expressed up to this point, occupies the next chapters.

CHAPTER IV

THE QUANTITATIVE DATA: RESEARCH STRATEGY

The interviews in postdoctoral laboratories and letters from former NIGMS postdoctorals provided excellent qualitative evidence of the impact of the post-doctoral training on the lives and careers of those so supported--from the standpoint of those directly involved. The Committee judged, however, that it would be imperative to secure "hard data"--quantitative information from sources unconnected with the program, by which to evaluate the effects of training. From this point of view, the various kinds of evidence that were or might be made available were reviewed. The objective was to secure data from existing data banks wherever possible, thus avoiding the time, expense, and annoyance to the scientific community that would be involved in sending out a questionnaire. It was soon discovered that there were several excellent data sources, several of which provide information without any requirement for the cooperation of the people involved--such as counts of publications and citations, records of award of research grants, and attainment of certain identifiable stages of an academic career. The methods involved in the development of these quantitative kinds of evidence deserve some detailed attention.

Career Development Data

The importance of postdoctorals to the medical schools and graduate schools had been brought out in the interview and letter data, but not quantified. However, by reference to the files of the Association of American Medical Colleges, it was possible to determine how many of any particular group of people had actually been hired as faculty members in medical schools, and also the rank attained in the medical school. This offered quite hard, objective, and quantitative information. Furthermore, it should be possible, the Committee decided, to set up some scale or index by which to sort out the medical schools according to the degree of research orientation they exhibited. As research is the primary objective of the postdoctoral training, it would be to be more in line with the objectives of the program if an individual should join the faculty of one of the strongly research-oriented institutions than if he should join the faculty of a less-research oriented school. It was in fact, found to be possible to set up such a scale (see Appendix A) and to use it as a further measure of career achievement.

Similar data were available regarding the careers of the academically-inclined who became members of graduate school faculties. For a very large proportion of the cases, data were available through the National Register of Scientific and Technical Information, as of 1970, regarding employer and type of work performed. In addition, data were available for a substantial portion of those not in the Register through the National Faculty Directory. A third source of information, regarding the academically-employed only, is the Thesis Adviser File, developed in the Office of Scientific Personnel as an offshoot of the Doctorate Records File. For the past decade, each new PhD has supplied information, at the time of graduation, that includes the name of his thesis adviser. This file, then, would give one indication of advancement up the academic ladder in the graduate schools. With respect to school quality, there was already available the Roose-Andersen ratings developed by the American Council on Education in 1970. Thus, several kinds of data were available, chiefly relating to academic careers, but not limited to them, as the National Register also contained data on employer categories other than academic, and major work activity regardless of type of employer.

Career Achievement Data

More than type of career was important, however, in assessment of career outcomes. The attainment of program objectives should be assessed, if possible, by quantitative measures of achievement that were not related to employer type or academic status. What additional quantitative measures might be found? One set of judgments that would be particularly applicable to the people engaged in research would be the winning of research grants in the stiff competition for such awards given by the National Institutes of Health or the National Science Foundation. There are many applications for such grants, which are carefully reviewed by panels of research scientists; only a fraction of such applications result in actual awards. The winning of such awards, therefore, can reasonably be considered to constitute a measure of scientific quality by the peers in one's research environment. It was determined that lists of such awards could be obtained to measure the performance of the NIGMS post-doctorals against the performance of other groups of PhD's.

All these measures appeared to be good, but the Committee had to consider whether a postdoctoral or any other MD or PhD who did not enter the academic world and did not seek or obtain a research grant from NIH or NSF, could, nevertheless, make important contributions to science and specifically to biomedical science. The answer was certainly "Yes", and it was obvious that among these contributions might well be articles in the scientific literature, the typical modality by which the body of science is built up. Furthermore, prior research had shown that one could not only count scientific publications, but, better, count the citations to one's work in the scientific literature. That is, of two publications, that one which is most often cited by other researchers may be deemed to be making the greatest contribution to science. This will not always be true, of course, but by and large, across all the hundreds and thousands of publications, those which are most frequently cited are cited because they have been helpful to the work of other researchers. We have, then, from the scientific literature, two measures - publications and citations - that enable us to measure an individual's scientific contributions in ways that are quite clisely in line with the program objectives of the NIGMS postdoctoral traineeships and fellowships.

What Comparative Standards?

Granted that it is possible to collect the statistics cited above, how is one to judge whether they are favorable or unfavorable, with respect to the program objectives? There are certainly no pre-specified numbers of publications or citations, or numbers for any of the quantifiable criteria. How may one judge, then, the performance of the NIGMS postdoctorals against a fair standard of performance? The Committee chose to base its judgment on the relative attainments of the NIGMS postdoctorals as compared with those of several other specified groups. One of these groups was to be a random sample of MD's drawn from the same medical school graduation cohorts as were the NIGMS post-MD's. For the PhD's, there was to be a similar random sample drawn from the Doctorate Records File (DRF) maintained by the NRC's Office of Scientific Personnel. The Committee decided to go farther, however, and to use a "select sample" of PhD's, matched with the NIGMS postdoctorals as nearly as possible, not only in terms of time of graduation, but in terms of field of specialization, institution of doctorate, and sex. Still other comparisons were possible, involving other groups of postdoctorals. The National Science Foundation had for many years supported a postdoctoral training program very similar in many respects to that of the NIGMS, but with slightly different field emphases and somewhat different selection techniques. Another program, very small in numbers, particularly in the biomedical sciences, but very high in selectivity, was the Postdoctoral Research Program of the Air Force Office of Scientific Research. Although the numbers were small, it was deemed advantageous to take into account the accomplishments of this additional group.

A caution was apparent from the first with respect to the use of these comparison groups. Even the "select sample" could not properly be called a "control group" in the sense in which that term is used in laboratory science. People apply for and are selected for all sorts of training programs, and there is no way in the practical world where people with fully equal qualifications can be arbitrarily assigned to "trained" and "untrained" groups after the manner of a controlled experiment. Yet, in spite of the many factors that would inevitably be beyond the scope of this research with respect to the abilities and motivations of the comparison groups, it was expected that these groups would furnish some sort of standard against which the performance of the NIGMS postdoctorals might be measured. As will be seen later in this report, additional refinements of technique permitted rather close tailoring of the samples and some control of extraneous variables, so that some of the comparison standards could fairly be said to reflect rather well the effect of training per se.

In assessing the evidence from the statistical data, the Committee recognized that there are two possible kinds of impacts of a program in support of training such as the NIGMS postdoctoral program. One possible effect is that people may be induced to enter research careers who would not have done so but for the availability of the necessary funds for advanced training. The other effect is that of facilitating and speeding the career development of people who have already decided upon research careers. By speeding the research career, the country would get the benefit of more of the best years of the researcher, as well as a larger total number of years spent in research activity. Both of these effects are closely tied up with the matter of selection for postdoctoral training, and it was not expected that the study could untangle the relative contributions of the postdoctoral support program to each of these kinds of results. In the unlikely event that the NIGMS postdoctoral program, although selecting good research-oriented people, failed to produce people who performed in accordance with the program objectives, that kind of negative evidence should at least become quite clear in the course of the analysis. On the other hand, it was recognized that if the NIGMS program had in fact supported superior individuals who were already headed toward successful research careers, at least the selective features of the program were working in the intended direction. The Committee took cognizance of these varying kinds of possibilities, although it could not expect, within the framework of the present study, to arrive at quantitative conclusions regarding the degree to which the various outcomes might be related to participation in the program.

Using this orientation as a guide, the Committee examined preliminary data on careers and career outcomes, set up a series of quantitative measures by which the operationally-defined program objectives might be measured, and decided to conduct site visits and invite letters from former postdoctorals supported by NIGMS. Using this field experience as a guide, further refinements of the quantitative measures were decided upon. As the data developed. it became apparent that it would be important to consider quite separately the career lines and career attainments of the post-MD's and post-PhD's, inasmuch as the two types of careers are so different as to make many of the measures not directly comparable. In the report, the post-MD's are considered first, in part because of the greater complexity of the data regarding the post-PhD's. However, as background for considering both of these sets of data, it will be advantageous to examine some information on the numbers and types of people supported by the NIGMS from the beginning of the program up to 1970. The next section deals with these data.

Background and Basic Data

The extent to which postdoctoral education has increased in the United States over the last decade and a half is indicated in Table 1 and Figure 1. The post-graduation plans of new PhD's are shown by graduation cohort, the first nine years being grouped into three 3-year periods, the last five years being shown separately for greater detail. The table and figure show the data separately for three general fields of science. Engineering, mathematics, and the physical sciences (EMP fields) are shown first, then biomedical sciences, followed by the social sciences and finally all science fields combined.

The data of Table 1 show a total for the period 1958-1970, because this is the period for which most of the data in this study were available. In addition. data on the 1971 PhD graduations and postdoctoral plans became available in time for inclusion here, although other data tables necessarily terminated with 1970. The inclusion of 1971 data here extend the previous series, although other tables will not include this year.

The growth in number of science doctorates is apparent on the bottom line of Table 1. The single year 1970 is larger in numbers - 18,252 - than the 18,159 in the three-year cohort of 1958-1960--a tripling in slightly over a decade. But over this same period the number of postdoctorals has increased from 1,471 for the 3-year period to 4,050 for the single year 1970--an increase of over 825%. It should be noted that, although the data of Table 1 and Figure 1 represent only plans at the time of graduation, various follow-up studies have indicated that thes plans correspond well with actual outcomes. It should further be noted that these are only immediate postdoctorals; many others enter training after a lapse of a few years. These are, of course, only the data on PhD's; post-MD training is in addition to these figures.

It will be noted that there was a small but significant increase in the percentage whose plans were uncertain in the 1971 data, reflecting the increasing impact of the cutback in support programs at this point. In all fields the actual number of postdoctorals has continued to increase; in the life and social sciences the proportions increased up to 1971, where a slight percentage decrease was recorded. Since 1969, over a third of all new PhD's in the biomedical sciences entered post-doctoral training on graduation.

Over the 1958-1970 period, a total of approximately 8,420 new biomedical PhD's have entered postdoctoral training (Table 1, life sciences minus agriculture). Of these, 2,977 have had NIGMS support. (An additional 1,090 in engineering, math, and physical sciences, and 203 in the social sciences have also been supported by NIGMS.) Thus in the biomedical fields, the NIGMS-supported people constitute about

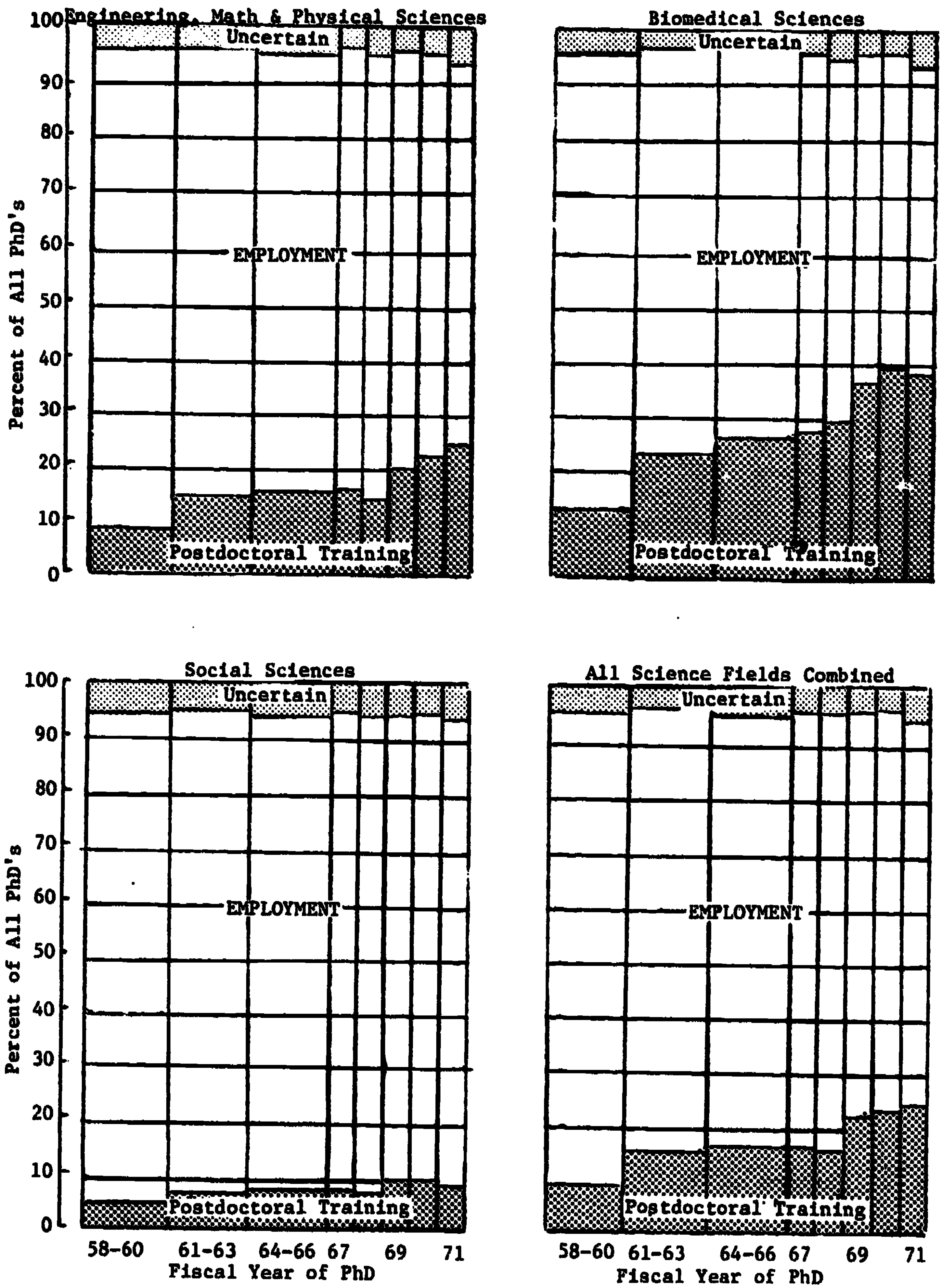
TABLE 1

Postdoctoral Plans of 1958-1971 PhD's

Postdoctoral Plans		FY 58-60	FY 61-63	FY 64-66	FY 67	FY 68	FY 69	FY 70	Total 58-70	FY 71
Engineering, Math, and Physical Sciences										
Postdoctoral Training	N	671	1,600	2,435	1,042	1,010	1,639	1,932	10,329	2,216
	%	8.1	14.2	14.7	15.0	13.5	19.9	21.4	13.8	24.0
Employment	N	7,275	9,249	13,355	5,615	6,167	6,282	6,735	61,140	6,462
	%	88.1	82.3	80.8	80.9	82.4	76.4	74.5	81.8	70.0
Uncertain	N	307	382	740	277	307	303	372	3,235	547
	%	3.7	3.4	4.5	4.0	4.1	3.7	4.1	4.3	5.9
Total	N	8,253	11,231	16,530	6,934	9,484	8,224	9,039	74,704	9,225
Biomedical Sciences										
Postdoctoral Training	N	603	1,299	1,998	835	1,049	1,470	1,742	8,996	1,877
	%	12.2	22.2	25.2	26.6	28.4	35.7	38.2	24.1	37.1
Employment	N	4,139	4,376	5,661	2,181	2,480	2,491	2,644	26,830	2,858
	%	83.9	74.9	71.4	69.4	67.2	60.5	57.9	71.7	56.5
Uncertain	N	192	165	273	126	165	158	178	1,573	316
	%	3.9	2.8	3.4	4.0	4.5	3.8	3.9	4.2	6.2
Total	N	4,934	5,840	7,932	3,142	3,694	4,119	4,564	37,399	5,051
Social Sciences										
Postdoctoral Training	N	197	353	488	208	220	329	376	2,171	401
	%	4.0	6.1	6.6	6.5	6.1	8.1	8.1	5.7	7.7
Employment	N	4,509	5,203	6,476	2,801	3,167	3,513	4,041	34,166	4,438
	%	90.7	89.3	87.9	88.1	88.5	86.5	86.9	89.0	86.0
Uncertain	N	266	271	406	169	194	219	232	2,073	316
	%	5.3	4.7	5.5	5.3	5.8	5.4	5.0	5.4	6.1
Total	N	4,972	5,827	7,370	3,178	3,581	4,061	4,649	38,410	5,115
All Sciences Combined										
Postdoctoral Training	N	1,471	3,252	4,921	2,085	2,279	3,438	4,050	21,496	4,494
	%	8.1	14.2	15.5	15.7	15.4	21.0	22.2	14.3	23.1
Employment	N	15,923	18,828	25,492	10,597	11,814	12,286	13,420	122,136	13,758
	%	87.7	82.2	80.1	80.0	80.0	74.9	73.5	81.1	70.8
Uncertain	N	765	818	1,419	572	666	680	782	6,881	1,179
	%	4.2	3.6	4.5	4.3	4.5	4.1	4.3	4.6	6.1
Total	N	18,159	22,898	31,832	13,254	14,759	16,404	18,252	150,513	19,431

Source: Doctorate Records File, Office of Scientific Personnel

FIGURE 1 Postdoctoral plans of 1958-1971 PhD's



Source: Doctorate Records File, Office of Scientific Personnel

35% of the total - but again it must be noted that the NIGMS figures include not only the new graduates, but those entering such training at later dates. Another way of approaching the relative contribution of the NIGMS to this field is to note the total number of post-PhD's and post-MD's supported by NIGMS in each year from 1958 through 1970. These data are given in Table 2. It must be remembered, in interpreting Table 2, that these data include the same individual in more than one year if the traineeship or fellowship extended over two or more years. These data, then represent a level of support, rather than numbers of different individuals. The right-hand portion of this table shows the number of thousands of dollars of support in each year, separated into traineeship and fellowship categories, and combining post-PhD's and post-MD's. The total expenditures, approximately 86.5 million, are the equivalent of about $5,850 per man-year of support over the period shown. From a beginning in 1958 with 48 people supported, the program has grown to 1,767 people supported in fiscal 1970. The greatest growth, however, was in the first six years; since 1963, growth has been moderate in numbers, while costs have continued to rise more steadily because of inflation and increases in stipends to try to keep up with the rise in the cost of living. These data are shown graphically in Figure 2. The number of people supported each year is shown by the upper line, with the scale at the left. The dollars expended each year is shown by the lower line, with the scale at the right. The tendency for the two lines to converge in recent years is a reflection of the inflation of costs.

This furnishes a general background with respect to postdoctoral education in the biomedical sciences, as the situation existed when the NIGMS requested the NRC to undertake an evaluative study of their postdoctoral program. The next paragraphs give a general description of the categories of people supported by the NIGMS and relate these categories to the plan of the evaluative study.

Categories of Postdoctorals

The NIGMS began its postdoctoral program in 1958, and from the beginning included both post-PhD's and post-MD's in its training program. Two general types of training were provided: fellows, who were selected in a national competition, and trainees, who were locally selected by departments which had been awarded training grants by the NIGMS. (Training grants had an additional dimension - their impact on institutions and the development of training programs carefully tailored to biomedical needs. But these aspects are a separate story, which we will omit here.) Although the programs of study were not substantially different for the trainees and fellows, that they were selected by different means opens the possibility of their having different initial qualifications, and hence of possible different career outcomes related

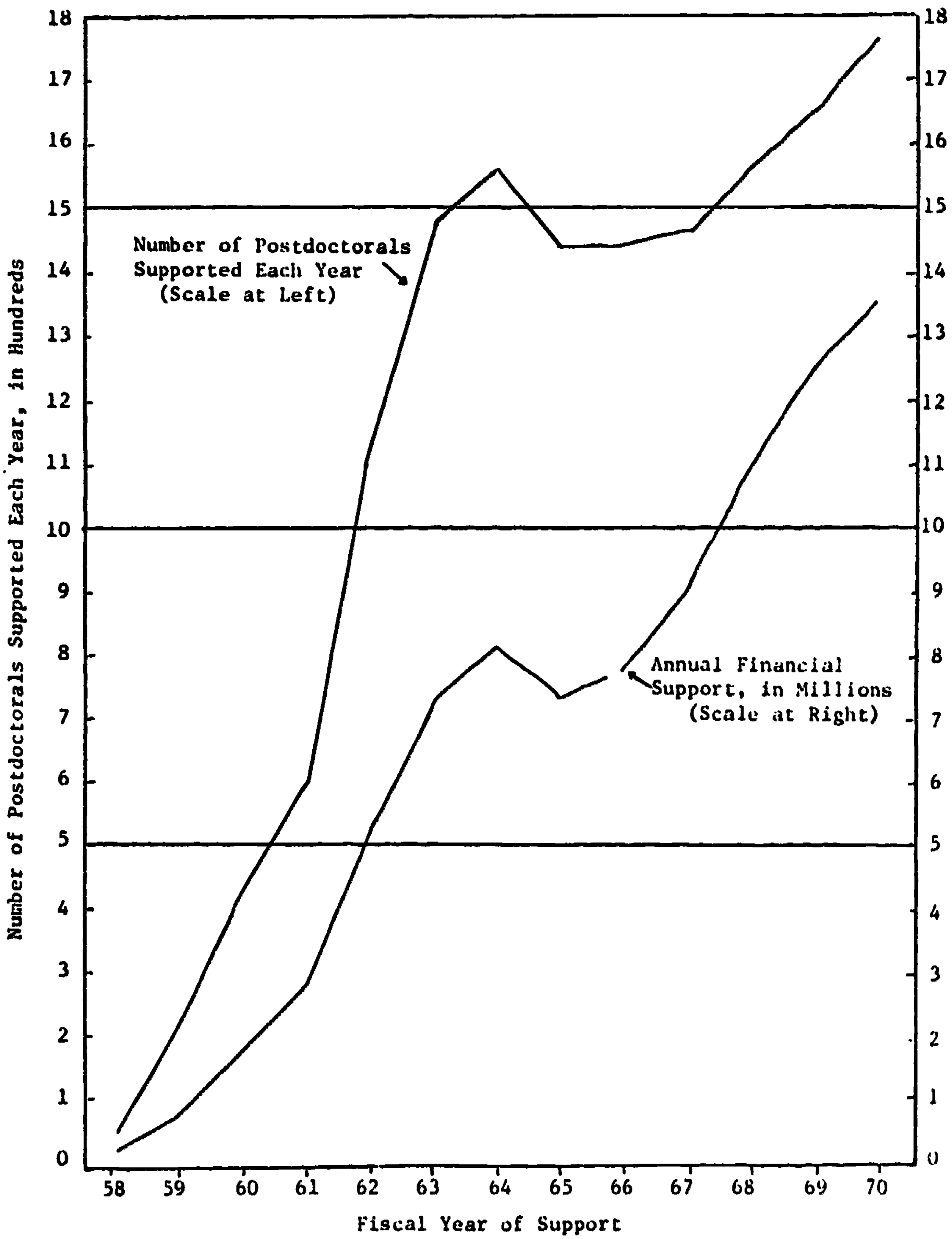
TABLE 2

Numbers of Post-MD's and Post-PhD's Supported by NIGMS in Each Year, 1958-1970 and Dollar Expenditures in Each Year for Traineeships and Fellowships

Fiscal Year	Numbers of People Supported, by Year of Award			Thousands of Dollars, by Fiscal Year on Duty		
	Post-MD	Post-PhD	Combined	Traineeships	Fellowships	Combined
1958	36	12	48	150	------	150
1959	152	64	216	652	60	712
1960	269	163	432	1,258	533	1,791
1961	364	239	603	1,970	755	2,745
1962	632	505	1,137	3,852	1,353	5,204
1963	825	646	1,471	4,852	2,294	7,146
1964	854	713	1,567	5,413	2,675	8,088
1965	761	675	1,436	5,096	2,145	7,241
1966	741	694	1,435	5,179	2,525	7,704
1967	741	721	1,462	5,530	3,452	8,982
1968	777	786	1,563	6,580	4,275	10,855
1969	820	827	1,652	7,715	4,712	12,427
1970	830	937	1,767	8,403	5,102	13,504
TOTAL	7,807	6,982	14,789	56,650	29,901	86,551

FIGURE 2

NIGMS postdoctorals supported, and annual costs, by year, 1958-1970



to these initial differences. As will be seen, this can become important when outcome data - professional achievements - for these groups are compared with those for other groups chosen to provide a normative framework for interpretation of results. A minor problem arose because some individuals (a small portion of the total) had held both fellowships and traineeships. Most of these appeared to be fellows who were given traineeships for brief periods before their fellowships became effective. The problem was resolved by placing each individual in that category in which he had received the most months of training. This had the effect of classifying most of this group as fellows, and thus in the category with the most explicit selection requirements. There was a total of fifty-one people who had both the PhD and MD degrees. These people are counted twice in Tables 3 and 4 (i.e., they are included in both the MD and the PhD figures).

Senior Postdoctorals

Another distinction which affects possible interpretation is the age and amount of experience the individual had received prior to entrance upon the fellowship or traineeship. A great many of the individuals supported had just completed their doctorates, while others had had many years of prior experience. It was necessary then, to provide some distinctions based on such prior experience. It turned out to be useful to make a simple dichotomy into what have been termed "regular" and "senior" postdoctorals, adhering as nearly as possible to the definitions (necessarily arbitrary) used for many years in the domain of postdoctoral work. Senior postdoctorals are defined as those more than five years past the doctorate for the PhD's, and over eight years past the doctorate for the MD's, to allow extra time for the internship and residency. There was one further distinction which affected primarily the stipend provided, rather than the training itself. A number of the fellows and trainees were at an advanced career stage where they could not afford to undertake training on the standard stipend. They were termed "specials" and a stipend was determined on a basis which would permit their leaving their regular employment to undertake the training without undue loss of income. As this was a financial arrangement, rather that an educational one, and inasmuch as it would be highly correlated with length of experience, this was a distinction which it was felt could be disregarded in the evaluation of outcomes.

The numbers of trainees and fellows, of seniors and regulars, both post-PhD and post-MD, are shown in Tables 3 and 4. In Table 3 it is seen that about 15% of both the PhD's and MD's are in the senior category.

TABLE 3

Proportions of NIGMS Senior and Regular Postdoctorals, by PhD and MD Categories, 1958-1970

		Post PhD	Post MD	Total
Senior Postdoctoral	N	660	686	1346
	%	15.1	15.9	15.5
Regular Postdoctoral	N	3713	3626	7339
	%	84.9	84.1	84.5
Total Postdoctorals	N	4373	4312	8685
	%	100.0	100.0	100.0

It is also apparent from Table 3 that the program divides almost evenly between post-PhD's and post-MD's. The division between trainees and fellows, however, is different for MD's and PhD's as shown in Table 4. The post-PhD's divide 55/45 between trainees and fellows, respectively, while for post-MD's the division is 90/100; conversely, 62% of the trainees were post-MD's, while 83% of the fellows were post-PhD's.

TABLE 4

Proportions of NIGMS Trainees and Fellows, for MD's and PhD's, 1958-1970

		Post PhD	Post MD	Total
Trainees	N	2384	3898	6284
	%	54.5	90.4	72.4
Fellows	N	1989	414	2401
	%	45.5	9.6	27.6
Total	N	4373	4312	8685
	%	100.0	100.0	100.0

Because both the training and the normal careers of PhD's are so different from those of MD's, the two groups of postdoctorals have been kept distinct throughout the evaluation study. Within each of these groups, the differences between regular and senior postdoctorals also require that they be treated separately in much of the analysis. However, the kinds of career outcomes for post-PhD's, whether regular or senior, would be expected to be the same in kind, although perhaps differing in quantitative terms. The same could be anticipated for the post-MD's. The data on the post-MD's will be considered first.

CHAPTER V

THE POST-MD'S: CAREER PATTERNS AND ACHIEVEMENTS

The careers of MD's who take postdoctoral research training such as that afforded by NIGMS traineeships or fellowships are quite different from those of the typical MD who enters clinical practice. Their career motivations are of course different, or they would not have applied for the postdoctoral training in the first place. A great many take this training because they plan careers in academic medicine, and are keenly aware that medical schools are increasingly requiring such training for new additions to their faculties.

As one comparison group for the NIGMS post-MD's, a typical sample of MD's of the same medical school graduating classes were examined for comparable data. This was done by selecting a ten percent random sample from the computer tape made available by the American Medical Association regarding all members of the medical profession, whether members of AMA or not. This tape, of course, included the NIGMS post-MD's, but only in the proportion their numbers bear to the total of all MD's of the same graduation cohorts. This overlap was eliminated; however, trainees of other NIH programs, who could not be identified, remain in the random sample of physicians. For purposes of analysis, the post-MD's were divided into two groups, a "pre-1961" cohort, and a 1961-70 cohort. These terms should perhaps be defined more clearly. For the NIGMS cases, it means all postdoctorals whose MD's were earned at any time prior to 1961. Most of them were earned in the late 1950's, but the group included a few senior trainees and fellows whose MD's were earned considerably earlier. For the random sample drawn from the AMA tape, however, a definite cut-off date was established because it would not be reasonably to include all the pre-1961 graduates. Consequently, the group actually includes a ten percent sample of all MD's on the AMA tape whose degrees were earned in the 1957-1960 period. The later cohort represents ten percent drawn at random from the MD graduates of the 1961-70 period. The same strict time limits apply to the NIGMS post-MD's for the later cohort.

To afford further comparison with the NIGMS post-MD's, data are presented also for the NIGMS post-PhD's. The post-PhD's were divided into an early pre-1964 cohort and a later 1964-70 cohort. the cut-off dates being different from those for the MD's, which allowed time for the internship and residency years.

TABLE 5

Numbers and Percentages of NIGMS Postdoctorals and Comparison Groups Who Became Members of Medical School Faculties, by Time Period of Graduation

Cohort	Comparison Group		Grand Total	Medical School Faculty	Medical School Faculty Status: Full Prof.	Assoc. Prof.	Asst. Prof.	Inst.	Other and Unknown
Total	NIGMS	N	4261	1460	182	384	642	215	37
	Post-MD's	%	100.0	34.3	12.5	26.3	44.0	14.7	2.5
Total	Random Sample	N	14933	1036	38	162	459	347	30
	of Physicians	%	100.0	6.9	3.7	15.6	44.3	33.5	2.9
Total	NIGMS	N	4322	807	88	189	451	63	16
	Post-PhD's	%	100.0	18.7	10.9	23.4	55.9	7.8	2.0
Total	NIGMS Post-	N	51	20	1	7	12	0	0
	MD/PhD's	%	100.0	39.2	5.0	35.0	60.0	0	0
Pre-61	NIGMS	N	2314	971	178	341	360	71	21
	Post-MD's	%	100.0	42.0	18.3	35.1	37.1	7.3	2.2
Pre-61	Random Sample	N	4592	491	30	136	214	97	14
	of Physicians	%	100.0	10.8	6.1	27.7	43.6	19.8	2.9
Pre-64	NIGMS	N	1907	421	88	160	154	10	9
	Post-PhD 's	%	100.0	22.1	20.9	38.0	36.6	2.4	2.1
1961-70	NIGMS	N	1947	489	4	43	282	144	16
	Post-MD's	%	100.0	25.1	0.8	8.8	57.7	29.4	3.3
1961-70	Random Sample	N	10341	545	8	26	245	250	16
	of Physicians	%	100.0	5.3	1.5	4.8	45.0	45.9	2.9
1964-70	NIGMS	N	2415	386	0	29	297	53	7
	Post-PhD's	%	100.0	16.0	0.0	7.5	76.9	13.7	1.8

The Committee first considered the percentage of each group found to be on the faculties of medical schools. These percentages were obtained by matching these groups against the computer tapes maintained by the Association of American Medical Colleges.

Table 5 shows the academic rank of the members of each of these groups, so that not only the fact of membership on a medical school faculty is available, but also the rank on the academic ladder which these groups have attained.

The first line of Table 5 shows that, of the 4,261 NIGMS post-MD's, 1,460, or 34% were found on the AAMC Faculty tape. This compares with 1,036, or 7% of the random sample of 14,933 physicians on the AMA tape and 807, or 19% of the 4,322 NIGMS post-PhD's. The comparison is not strictly that of persons having postdoctoral training with those who have not had such training, as a few of the physician random sample presumably had postdoctoral training under other programs. It is a comparison of the specific group of NIGMS postdoctorals with all physicians of the same graduation period, including those with post-doctoral training from other sources. Finally, n t as a comparison group, but rather as a special group of NIGMS postdoctorals, those who hold both MD and PhD degrees and had NIGMS postdoctoral training, are shown on line 4. Of this small group of 51, 20 people, or 39%, were medical school faculty members, none below the rank of assistant professor, and none in administrative positions.

Going on down the page in Table 5 we find a breakout of the same groups by graduation cohorts. These data are shown graphically in Figure 3. These further breakout indicate the importance of the time element, as some of the trainees and fellows were still in training status at the time the AAMC tape was prepared; it would have been impossible for them to have completed their training and to have moved to faculty positions. The same is true, of course, for the random sample of physicians from the AMA tape. With this in mind, one may note that 42% of the early cohort of NIGMS post-MD;s are on medical school faculties, as compared with 11% of the corresponding normative group of physicians. For the later period, 25% of the NIGMS post-MD's are found on the faculty roster, as compared with 5% of the random sample of physicians. For the PhD samples, we note that 22% of the early cohort and 16% of the later cohort of NIGMS postdoctorals are on medical school faculties.

The foregoing employs only the data on faculty membership; it does not exhaust the information of Table 5 which gives also the faculty rank or position attained by the members of the various groups. For the purpose of this tabulation, the four standard faculty ranks were included. The few who were classified as teaching or research assistants, administrators, or whose positions were not specified on the AAMC tape, are shown in the final column.

The data showing the proportion of each group found to be on a medical school faculty, as shown by the AAMC tape, are depicted graphically in Figure 3. The proportions of the faculty members in junior ranks (instructor, assistant professor) and senior ranks (associate professor, full professor) are shown in Figure 4.

The outstanding record of the NIGMS post-MD's with respect to attaining positions and advanced rank in medical schools shows up clearly in Figures 3 and 4. Figure 3 requires no further comment. Figure 4 shows the difference between the early and later cohorts, as might be expected. In the most recent cohorts, there are few with advanced faculty rank, as compared with approximately half in the older cohorts. The difference between the post-MD's and the random sample of physicians is also readily apparent. In making this particular comparison, it should be born in mind, as mentioned earlier, that the random sample presumably also contains postdoctorals supported by other sources, but in unknown numbers. It is also of interest to note in Figure 4 that, for those who have faculty appointments, the rate of advancement of the post-PhD's is even greater than that for the post-MD's. The comparison between the MD's and PhD's may not be of significance, but two possibilities come to mind to account for the fact that the PhD's have a slight edge in terms of advancement up the academic ladder. It is possible, considering the smaller percentage of the post-PhD's who have attained medical school faculty status, that they have been more rigorously selected. It is more probable, however, that the difference lies more in the schools on whose faculty they serve. Data to be shown below indicate that the post-MD's, on the average, are employed by older and more prestigious institutions; the post-PhD's have been employed in greater proportion by the less prestigious and newer institutions. They may, therefore, be functioning in an environment in which advancement is easier because of expansion of medical school faculties.

It is possible to secure yet another criterion of career achievement from the data on the proportions of the various groups who are found, by searching the AAMC tape, to be employed by medical schools. It can be argued quite cogently that it is a greater achievement to be employed by one of the more prestigious medical schools than one without an outstanding national reputation.

FIGURE 3

Percentage of NIGMS postdoctorals and comparison groups on medical school faculties, 1970, by graduation cohort

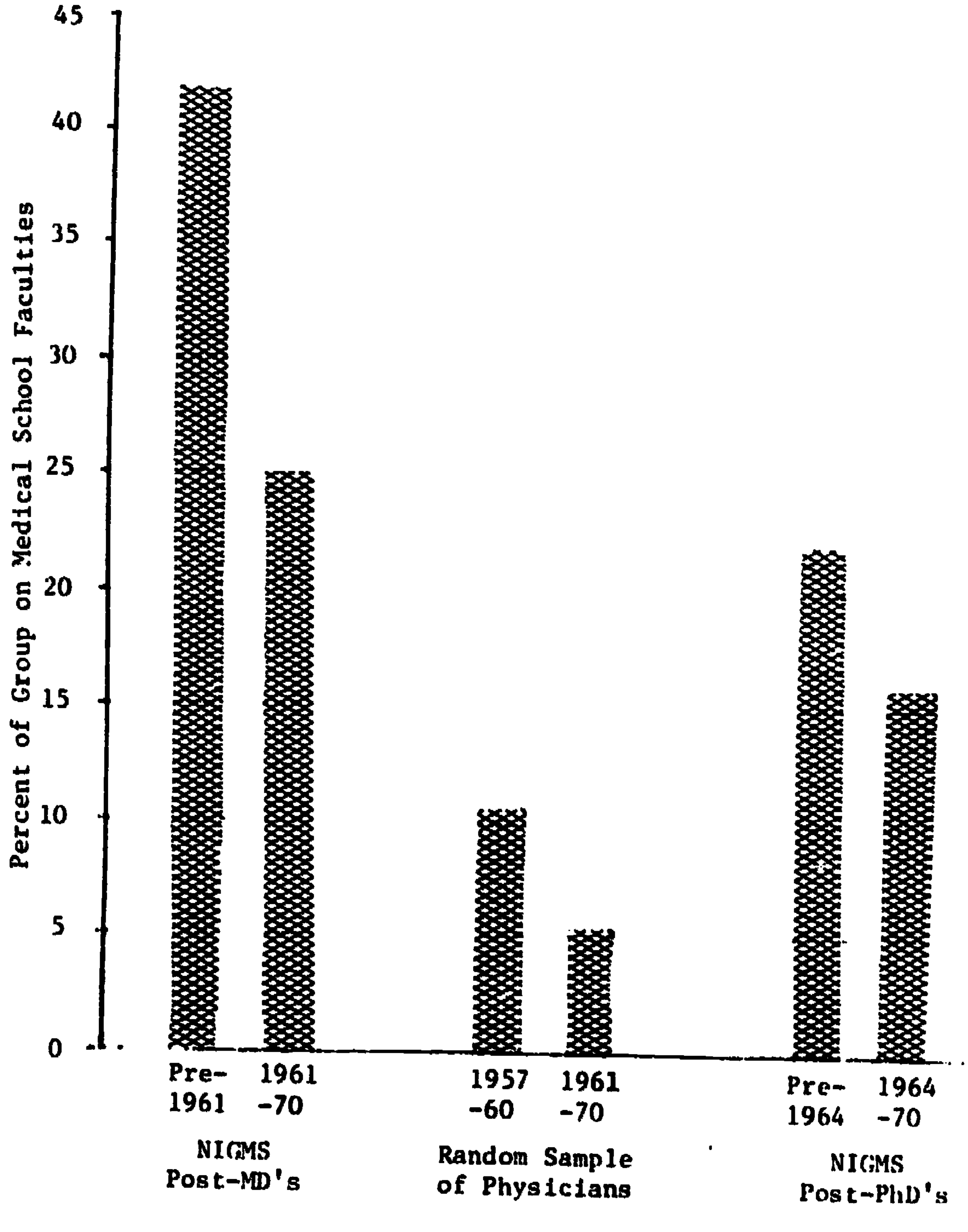
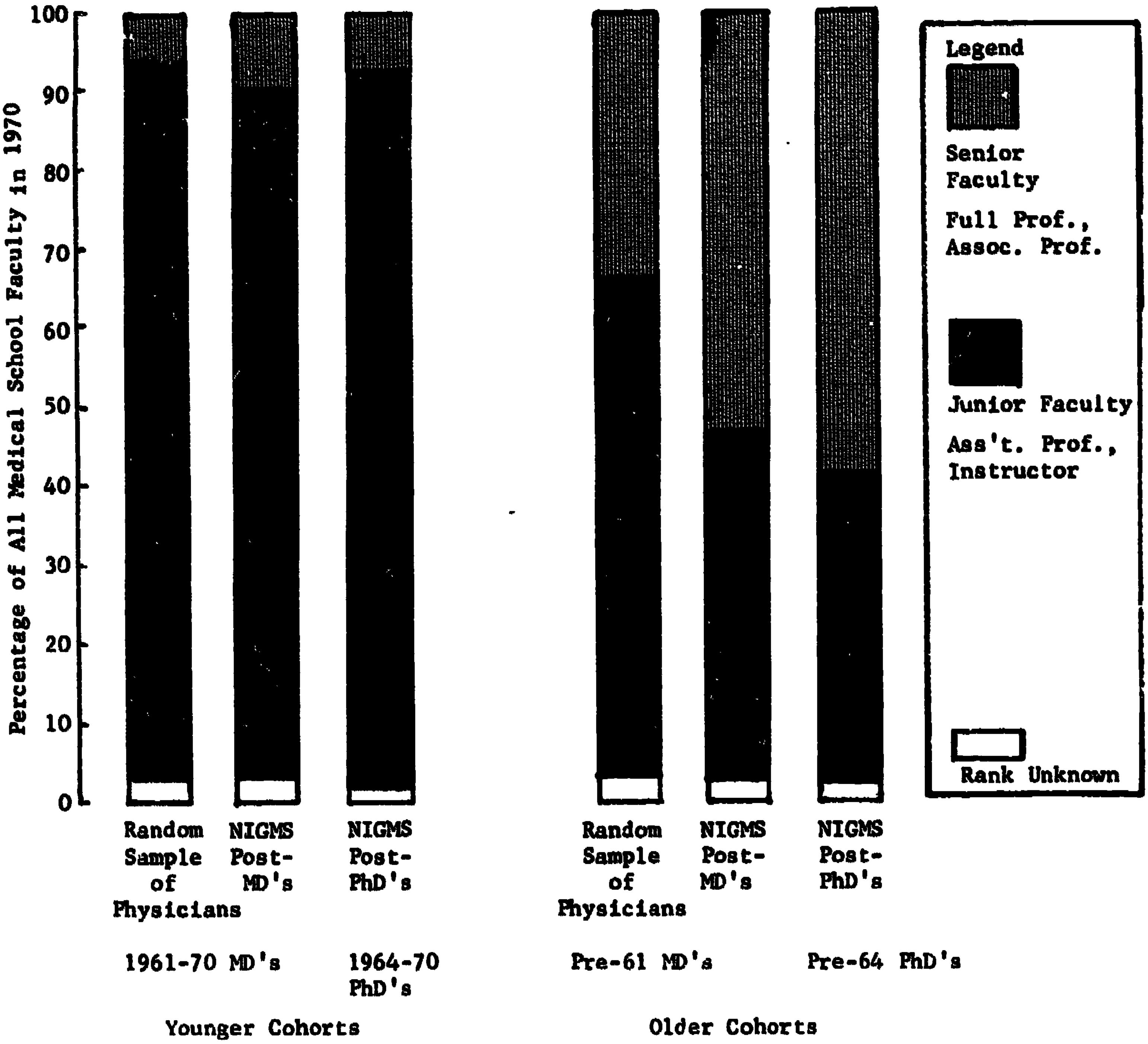


FIGURE 4

Faculty ranks of NIGMS postdoctorals and comparison groups employed by medical schools in 1970, by graduation cohort



Undoubtedly the institutions vary in their selectivity, and posts in the more prestigious institutions, which are also the more research-oriented, are sought after much more vigorously. We may well, then, use an index, or score, based on evidence of research orientation, if one can be derived, as another measure of achievement, and examine the results for the various comparison groups in these terms.

Medical School Research Orientation

There has been no nationally-recognized assessment of the medical schools analogous to that provided by the Cartter ratings and Roose-Andersen ratings of the graduate departments. And yet it is widely accepted that not all medical schools are alike, and certainly not all have the same research-orientation, which is a quality pertinent to the present study. Various sources of quantitative data regarding medical schools were therefore examined to see whether they might afford some basis for such a ranking. It was found that a number of quantitative indices were available, and that they tended to place the schools in approximately the same order. These factors were: (1) the percentage of the school's alumni who were later themselves employed as medical school faculty; (2) the percentage of alumni who passed one or more U.S. Specialty Boards and (3) the percentage of the whole student body who were graduate students or postdoctorals.

These three factors were combined in a simple empirical formula, producing a grouping of the medical schools with respect to the above-mentioned qualities appropriate to this study. The formula and the six groups of medical schools, designated by letters A through F, are given in Appendix A. No brief is held for the exactness of the scale, nor for the placing of any individual medical school. It is the sets of schools in the several groups that are important for the present purpose, which is to determine the extent to which the NIGMS postdoctorals sought and attained appointments in types of medical schools most appropriate to their research training.

Use of the Research-Orientation Groups

The research-orientation groupings were used in the following manner: The percentage of each of the postdoctoral groups (and the AMA random sample for comparison) who were, in 1970, employed in institutions of each category were computed.

By assigning numerical values to the several categories, an average index or score for institution of employment was derived for the various postdoctoral groups and for the AMA random sample comparison group.

When the mean "research-orientation score" was computed for each of the groups of NIGMS postdoctoral trainees and fellows, it was found that the cohort differences found with respect to the faculty rank did not hold up. However, other differences did appear, between the trainees and fellows. Among the post-MD trainees, a small but reliable difference appeared between the regular and senior trainees - but in the opposite direction to what might have been expected. A difference appeared, also, between the post-MD's and post-PhD's, as was mentioned earlier. The MD's were found on the average, to be employed by slightly higher-scoring medical schools than were the PhD's. Within the various NIGMS post-PhD groups, no significant differences appeared. The research-score means for the institutions of employment of all the NIGMS postdoctoral groups are shown in Table 6.

TABLE 6

Medical School Research-Orientation Means* of NIGMS Post-MD and Post-PhD Fellows and Trainees, Regular and Senior, in Two Time Period (Those on Medical School Faculties)

	Post-MD's				Post-PhD's				MD/PhD's
	Trainees		Fellows		Trainees		Fellows		
	Reg.	Sr.	Reg.	Sr.	Reg.	Sr.	Reg.	Sr.	Total
Pre-1964	4.03	3.59	4.27	4.25	3.80	3.87	3.91	3.82	---
1964 et seq	3.99	3.60	3.94	---	3.84	---	3.84	---	---
Total	4.01	3.59	4.15	4.19	3.82	3.87	3.87	3.82	4.00

* A dash indicates fewer than five cases; MD/PhD's not broken out by time.

A somewhat different view of the same data is provided by Table 7, in which the numbers and percentages of the members of each of the comparison groups (combining cohorts) are given for each of the research-orientation categories, A through F. There is also a category of medical schools too new to have accumulated the data used for computation of the prestige score. This group is shown as un-rated in Table 7. The table also includes, for purposes of comparison, data on the random sample of physicians.

TABLE 7

Numbers and Percentages of NIGMS Fellows and Trainees, Post-MD and Post-PhD, and Random Sample of Physicians, in Each Medical School Research-Orientation Category, All Cohorts Combined

Postdoctoral Group		Total	Research-Orientation Groups A	B	C	D	E	F	Unrated
Post-MD Trainees	N	1251	170	215	288	247	102	54	175
	%	100.0	13.6	17.2	23.0	19.7	8.2	4.3	14.0
Post-MD Fellows	N	209	43	33	48	38	15	7	25
	%	100.0	20.6	15.8	23.0	18.2	7.2	3.3	12.0
Random Sample of Physicians	N	1036	116	123	252	290	104	17	134
	%	100.0	11.2	11.9	24.3	28.0	10.0	1.6	12.9
Post-PhD Trainees	N	528	50	78	129	121	53	9	88
	%	100.0	9.5	14.8	24.4	22.9	10.0	1.7	16.7
Post-PhD Fellows	N	279	27	44	61	57	23	9	58
	%	100.0	9.7	15.8	21.9	20.4	8.2	3.2	20.8
MD-PhD's (Total)	N	20	2	3	6	3	2	0	4
	%	100.0	10.0	15.0	30.0	15.0	10.0	0.0	20.0

The especially interesting data of Table 7 are the markedly higher proportions of the post-MD's, as compared with PhD's, who are on the faculties of the highest-rated category of medical schools. Within the MD group, the "A" group concentration of the fellows is also quite evident, but even the random sample of physicians is found in Group A in greater proportion than are any of the PhD groups. The last column is of considerable interest also. It shows that the newer medical schools, which have not been in operation long enough to have generated the data used for computation of the prestige scores, employ relatively more PhD's than MD's, as compared with the schools in the rated categories. The data for the MD-PhD postdoctorals is presented for completeness sake; because of the small number of cases, no statistical conclusions are warranted for this group.

Contributions to Biomedical Research

One of the objectives of the NIGMS postdoctoral training program was to upgrade the faculties of medical schools by providing teachers with research training and experience. The foregoing data show that this objective has, in fact, been accomplished to a considerable extent: The postdoctorals, both trainees and fellows, have been employed by medical schools in proportions far greater than have physicians who have not had such training. Another objective of the program was that of enlarging the number of people doing research and contributing to the growth of biomedical science. The question then becomes one of measuring in some way the contributions the postdoctorals have made, as compared with the contributions of the random sample of physicians, few of whom have had postdoctoral training.

Publications and Citations

Because science is, almost by definition, a public body of knowledge, contributions to the scientific literature constitute the building blocks of science. While books constitute key elements, the chief day-to-day building-stones in this edifice are articles appearing in the scientific journals. One measure, then, of a scientist's contribution to the body of science is the number of his articles that appear in the journals. Not all of these articles, however, are of equal merit--not all the stones are of the same dimensions. As each article usually cites several preceding ones, the citations outnumber the publications several times over. A typical article might be cited four or five times. Some may never be cited. Others are cited hundreds or thousands of times, and are of such key importance that they continue to be cited for years--even decades. Although occasional articles may be cited for reasons other than major contributions (correction of error, for example), such citations are not frequent enough to have a significant effect on the statistics. The chief contributions are the frequently-cited articles. From this it follows that those scientists who make the greatest contributions, by and large, are those who contribute the articles that are most frequently cited. Consequently, the simplest way of measuring the over-all effect of a given scientist on the growth of science is to count the number of times his works are cited. We thus have two measures by which an individual's impact on science is measured--by the number of his publications and the number of his citations. The latter are generally deemed to be the more conclusive evidence of scientific stature. (See Appendix B, page 112.)

It must be recognized that neither of these measures is perfect. Some works of deep insight and significance are unnoticed for a long time, as for example those of Mendel. Some scientists make highly important contributions through their administration of programs of science, the outputs of which are published by others. Some make their chief contributions--and vitally important ones--through the teaching of science both to students who will be future scientists and to a more general public whose understanding of science is essential to its public support. No single measure, and no combinations of measures practically available at any given time, can thus constitute a completely valid criterion of any person's contributions to science. But among those that are practically available, the number of citations in the literature is one of the best, and a count of publications (which must pass critical scrutiny to get published at all) is not far behind as a measure of an individual's scientific merit. For these reasons, attention was turned to means of ascertaining the publications and citations attributable to each member of the NIGMS postdoctoral groups and the associated comparison groups.

One could ask each individual in a group under study to submit a bibliography. In the past this has sometimes been done, but in the present case it was deemed infeasible and unnecessary. Such a request would impose a very considerable burden not only on the NIGMS-supported individuals, but also on the members of the comparison groups. Also, common sense and actual experience indicates that not all individuals who are asked to submit bibliographies would do so. Finally, such bibliographies would provide only the minor answer--publications, but not the major one--citations. One has no way of knowing all the citations that may be made to his work, although he may know of many of them. For all of these reasons, a different and more satisfactory method--although not a completely satisfactory one--was used: utilization of the Science Citation Index and Publications Index, maintained by the Institute for Scientific Information.

A Computerized Source

Beginning in 1961, the Institute for Scientific Information has prepared and computerized lists of publications in the scientific literature, including the bibliographies attached to those publications. As of the time the present study was under way, such computerized lists were available for the publication years 1961 and 1964-70. The lists include principal authors and co-authors of the published articles, but name only the principal authors of the cited works occuring in the bibliographies that follow the publications. The method of listing the citations allows for exclusion of self-citations, and this was done in the counts that were made for this study. These counts are shown in Tables 8 and 9, and Figures 5 and 6. It was later discovered that the group differences shown by these figures were somewhat too conservative, due to the problem of fully identifying the individual authors. That is, people with names that appear more than once in the file are not clearly distinguished. In the data that appear here, the publications and citations counts for such people were divided by the number of times each name appears, thus averaging the counts for all such multi-person names. It was found that such averaging tends to reduce the range of scores, as the very prolific authors are averaged in with those who publish little or not at all. The people whose scores are so averaged are, also, quite possibly, in two or more of the groups being compared. The result, therefore, is to reduce group differences, and hence to produce conversative results. However, because the group differences that were found were so strong and clear-cut, no further refinement was attempted at this point. For the somewhat more complex analyses performed with some special groups in the study of PhD career outcomes, to be reported later, further measures were taken, as described at that point.

Postdoctorals Publish More

Table 8 shows quite clearly that the NIGMS post-MD's were not only much more likely to publish, but that those who did publish had more articles in print in the scientific literature. The top lines of Table 8 show the data for all graduation cohorts combined, for the NIGMS post-MD's and for the random smaple of physicians. Of the NIGMS group, over 86% had publications; of the random sample, 59% had publications in the scientific literature. The number of publications is shown in the last three columns, which give data for the 25th percentile, the 50th percentile (median) and the 75th percentile, respectively. The 25th percentile column indicates that, of those who had any publications, 25% of the NIGMS group had at least 1.81 publications, as compared with .83 for the random sample. The median number of publications for the NIGMS group was 4.25 as compared with 2.01 for the random sample. Finally, the last

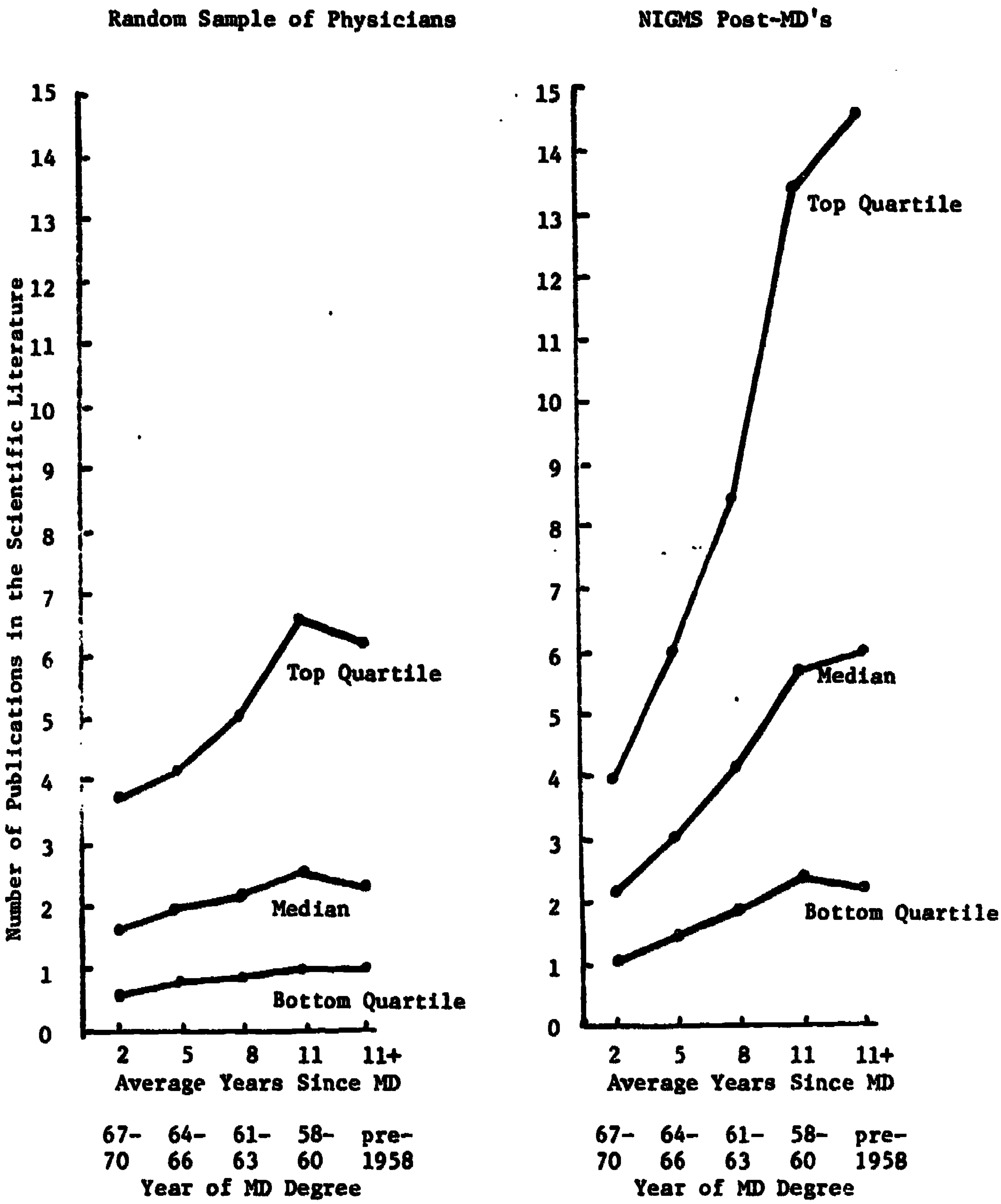
TABLE 8

Publications of NIGMS Post-MD's and Random Sample of Physicians, by Cohort of Graduation

Graduation Cohort	Comparison Group	Total N in Group	Total With Publications: Number	Total With Publications: %	Numbers of Publications: 25th Percentile	Numbers of Publications: Median	Numbers of Publications: 75th Percentile
Total	NIGMS Post-MD's	4312	3743	86.8	1.81	4.25	10.[illegible]9
	AMA Random Sample	14933	8796	58.9	0.83	2.01	4.56
Pre-58	NIGMS Post-MD's	1446	1267	87.6	2.20	5.96	14.59
	AMA Random Sample	883	564	63.9	0.98	2.32	6.19
1958-60	NIGMS Post-MD's	871	782	89.8	2.37	5.67	13.36
	AMA Random Sample	2838	1840	64.8	1.01	2.52	6.59
1961-63	NIGMS Post-MD's	926	832	89.8	1.85	4.12	8.50
	AMA Random Sample	3228	2012	62.3	0.88	2.13	5.02
1964-66	NIGMS Post-MD's	760	625	82.2	1.41	3.00	6.04
	AMA Random Sample	3243	1876	57.8	0.84	1.98	4.17
1967-70	NIGMS Post-MD's	309	237	76.7	1.02	2.09	3.90
	AMA Random Sample	4741	2504	52.8	0.65	1.55	3.75

FIGURE 5

Publication counts of NIGMS post-MD's and random sample of physicians, giving medians and quartiles by cohort



column shows that 75% of the NIGMS group had 10.49 or fewer publications - the most prolific 25% of the group had more than that. In the random sample, the top 25% had 4.56 or more publications, by way of comparison. Figure 5 presents these data graphically.

The rest of the table is to be read in the same way, cohort by cohort. It is quite apparent that the early cohorts had more publications, and that the higher publication rate for the NIGMS group increases with time since graduation. For the earliest cohort, the median number of publications of the NIGMS group is more than twice that of the random sample, and furthermore, 88% of this group had publications, as compared with only 64% of the random sample. Going on down to the more recent cohorts, the difference between the NIGMS group and the random sample diminishes, but is still clearly apparent even for the 1967-70 group, where most of the NIGMS post-MD's, were still in training. Previous studies have indicated that, for PhD's, remaining in study status tends to retard early publication, in comparison with those who enter employment directly.[4] However, in the case of the post-MD's, 77% of the most recent cohort have publications, and, for these, the mediam number of publications is 2.09, as compared with 1.55 for the 53% of the random sample who have publications. The reduced inter-group difference for the recent cohort gives some hint of publication delay related to the extended training, and the data on citations tends to point in the same direction, as shown by Table 9.

Table 9 gives data similar to that of Table 8, but it concerns the numbers of citations by others in the scientific literature. Here the data are even more striking than for publications. The column on numbers with citations is omitted as redundant in Table 9. The data on median number of citations, and the corresponding data at the 25th and 75th percentiles, shows that, for the earliest cohort, the citation rate is almost four times as high for the NIGMS post-MD's as for the random sample of physicians. As with the publications table, the inter-group difference diminishes as we go toward the later cohorts, and is actually reversed for the most recent cohort. This is probably a function of publication lag, as referred to in the preceding paragraph. The publications of the NIGMS group, if they were delayed by a year or so, had not had sufficient time to be cited. The fact that the inter-group difference is persistent and increases over time indicates that it is probably such a lag, rather than differences in merit of the publications of the more recent cohorts, that accounts for the trend shown. These data are depicted graphically in Figure 6.

[4] Ibid.

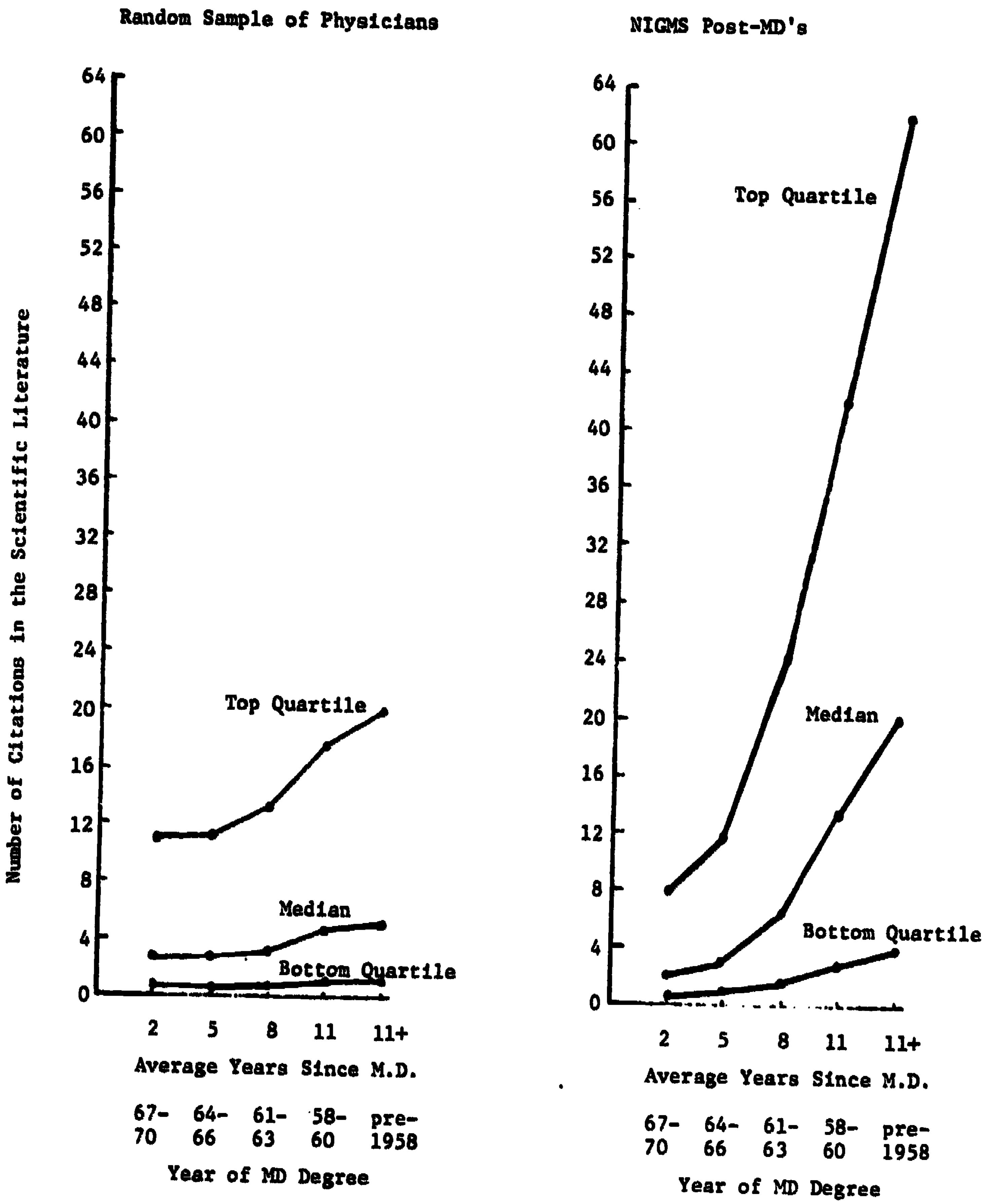
TABLE 9

Citations of NIGMS Post-MD's and Random Sample of Physicians, by Cohort of Graduation

Graduation Cohort	Comparison Group	Total N in Group	Numbers of Citations: 25th Percentile	Median	75th Percentile
Total	NIGMS Post-MD's	4,312	1.62	8.85	34.05
	AMA Random Sample	14,933	0.81	3.37	13.48
Pre-58	NIGMS Post-MD's	1,446	4.02	19.76	62.36
	AMA Random Sample	883	1.19	5.21	19.66
1958-60	NIGMS Post-MD's	871	3.09	13.55	42.21
	AMA Random Sample	2,838	0.99	4.65	17.49
1961-63	NIGMS Post-MD's	926	1.29	6.47	24.26
	AMA Random Sample	3,228	0.80	3.38	13.11
1964-66	NIGMS Post-MD's	760	0.62	3.18	11.99
	AMA Random Sample	3,243	0.70	2.87	11.39
1967-70	NIGMS Post-MD's	309	0.38	2.05	8.17
	AMA Random Sample	4,741	0.73	2.60	11.11

FIGURE 6

Citation counts of NIGMS post-MD's and random sample of physicians, giving medians and quartiles by cohort



Winning of Research Grants

One final criterion is available - that of meeting competitive standards with respect to applications for research grants. Two government agencies, the National Institutes of Health and the National Science Foundation, made their award lists available on computer tape for matching with the NIGMS post-doctoral lists and the random sample of physicians. The awards shown on these lists are the result of vigorous competition, in which applications for research grants are reviewed by committees of peers. Only a fraction of the applications are actually approved and funded, so the winning of such awards means the passing of a sever test of peer judgment. The results of this final quantitative test of merit are shown in Table 10, where the NIGMS postdoctorals and the random sample of physicians are compared in terms of the percentage of each group who have won such competitive research grants. Figure 7 presents these data graphically. The difference between the NIGMS postdoctorals and the random sample of physicians increases progressively and sharply.

TABLE 10

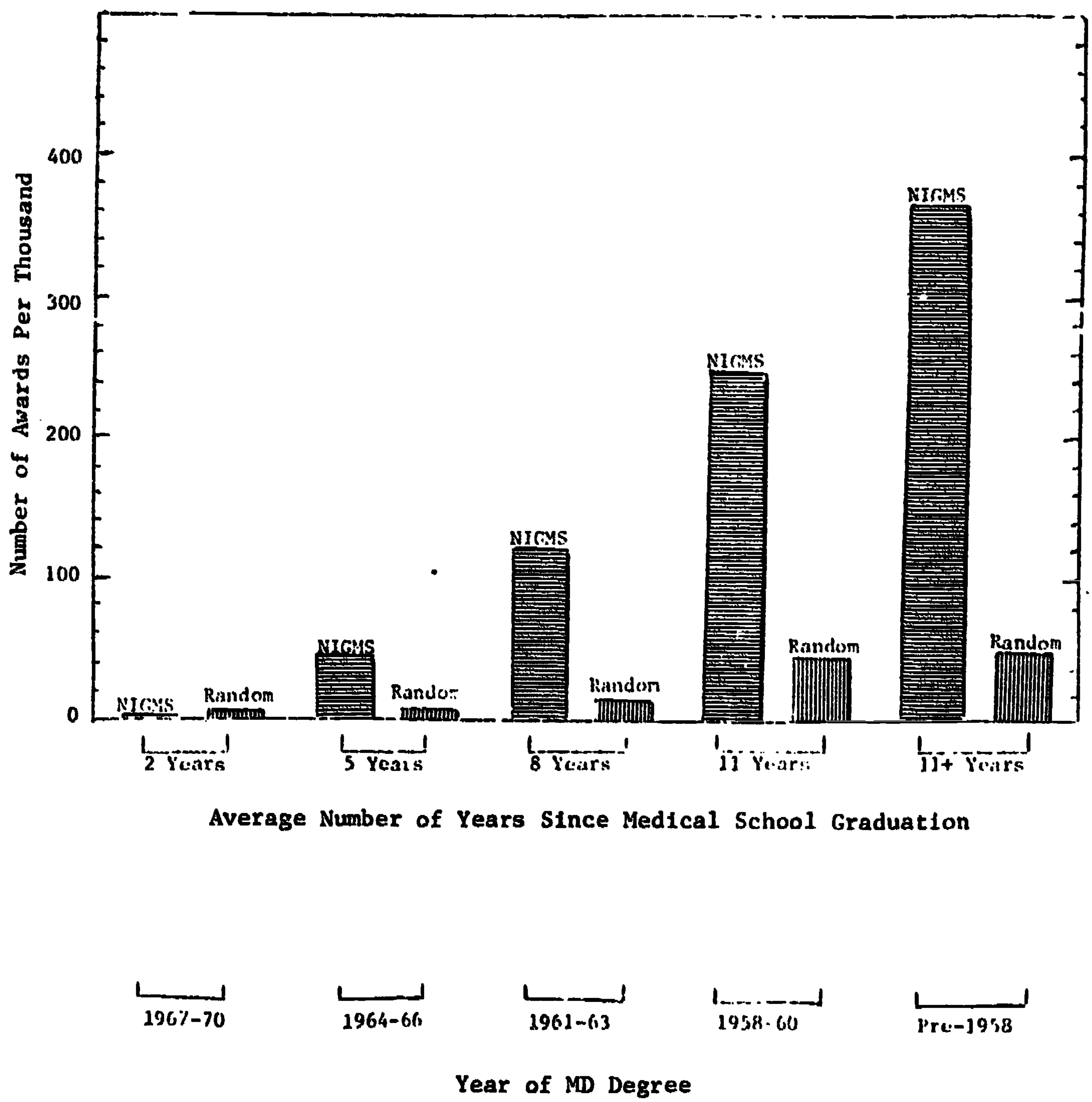
Mean Number of Research Grants Awarded, NIGMS Post-MD's and Random Sample of Physicians, by Cohort

Comparison Group		Total All Cohorts	Cohort of MD Degree: Pre-1958 and Unk.	1958-60	1961-63	1964-66	1967-70
NIGMS	N	4,312	1,446	871	926	760	309
Post-MD's	Mean	.207	.365	.249	.122	.048	.003
Random Sample	N	14,933	887	2,827	3,224	3,240	4,755
of Physicians	Mean	.020	.051	.045	.016	.008	.009

Table 10 and Figure 7 show quite clearly that the mean number of research grants awarded is in line with other evidence regarding the relationship of the postdoctoral training to research activity. On the whole, including all

FIGURE 7

Mean Number of Research Grants Awarded, NIGMS Post-MD's and Random Sample of Physicians, by Cohort



MD cohorts, there were 207 awards per thousand NIGMS postdoctorals, as compared with 20 per thousand for the random sample of physicians. The increase in number of research grants with age is quite apparent also, rising from 3 per thousand for the most recent cohort to 365 for the pre-1958 cohort of NIGMS post-MD's, and from 9 to 51 for the random sample, for the corresponding graduation cohorts.

Summary Regarding Post-MD's

The career development lines and career achievements of the NIGMS post-MD's have been examined, and compared with corresponding data for a random sample of physicians graduating in the same years from medical schools, to try to discover whether there is evidence that the objectives of the NIGMS postdoctoral program have been attained. These objectives concern the development of medical researchers and the preparation of a more scientifically trained group of teachers for medical schools. The evidence examined concerns the proportions who eventually become medical school faculty members, the ranks attained by those who do join medical school faculties, and the research-orientation of the medical schools with which they affiliate. Another set of evidence concerns the relative contributions to the scientific literature, the extent to which these publications are cited by others, and finally, the proportions of the several groups who win research grants in the national competitions of the National Science Foundation and the National Institutes of Health. The evidence from all these sources is quite consistent: The proportion entering academic medicine is five times as great for the NIGMS post-MD's as for the random sample of physicians; they advance more rapidly in more prestigious medical schools, they contribute more to the scientific literature, and the average value of their contributions is greater, as judged by the number of times they are cited by other investigators. They win seven times as many research grants in the national competition.

In short, by all the quantitative criteria which the committee could adduce, the post-MD training programs appear to be attaining the objectives sought for the programs. The data suppo-t the interviews and the statements of individuals actually involved in the prog-ams presented earlier in the report.

CHAPTER VI

THE POST-PHD'S: CAREER PATTERNS

The careers of PhD's, whether they take postdoctoral training or not, are vastly different from those of MD's, based on initial differences in orientation and training. Typically, during their graduate education, they look forward to careers as teachers or as researchers, or as both combined. In the present study, the data regarding the post-PhD's is also different from that of the post-MD's in large part because of the different data sources that were available--data banks that could be consulted without the expense and inconvenience to the persons involved of a special questionnaire. One of the differences from the study of the post-MD's concerns the quite different source of the comparison groups.

As with the post-MD's, a random sample of PhD's was desired, covering approximately the same span of years of graduation as the postdoctorals themselves. There was, fortunately, a readily available source in the Doctorate Records File maintained by the Office of Scientific Personnel. This file includes data about virtually all PhD's graduating from U.S. universities since 1920. It was a simple matter to draw from this file a random 10% sample of science PhD's from the period 1954-1970, to be used as a basic comparison group. It was decided, however, to go further, and to select another sample, matching the NIGMS post-PhD's as nearly as possible with respect to field of specialization, institution of PhD, year of graduation, and sex. This second sample was known as the "select sample", and it was expected that the data from this sample would resemble that for the postdoctorals much more closely than would that for the random sample. For both of these comparison groups, data were available with respect to their immediate post-graduation plans--i.e., whether they planned to enter postdoctoral training or immediate employment. Previous research[5] shows that this information is not only quite reliable, but also gives a good indication of probable career lines for several years after graduation. As will be seen, this datum was of crucial importance in the data analyses.

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[5] Mobility of PhD's: Before and After the Doctorate, (Washington, D.C.: National Academy of Sciences, 1971. Chapter V.)

Fortunately, there was available another substantial set of data--that concerning the postdoctorals supported by the National Science Foundation over the same period as those of the NIGMS program (1958-1970). The NSF postdoctoral fellowship selection procedures were somewhat different than those used by the NIGMS, and, as it turned out upon examination of the relevant data, a significantly smaller proportion of the NSF applicants were awarded fellowships. This would be expected to result in a somewhat higher average level of quality of the awardees because when awards are made on the basis of merit alone (as they are in both of these programs) the higher the cut-point, the higher the proportion of the really outstanding students who will be selected.

There was still another postdoctoral program whose awardees could be used as a comparison group, and, within this program, selection was even more rigorous than in the NSF program. That was the Postdoctoral Research Program sponsored by the Air Force Office of Scientific Research (AFOSR). There was another difference between the AFOSR and NSF programs and the NIGMS program, one of field emphasis. Whereas the NIGMS program emphasized the biomedical fields, the other two were more general, and had, relatively, a much heavier emphasis on the physical sciences, engineering, and mathematics. All three programs, however, actually covered all fields of science, including the social sciences. Thus by controlling for field, it was possible to eliminate data biases due to the relative field emphases of the several programs.

The decision on what field groups to use was relatively simple. Too much field fractionation would result in too many small fields, making for confusion because of the numbers of comparisons needed and because of the relatively small sample size in each field, leading to large error estimates. The decision was to employ three field groups: (1) biosciences, (2) chemistry, and (3) all other fields combined. The latter group is very heterogeneous, and it is difficult to draw conclusions from it. It is included, however, for the sake of completeness, in order to show all the data. The major focus, for most of the comparison, however, will be on the biosciences, as this is the largest field group, and the one most central to the mission of the NIGMS.

The primary source of data on later careers of all the comparison groups was the 1970 National Register of Scientific and Technical Personnel. This file, maintained by the National Science Foundation for many years but discontinued after the 1970 registration, was maintained by voluntary cooperation, and provided data about the education, work experience, and current employment of all the persons included in the file. A very large proportion of all practicing scientists regularly completed this survey questionnaire. The results were available for study purposes, with the stiplulation that data regarding individuals would not be divulged, and statistical results only be presented. This survey indicated not only the field of specialization of each respondent, but also the category of employer and major on-the-job activity. Thus research, which is the primary objective of the postdoctoral traineeship and fellowship programs of the NIGMS, could be sorted out from all other types of work activity, to see whether research is more frequently the major function of those who have had postdoctoral training than of those who have not had such training.

A further source of information, which provides data only on members of college and university faculties, is the National Faculty Directory. This Directory, which seeks to be all-inclusive with respect to United States universities, and also includes some Canadian institutions, gives information only on the institution and department in which the individual is employed. (No information on field of specialization or on-the-job function is available, for example.) When added to the data from the 1970 National Register, however, it furnishes some information about those not there included. This Directory is published periodically in book form, but computer tapes of the information in it were secured for the purposes of the present study, thus making possible a rapid and reasonably inexpensive source of information regarding those members of the comparison groups who were employed in higher education. Listing in the National Faculty Directory does not depend on individual cooperation, as the data were secured initially from college catalogs. The data tape used in the present study included data referring primarily to 1970, although exact information on the time frame covered is not available due to varying reporting times in the basic source.

Career Outcomes of Comparison Groups

One of the objectives of the NIGMS postdoctoral program was to prepare people for careers in research-oriented universities, as teachers or as researchers or, more commonly, as persons who combined teaching and research in a productive way. But the program was not aimed solely at the academic world; many scientists pursue careers as researchers in industry, in government agencies, and in non-profit organizations. It is important, therefore, to consider both the categories of employers and the kinds of work activities to determine whether the NIGMS postdoctorals are performing in the ways intended by the program. The comparison groups provide some landmarks by which to judge the degree to which these career outcomes are attained. Our attention will focus first on the categories of employers found by examining the data from the National Register of Scientific and Technical Personnel.

Career outcomes of the NIGMS postdoctorals and the various comparison groups in terms of employer categories and primary work activities for the PhD's found in the National Register in 1970 are given in Table 11. At the bottom of the table, the number whose status is known (from the Register), the number and percentage whose status is unknown, and the total number in each comparison group is shown. This table includes all relevant doctoral fields. Figure 8 shows graphically the employer category data from Table 11.

Taking the total of all fields and cohorts combined, and including both sexes, as in Table 11 and Figure 8, it is apparent that for all the groups the primary employer category is that of colleges and universities, and that research is the primary work activity. For both trainees and fellows of the NIGMS postdoctoral program, university employment characterizes 77% to 79% of the groups, appreciably higher than for either the DRF random sample or DRF select sample, where the university employment percentages were 72% for both samples of those who took immediate postdoctorals, and 61% and 63% for those who entered immediate employment after the PhD. (Some of the

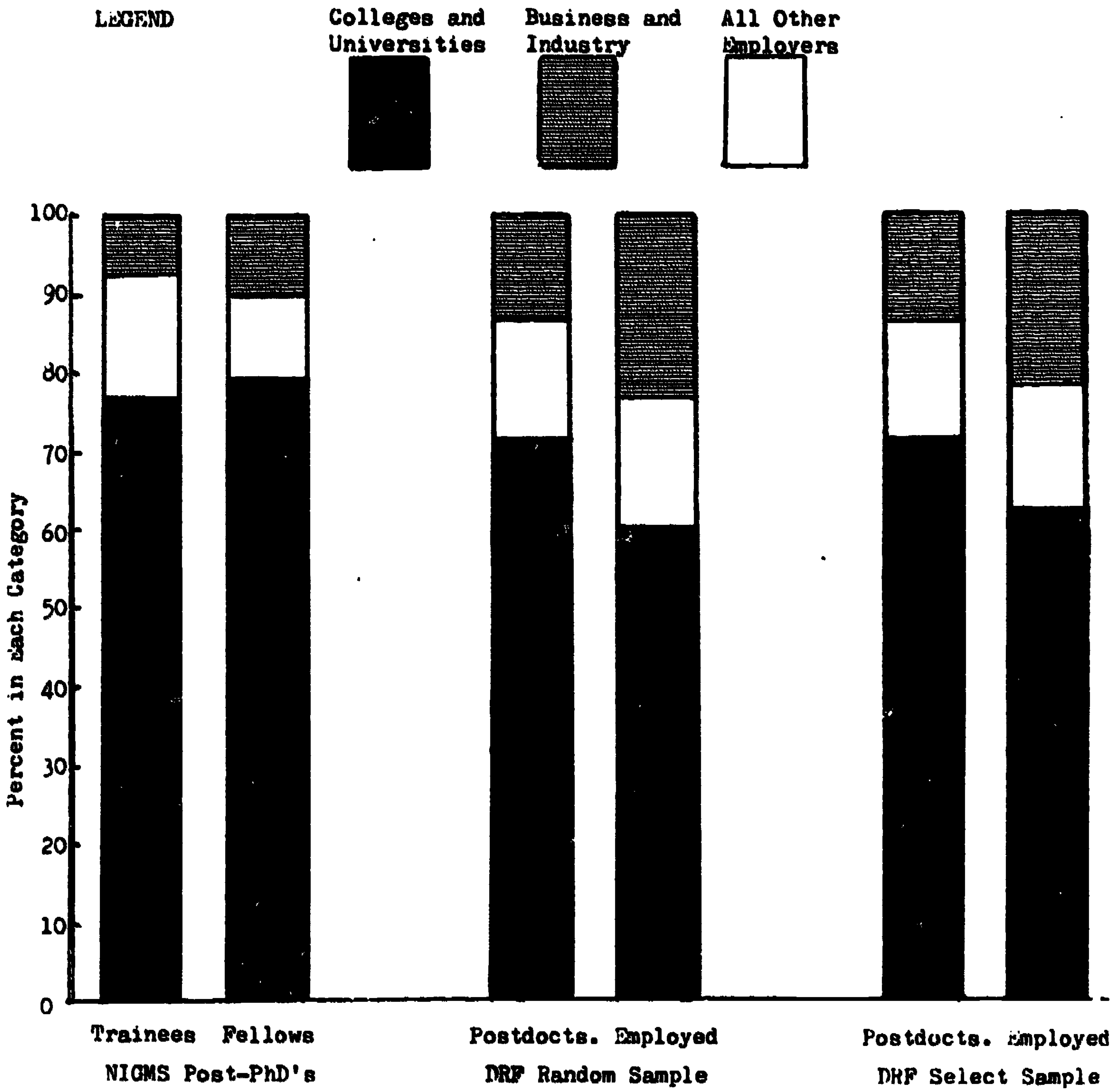
TABLE 11

Career Outcomes of PhD Comparison Groups, as Found in 1970 National Register, All Science Fields, All Cohorts, Men and Women Combined

1970 Career Status		NIGMS Postdoctorals			DRF Random Sample			DRF Select Sample			AFOSR			NSF
		Trainee	Fellow	Total	Postdoc. Training	Empl.	Total	Postdoc. Training	Empl.	Total	Awardees	Fellows Non-Award.	Total	Postdoc Fellows
by Employer Category														
University	N	856	940	1796	856	3971	4827	756	660	1416	57	509	566	[illegible]
	%	76.9	79.3	78.2	71.6	60.6	62.3	71.5	62.6	67.0	95.0	95.1	95.1	80.8
Business and Industry	N	82	126	208	156	1531	1687	143	229	372	1	11	12	109
	%	7.4	10.6	9.1	13.0	23.4	21.8	13.5	21.7	17.6	1.7	2.1	2.0	9.8
All Other Employers	N	175	119	294	184	1049	1233	159	166	325	2	15	17	104
	%	15.7	10.0	12.8	15.4	16.0	15.9	15.0	15.7	15.4	3.3	2.8	2.9	9.4
by Work Activity														
Research	N	729	780	1509	792	2625	3417	765	484	1249	37	321	358	685
	%	65.5	65.8	65.7	66.2	40.1	44.1	72.3	45.9	59.1	61.7	60.0	60.2	61.8
Teaching	N	278	352	630	307	2425	2732	236	352	588	19	200	219	372
	%	25.0	29.7	27.4	25.7	37.0	35.3	22.3	33.4	27.8	31.7	37.4	36.8	33.5
All Other	N	106	53	159	97	1501	1598	57	219	276	4	14	18	52
	%	9.5	4.5	6.9	8.1	22.9	20.6	5.4	20.8	13.1	6.7	2.6	3.0	4.7
Total Status Known	N	1113	1185	2298	1196	6551	7747	1058	1055	2113	60	535	595	1109
	%	46.7	59.6	52.5	53.1	48.6	49.3	53.6	52.7	53.1	41.1	45.9	45.4	56.3
Status Unknown	N	1271	804	2075	1057	6921	7978	916	947	1863	86	630	716	861
	%	53.3	40.4	47.5	46.9	51.4	50.7	46.4	47.3	46.9	58.9	54.1	54.6	43.7
Grand Total	N	2384	1989	4373	2253	13472	15725	1974	2002	3976	146	1165	1311	1970

FIGURE 8

Career Outcomes for Comparison Groups: Employer Categories in 1970, as Found in National Register, All Sciences and Cohorts, Both Sexes Combined



latter groups probably held delayed postdoctoral appointments, but we have no data on this point.) The comparisons with the other postdoctoral groups show smaller differences, but are in line with expectations based on the selectivity of the programs. The AFOSR program drew heavily from those already academically-oriented, as shown by the fact that 95% of both the awardees and the unsuccessful applicants are found on follow-up to be employed in academe. The ratio of applicants to awardees, as shown in Table 11, was 8:1. Probably, many of the non-awardees in the AFOSR competition received postdoctoral support elsewhere, but this information is not available. For the NSF fellowship program, the percent in academic employment is very close to that for the NIGMS fellows, being 81% vs. 79% for the NIGSM postdoctoral fellows. The NSF selection ratio is more severe than that of the NIGMS fellowship program, but both are selective on a national basis. By contrast, in the NIGMS traineeship program, selections are made locally according to the plans and purposes of each of the training programs, and no information on selection ratios is available.

Primary Work Activity

Data with respect to primary work activity are shown in the bottom portion of Table 11. It is apparent here that research is the primary activity of the people of all the comparison groups. Slightly over 65% of both the NIGMS fellows and trainees are engaged primarily in research, as compared with 66% for the DRF random sample postdoctorals and 72% for the DRF select sample postdoctorals. These percentages are much greater than for the non-postdoctorals in either the random or select samples, where research occupied 40% and 46% respectively. Among the AFOSR postdoctorals, research was the primary activity of 62% of the awardees and 60% of the non-awardees. Of the NSF postdoctorals, 62% are found in research. The contrast, therefore, is between postdoctorals and non-postdoctorals, rather than among the various postdoctoral programs.

A somewhat similar situation exists with respect to teaching and other activity. The most marked contrasts are between the postdoctorals and those who entered employment immediately after the doctorate. For the latter group, the teaching percentage was 37% for the random sample and 33% for the select sample, while 23% and 21% respectively of these groups were in all other types of activity. The percentage primarily engaged in teaching, for the postdoctorals, ranged from 22% for the select sample and 26% for the random sample, through 25% for the NIGMS trainees and 30% for the NIGMS fellows to 32% for the AFOSR awardees, 37% for the non-awardees, and 34% for the NSF postdoctorals. The percentage engaged "primarily in other activity" was, for all of the postdoctoral groups, less than 10%--less than half of that for the "immediate employment" groups.

In summary, then, it is clear that insofar as the NIGMS postdoctoral programs were intended to produce researchers, they succeeded, their results being quite in line with those of other postdoctoral programs. The percentage in research reflects the relative degree of selectivity of the postdoctoral programs. Whether the NIGMS and/or other postdoctoral programs caused more people to choose research careers or whether they chiefly facilitated the training of those who were headed in that direction cannot be deduced from these data. In either case, the outcomes seem to be in accord with the program objectives.

Bioscience Data

The foregoing data were for all fields combined. The data for the bioscientists, shown in Table 12, are very similar, but with uniformly higher percentages in university employment and in research, as compared with the total of all fields. Among the NIGMS trainees, 77% are in university employment, and 68% are engaged primarily in research. For the NIGMS fellows, the corresponding proportions are 84% and 68%. The NSF postdoctoral program shows data very similar to that for NIGMS--78% in university employment and 66% in research. The percentage employed by business and industry goes up to 12-13% for the DRF select and random samples of "immediate employment" cases, where the proportion in "other activity" is, as with the total of all fields, over twice as high as for any of the postdoctoral groups--a minimum of 17% contrasted with a maximum of 8% for the NIGMS trainees and 4% for the NIGMS fellows. Figure 9 displays graphically the essential data regarding work activity shown in Table 12. One can summarize, without belaboring the statistical data, by saying that in the bioscience fields, even more than in the total of all fields, the NIGMS programs show outcomes in line with program objectives, and of about the same magnitude as comparable programs of other agencies.

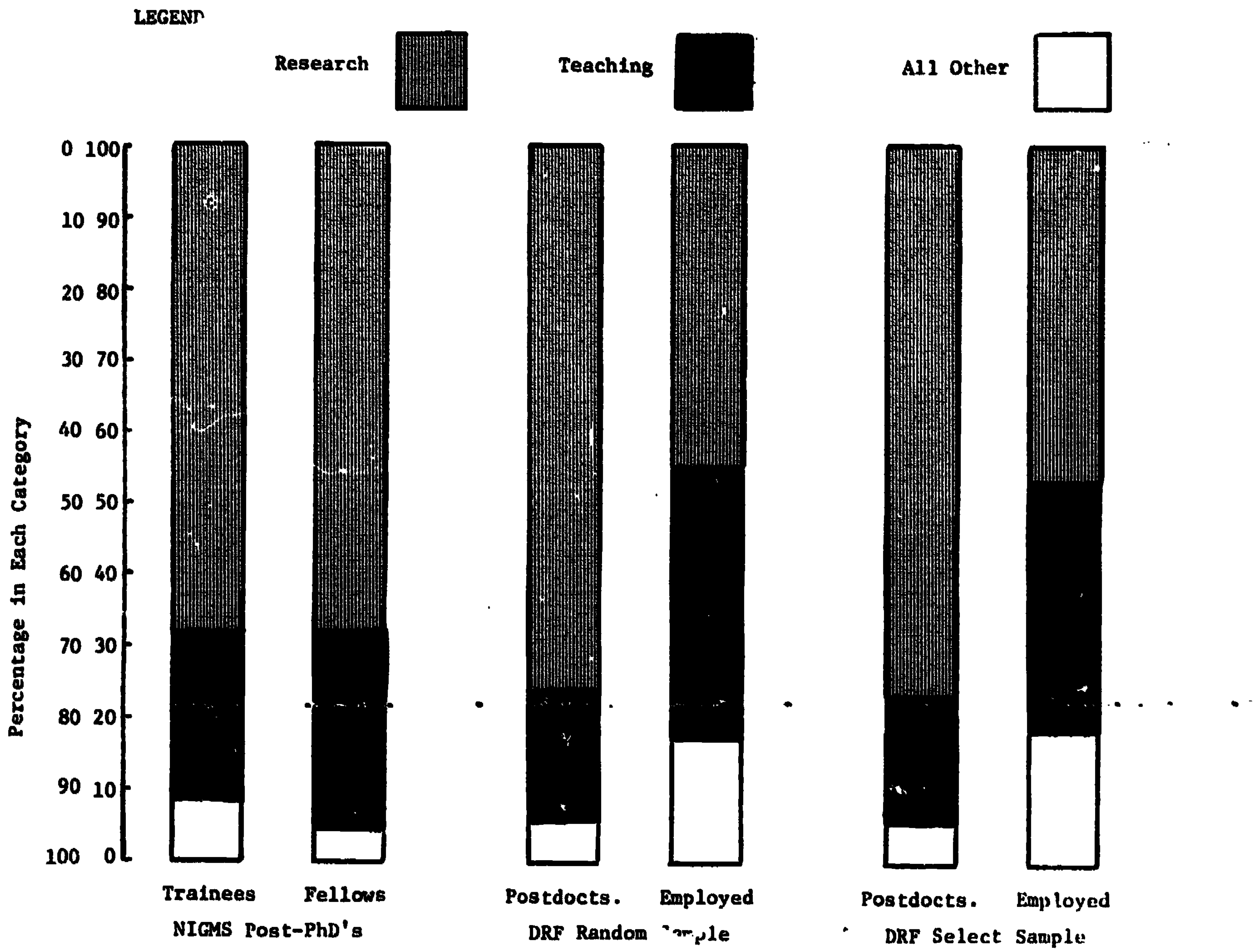
TABLE 12

Career Outcomes of PhD Comparison Groups, as Found in 1970 National Register, Bioscience Fields, All Cohorts, Men and Women Combined

1970 Career Status		NIGMS Postdoctorals			DRF Random Sample			DRF Select Sample			AFOSR			NSF
		Trainee	Fellow	Total	Postdoc. Training	Empl.	Total	Postdoc. Training	Empl.	Total	Awardees	Fellows Non-Award.	Total	Postdoc. Fellows
by Employer Category														
University	N	635	573	1208	312	809	1121	490	[illegible]	967	12	86	98	196
	%	77.4	84.1	80.5	71.6	66.6	67.9	72.6	68.9	70.7	100.0	87.8	89.1	78.4
Business and Industry	N	51	25	76	31	160	191	58	86	144	0	4	4	17
	%	6.2	3.7	5.1	7.1	13.2	11.6	8.6	12.4	10.5	0.0	4.1	3.6	6.8
All Other Employers	N	134	83	217	93	246	339	127	129	256	0	8	8	37
	%	16.3	12.2	14.5	21.3	20.2	20.5	18.8	18.6	18.7	0.0	8.2	7.3	14.8
by Work Activity														
Research	N	556	462	1018	331	541	872	518	322	840	10	74	84	[illegible]
	%	67.8	67.8	67.8	75.9	44.5	52.8	76.7	46.5	61.4	83.3	75.5	76.4	[illegible]
Teaching	N	196	191	387	80	466	546	118	243	361	2	18	20	67
	%	23.9	28.0	25.8	18.3	38.4	33.1	17.5	35.1	26.4	16.7	18.4	18.2	26.8
All Other	N	68	28	96	25	208	233	39	127	166	0	6	6	17
	%	8.3	4.1	6.4	5.7	17.1	14.1	5.8	18.4	12.1	0.0	6.1	5.5	6.8
Total Status Known	N	820	681	1501	436	1215	1651	675	692	1367	12	98	110	250
	%	54.0	60.2	56.6	51.1	[illegible]	52.4	49.6	51.6	50.6	42.9	46.4	46.0	60.2
Status Unknown	N	699	450	1149	417	1082	1499	685	649	1374	16	113	129	165
	%	46.0	39.8	43.4	48.9	47.1	47.6	50.4	48.4	49.4	57.1	53.6	54.0	39.8
Grand Total	N	1519	1131	2650	853	2297	3150	1360	1341	2701	28	211	239	415

FIGURE 9

Career Outcomes of Comparison Groups, as Found in 1970 National Register, Bioscience Fields, All Cohorts, Men and Women Combined: Primary Work Activity



Employer Categories and Postdoctoral Training

Postdoctoral training in general, and training sponsored by the NIGMS in particular, is intended to prepare people to serve on the faculties of colleges and universities where a research orientation is important. It is not expected, of course, that all persons with this advanced training in research methodology will become faculty members. Some will serve in the laboratories of private industry and of government, and some will carry the skills and attitudes acquired during the postdoctoral experience into administrative positions. Yet the major thrust of postdoctoral education is toward better preparation of teachers for the graduate schools, especially those who will be the mentors of PhD candidates. With this in mind, the data on 1970 employment of the NIGMS postdoctorals and comparison groups were examined with respect to the nature of the institutions of employment of these groups. The categories used here group nonacademic employers into a single category, and classify the academic institutions according to level of highest degree granted. For the PhD-granting institutions, the Roose-Andersen ratings[6] are used for a further sub-division. The Roose-Andersen ratings used here average the university's bioscience department ratings, as departments of employment of the individual were not known.

Table 13 gives the data for the NIGMS postdoctorals and comparison groups, all fields and cohorts combined, and for the bioscientists separately. The data for this table were derived from the National Register of Scientific and Technical Personnel for 1970, and the National Faculty Directory for the same year. In both sources, institution of employment was given; the academic institutions were then sub-sorted as described above, by level of highest degree and by Roose-Andersen ratings. Only two categories of R-A ratings were used for this purpose; about 40% fell in the "high" category, and 60% in the low category. PhD-granting institutions for which no R-A ratings were available were grouped with the masters-granting schools into a single category. Those schools which grant baccalaureate degrees only constituted the fourth academic-employment category.

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[6] Kenneth D. Roose and Charles J. Andersen, A Rating of Graduate Programs, (Washington, D. C.: American Council on Education, 1970)

TABLE 13

Categories of Institutions of Academic Employment in 1970, NIGMS Postdoctorals and Comparison Groups, All Cohorts Combined

Category of Institution of 1970 Employment		NIGMS Postdoctorals			Samples from Doctorate Record Files: Random			Samples from Doctorate Record Files: Select			NSF Post Docs	AFOSR Post Docs
		Trainees	Fellows	Total	Post Docs	Empl	Total	Post Docs	Empl	Total		
A: Total of All Fields												
R-A Rating High	N	364	435	799	326	992	1318	326	184	510	558	(52)
	%	31.1	35.6	33.4	29.7	16.4	18.4	32.4	20.1	26.5	45.9	60.5
R-A Rating Low	N	358	421	779	360	2057	2417	316	280	596	382	(22)
	%	30.6	34.5	32.6	32.8	34.0	33.8	31.4	30.5	31.0	31.4	25.6
MA Granting & Unrated	N	303	253	556	241	1932	2173	236	297	533	197	(10)
	%	25.9	20.7	23.2	22.0	31.9	30.4	23.5	32.4	27.7	16.2	11.6
BA Granting Only	N	146	113	259	169	1073	1242	128	156	284	78	(2)
	%	12.5	9.2	10.8	15.4	17.7	17.4	12.7	17.0	14.8	6.4	2.3
Academic Total	N	1171	1222	2393	1096	6054	7150	1006	917	1923	1215	86
	%	80.8	81.3	81.0	74.5	69.0	69.8	75.1	68.7	71.9	83.7	96.6
Non-Academic	N	279	281	560	376	2722	3098	333	417	750	236	(3)
	%	19.2	18.7	19.0	25.5	31.0	30.2	24.9	31.3	28.1	16.3	3.4
Total Known	N	1450	1503	2953	1472	8776	10248	1339	1334	2673	1451	89
	%	60.8	75.6	67.5	65.3	65.1	65.2	67.8	66.6	67.2	73.7	61.0
Unknown Employment	N	934	486	1420	781	4696	5477	635	668	1303	519	(57)
	%	39.2	24.4	32.5	34.7	34.9	34.8	32.2	33.4	32.8	26.3	39.0
Grand Total	N	2384	1989	4373	2253	13472	15725	1974	2002	3976	1970	146
B. Biosciences												
R-A Rating High	N	268	281	549	125	179	304	227	134	361	119	(10)
	%	31.3	38.0	34.4	30.9	15.6	19.6	33.5	20.3	27.0	46.5	-
R-A Rating Low	N	272	250	522	125	359	484	201	201	402	75	(5)
	%	31.8	33.8	32.7	30.9	31.3	31.2	29.6	30.5	30.0	29.3	-
MA Granting & Unrated	N	228	149	377	93	398	491	162	218	380	(51)	(3)
	%	26.7	20.2	23.7	23.0	34.7	31.6	23.9	33.0	28.4	19.9	-
BA Granting Only	N	87	(59)	146	(62)	211	273	88	107	195	(11)	0
	%	10.2	8.0	9.2	15.3	18.4	17.6	13.0	16.2	14.6	4.3	-
Academic Total	N	855	739	1594	405	1147	1552	678	660	1338	256	(18)
	%	80.8	85.5	82.9	73.8	72.5	72.8	76.6	74.3	75.5	80.8	100.0
Non-Academic	N	203	125	328	144	435	579	207	228	435	(61)	0
	%	19.2	14.5	17.1	26.2	27.5	27.2	23.4	25.7	24.5	19.2	0
Total Known	N	1058	864	1922	549	1582	2131	885	888	1773	317	(18)
	%	69.7	76.4	72.5	64.4	68.9	67.7	65.1	66.2	65.6	76.4	64.3
Unknown Employment	N	461	267	728	304	715	1019	475	453	928	98	(10)
	%	30.3	23.6	27.5	35.6	31.1	32.3	34.9	33.8	34.4	23.6	35.7
Grand Total	N	1519	1131	2650	853	2297	3150	1360	1341	2701	415	(28)

Percentages of academic institution categories are based on total in academic employment.
Percentages of academic and non-academic categories are based on known total.
() Fewer than 75 cases.
- Percentages based on fewer than 20 cases.

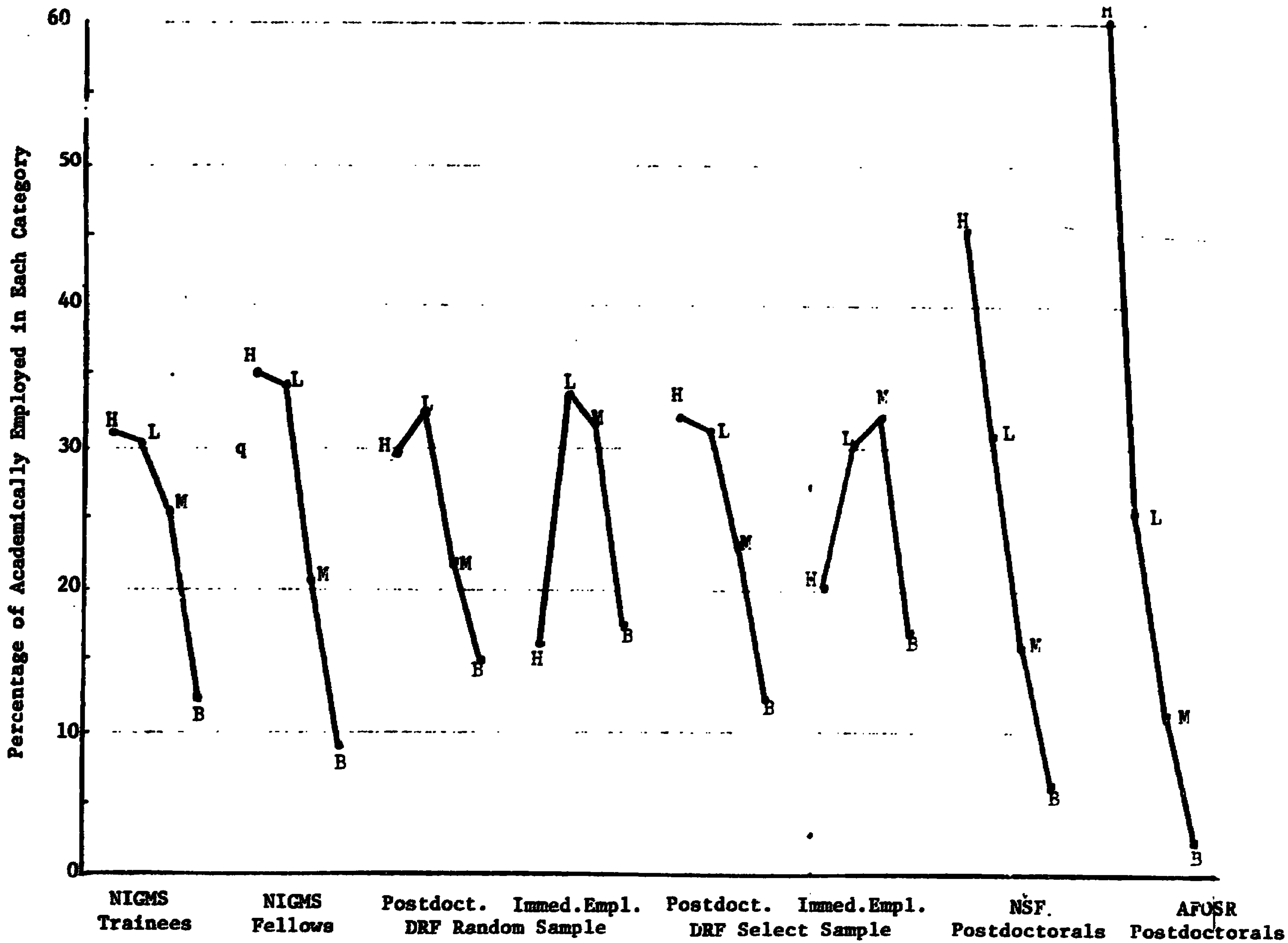
The data for all cohorts are combined in Table 13, because tabulations by cohort had shown only very minor differences in the distributions of the various institutional categories, and the combined data, being based on a larger number of cases, are more reliable, making the variations across the comparison groups more readily apparent. One cohort variation is worth noting, however: The number of cases for whom no data are available is higher for the most recent cohort, simply because the sources from which data were obtained had not yet been able to secure the necessary information from the latest graduates. It takes a couple of years for the National Register to reach the normal percentage coverage of new PhD's, and, of course, many of these are still in postdoctoral training.

In Table 13, the first four rows show data for the four academic institution categories described above. The percentages here are based on the total of the academically-employed. The percentages of academic and nonacademic categories are based on the total for whom employment data are available. These, with the cases for whom no data are available, constitute the grand total figures on the bottom line of Table 13. The data from the first four percentage rows in Table 13 are shown graphically in Figure 10. The data for the bioscientists are not shown graphically, as they differed so little from the total of all fields as to be practically indistinguishable. Also, there were not enough cases in the bioscience AFOSR postdoctoral group to justify computation of percentages. The graphs, therefore, represent the total of all fields combined.

In Figure 10, the data for the four institutional categories are plotted for each of the comparison groups, the high-rated PhD-granting institution to the baccalaureate-granting institution constituting a profile for each of the comparison groups. The four institutional categories are designated H (for high R-A ratings), L (for lower-rating institutions), M (for masters-granting institutions) and B (for baccalaureate-granting institutions) from left to right across each profile. There is a rather clear family resemblance among the profiles of the several postdoctoral groups that distinguishes them from the non-postdoctoral groups. The general slope, for the postdoctorals, is downward from left to right, the steepness of the slope being related directly to the selectivity of the procedures used in each program. For the non-post-

FIGURE 10

Institutional category profiels of NIGMS postdoctorals and comparison groups, all cohorts and fields combined



doctorals, however, the curve is an inverted V, with the lower-rated or masters-granting institutions being at the apex, the high R-A rated PhD institutions always being relatively low in the percentage of the group's members.

Again, the interpretation is relatively straight forward. The two NIGMS programs differ slightly in the direction to be expected by the relative selectivity of the trainee and fellowship programs. They compare favorably with the postdoctorals in both the random and select DRF samples, but are over-shadowed by the more selective NSF and AFOSR programs. The NIGMS postdoctorals clearly enter the faculties of the nation's PhD-granting institutions in numb ers in line with reasonable expectations and with the program objectives. The next question becomes the extent to which, in these institutions, they have contributed to producing the next generation of PhD scientists.

CHAPTER VII

THE POST-PHD'S: CAREER ACHIEVEMENTS

Attainment of Thesis Adviser Status

For the academically-employed, one measure of career achievement that is available is attainment of the status of a thesis adviser in a PhD-granting university. The necessary data were obtained from the Thesis Advisers File in the Office of Scientific Personnel. This file was derived from the Doctorate Records File by virtue of the fact that each PhD since 1962 has been asked to name his thesis adviser. The names so obtained were combined into a single file and collated with the names of the people in the various comparison groups. The percentage of each comparison group appearing in the Thesis Advisers File is thus a measure of the extent to which members of that group have attained this particular status in the academic world. Persons entering industry or government or nonprofit organizations will not appear, unless at some time since 1962 they have also been in the academic world and have advised a successful PhD candidate. This percentage figure, then, is strictly a measure of academic attainment, but is certainly in line with the objectives of the NIGMS postdoctoral program.

The data on thesis adviser status were examined for both the total of all fields combined, and for the biosciences separately, for the NIGMS postdoctorals and comparison groups, for the several graduation cohorts and for the total of all cohorts combined. If one looks simply at the totals for all cohorts combined, for postdoctorals and for non-postdoctorals, an anomaly appears: The postdoctorals show up with a lower percentage than do the non-postdoctorals, while on a cohort-by-cohort basis, the postdoctorals are clearly ahead. The anomaly arises from the fact that the percentage of PhD's receiving postdoctoral fellowships has gone up strikingly over time, as noted in the introductory chapter and in Figure 1 and Table 1. The postdoctorals, therefore, have been PhD's for a shorter time, on the average, than have the non-postdoctorals and have had less opportunity to advance to the thesis adviser stage. Some means was needed to remove this inequity in order to sum the data for all cohorts into a single comprehensible figure.

The means used to equate for time since the PhD was to analyze each cohort separately, using as a norm the percentage of a random sample of PhD's who attain thesis adviser status in each cohort. This average base of 100% may be used to compare the various groups across a given cohort, and may also be used to sum the data across cohorts for the various groups. It has the advantage of rendering the comparison group differences on an easily-understood basis, as being above or below the norm by a given number of percentage points. If this percentage increases across the several cohorts for a particular group, then there is evidence of a cumulative effect of membership in that particular group. The norm for the average PhD, of course, remains 100. The data are presented in Table 14 while Figure 11 shows the bioscience data in graphic form.

Table 14 shows the data for all fields combined in Part A, and for the biosciences in Part B, for each cohort (except 1967070, for which data were too sparse for significant statistics) and for the combination of the four earlier cohorts. It is noteworthy that the postdoctorals, whether NIGMS or other, tend to show up less favorably in the 1964-66 cohort. This is probably because they had one, two, or occasionally more years of postdoctoral experience before entering a faculty on a regular basis. Those who entered faculties directly after the doctorate had had more time to attain thesis adviser status. However, after the first few years, the postdoctoral experience seems to have a cumulative effect, increasing from cohort to cohort as careers mature. While not universally true, this generalization holds with sufficient scope to be worthy of particular note.

The difference between the NIGMS trainees and fellows shown in Table 14 is probably a function of the selection of the latter, who, like the NSF fellows with whom they are here compared, were carefully selected in a national competition, and undoubtedly had ability and environmental differences in their favor as compared with the trainees. It is known also, that fellows in far larger proportion chose academic careers than did the trainees, a larger proportion of whom entered non-academic and non-research positions. The AFOSR cases, of whom there were not enough cases in the biosciences for a reliable comparison, were more highly selected than were even the NSF fellows, the

TABLE 14

Relative Career Achievement of Comparison Groups: Attainment of Thesis Adviser Status, by Cohort and for All Cohorts Combined

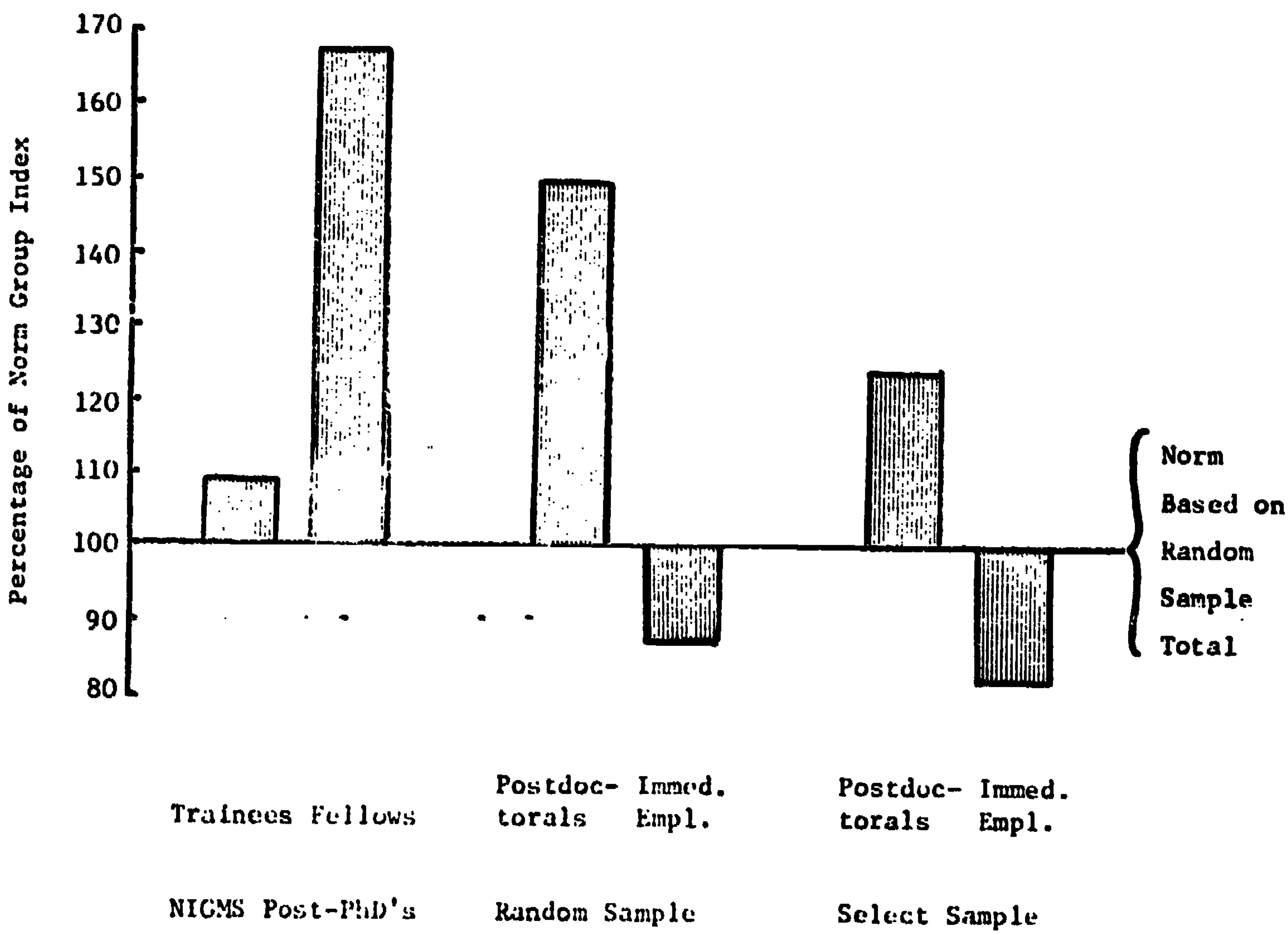
	NIGMS Postdoctorals			DRF Random Sample			DRF Select Sample			AFOSR Fellows			NSF Post-doctoral Fellows
	Trainee	Fellow	Total	Postdoc. Training	Empl.	Total*	Postdoc. Training	Empl.	Total	Awardees	Non-Award	Total	
A. Total of All Fields, Male and Female combined — Percent of Norm*													
Pre-58	74	315	185	-	-	100	-	-	121	-	26	23	111
58-60	90	249	152	195	91	100	160	78	108	-	155	162	245
61-63	91	164	122	134	94	100	115	71	92	236	150	151	227
64-66	55	60	57	87	104	100	95	71	83	435	139	175	199
Pre-58 to 66 Average	78	197	129	150	97	100	123	85	101	336	118	128	196
B. Bioscience Total, Male and Female combined — Percent of Norm*													
Pre-58	101	258	190	-	-	100	-	-	109	-	-	-	-
58-60	101	215	142	180	88	100	133	86	104	-	-	-	195
61-63	139	214	171	153	78	100	144	94	117	-	127	176	228
64-66	88	73	82	113	95	100	96	66	82	-	86	143	175
Pre-58 to 66 Average	107	190	146	149	90	100	124	89	103	-	107	160	199

* The Random Sample Total was taken as the norm for comparison purposes.

Note: Dashes denote groups too small for reliable statistics; for the pre-58 cohorts in the random and select sample, data on postgraduation plans were not available.

Figure 11

Relative attainment of thesis adviser status by NIGMS postdoctorals and comparison groups, biosciences only



applicant/awardees ratio being on the order of 8:1. Apparently, also, they were older at the time of selection, particularly in the early days of the program, so that some of them had already launched their academic careers prior to selection. Over 95% of the pre-1967 AFOSR fellows and applicants entered academic employment on graduation.

Awarding of Research Grants

The award of competitive research grants by the National Science Foundation and the National Institutes of Health, as explained in the chapter on the post-MD's, can be considered a measure of career achievement, as it constitutes the pooled judgment of a jury of peers as to the merit of the research proposal. The data with respect to awards by these two agencies to post-PhD's are given in Table 15 and in Figure 12, for the total of all fields combined, by graduation cohort from 1958 through 1960, and for the total of all graduation cohort combined. As with the data on other measures of career progress or achievement, the differences among the several comparison groups are what one might well expect on the basis of selectivity. The curves for the NSF and NIGMS postdoctoral fellows criss-cross, and that for the select sample of postdoctorals drawn from the Doctorate Records File is not far behind. The curves for the NIGMS trainees and the random sample of postdoctorals from the DRF also cross, while the two groups of PhD's who entered immediate employment are at the bottom of the chart.

One anomaly appears in that the mean for the combined 1958-1970 cohorts for the DRF random sample of postdoctorals is much lower than one would expect on the basis of the cohort means. This is due quite simply to the heavy weighting of the most recent cohort, where there has not yet been enough time for the award of many research grants. The number of postdoctorals has grown quite rapidly, as discussed earlier, and this accounts for the heavy weighting of the most recent cohort in the total for this group of postdoctorals.

It seems quite reasonable to conclude that this set of data gives further evidence of the achievement of career goals quite in line with the objective of the NIGMS program to produce high-quality research scientists, as judged by the criterion of peer review of grant application. There remains one more set of data, which refers more to the outcomes of the research than the proposals, namely publications. This set of data will be reviewed next.

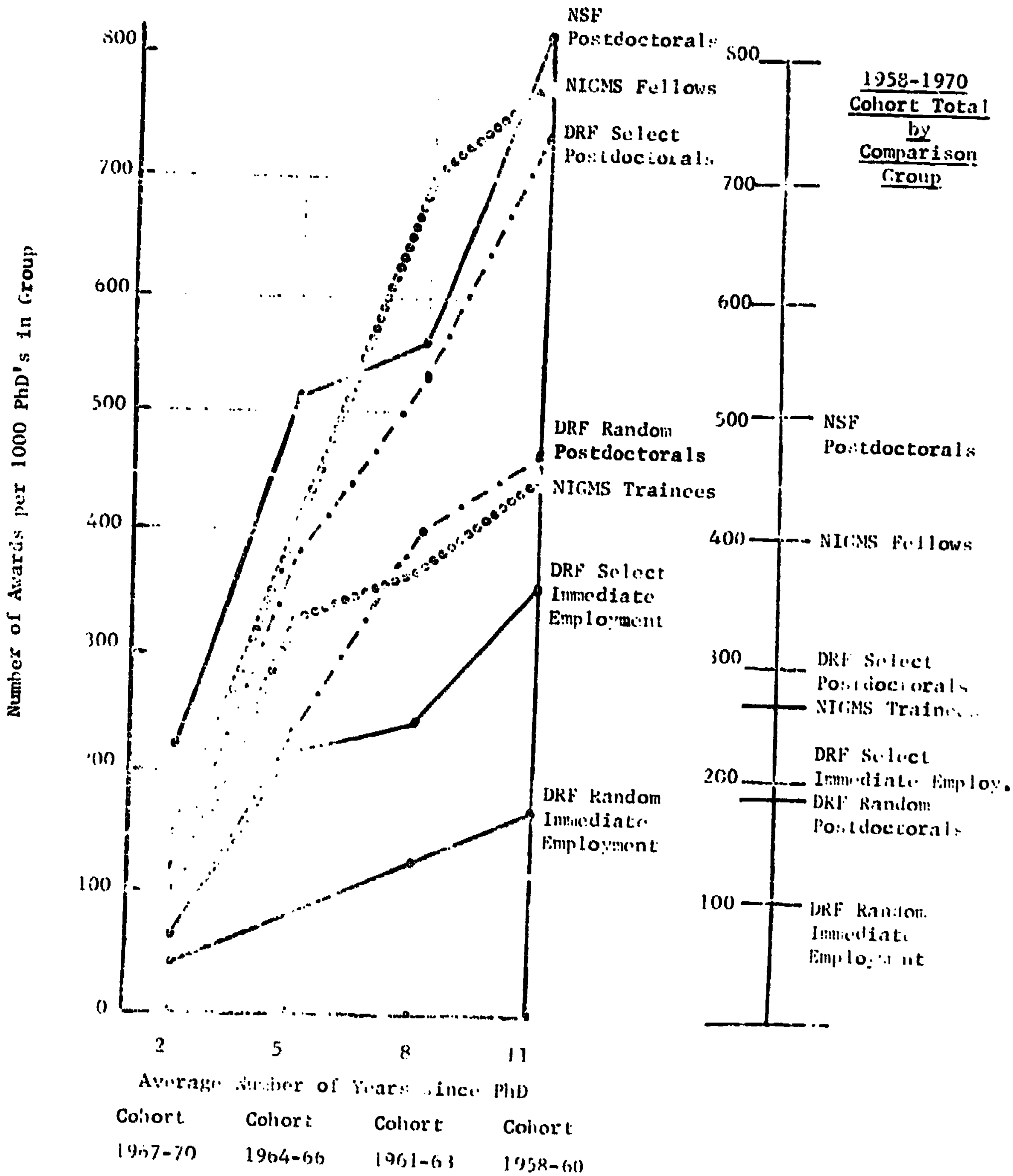
TABLE 15

Mean Number of Awards of Research Grants by NIH and NSF to NIGMS Postdoctorals and Comparison Groups, by Cohort, 1958-1970

Cohort of PhD Graduation		NIGMS Postdoctorals		Samples from Doctorate Record Fields				NSF Post Doctorals
				Random		Select		
		Trainees	Fellows	Post Doctorals	Employed	Post Doctorals	Employed	
1958-60	N	275	177	152	1669	145	248	330
	Mean	.447	.779	.467	.170	.731	.362	.815
1961-63	N	496	368	351	1909	370	395	457
	Mean	.370	.701	.404	.138	.524	.245	.549
1964-66	N	562	441	525	2643	507	443	462
	Mean	.334	.392	.230	.089	.386	.221	.519
1967-70	N	727	728	1203	5173	939	480	452
	Mean	.094	.144	.064	.040	.112	.068	.219
Total 1958-70	N	2060	1714	2231	11394	1961	1566	1701
	Mean	.273	.393	.184	.087	.306	.203	.504

FIGURE 12

Mean number of awards of research grants to NIGMS postdoctorals and comparison groups, by cohort, 1958-1970



Publications and Citations

In all the considerations of the careers of the PhD postdoctorals up to this point, it has been clear that the career lines, or roles, of these people are not as clearly differentiated from those of non-postdoctorals as are the roles of the MD postdoctorals from those of MD's without postdoctoral training. In the case of the MD's, postdoctoral training has constituted an introduction to research technique, and a career shift from an almost exclusive devotion to medical practice, to research and academic medicine. For the PhD postdoctorals, the shift is less drastic - an upgrading of research skills, and, for some, shifts in direction of research. But the typical PhD is already oriented to research, and expects to pursue an academic career in the majority of cases. The result is that the career outcomes or achievements of postdoctorals are not as clearly separated from a random sample of non-postdoctorals as is the case for the physicians. The consequences of this fact became most clearly apparent when the data on publications and citations were examined.

The first step in the analysis of publications and citations was the same for the PhD's as for the physicians, i.e., all of the names occurring in the NIGMS fellowship and traineeship lists, all of the names in the Doctorate Records File, and all of the names of PhD's in the National Register Scientific and Technical Personnel were combined into a single file, eliminating overlapping memberships in the several groups. The result was a list of close to a half-million names that was matched with the ISI tapes mentioned above. This list was used to obtain publication and citation counts for all of these people, some of whom were NIGMS supported, and others of whom were sampled for development of comparison groups. The frequency with which duplicate names occurred in this half-million list was also noted.

The result is shown graphically in Figures 13 and 14. (No data tables are provided, because - as will be reported shortly - it was decided to go on to a refinement which, it was felt, would present the data more clearly.) Figures 13 and 14 present median publication and citation counts for the several comparison groups, with minimal breakout, for the biosciences and for chemistry. The data for the miscellaneous

FIGURE 13

Median publication counts for NIGMS postdoctorals and comparison groups, by cohort, 1958-1970, in two field groups

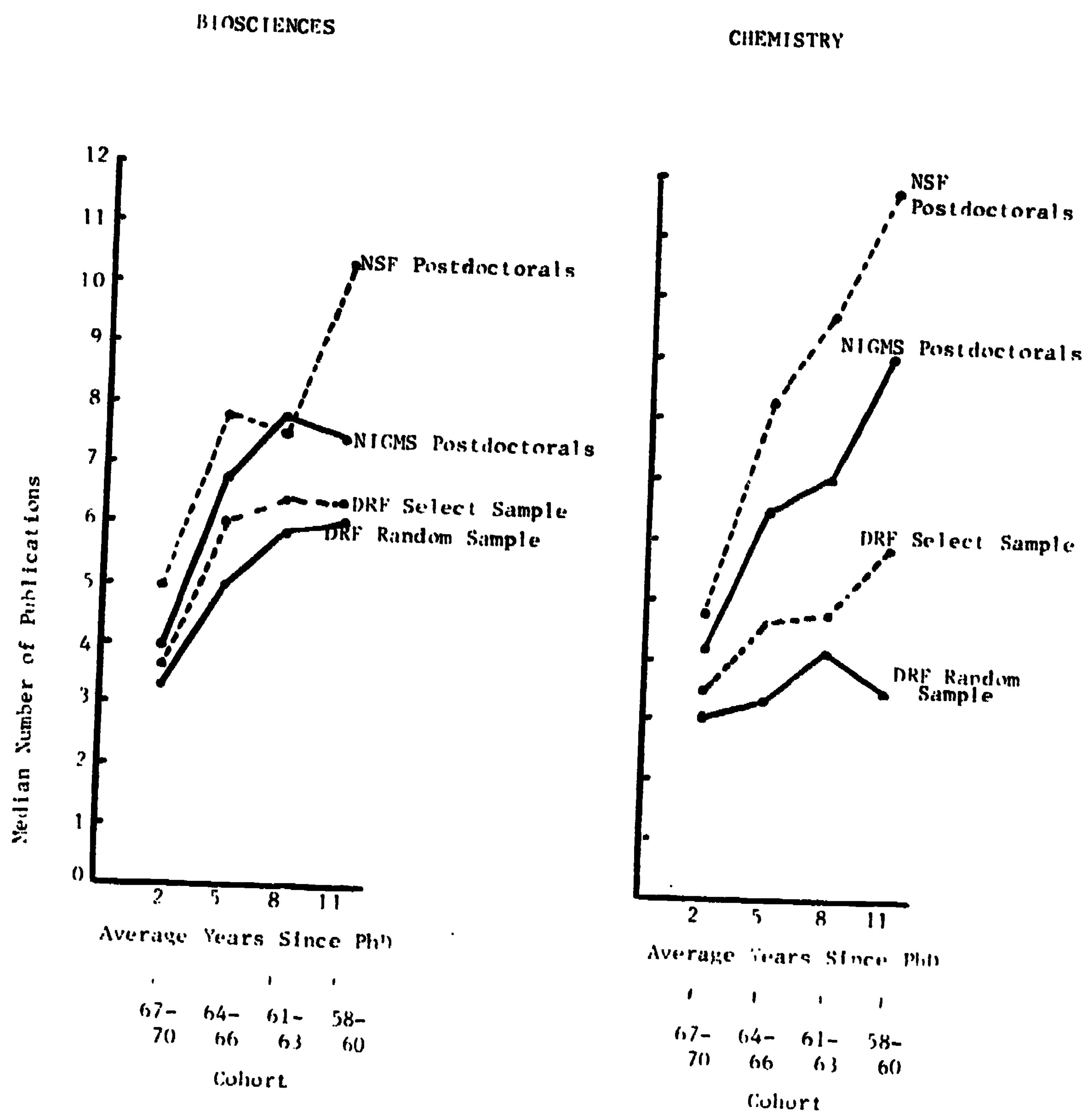
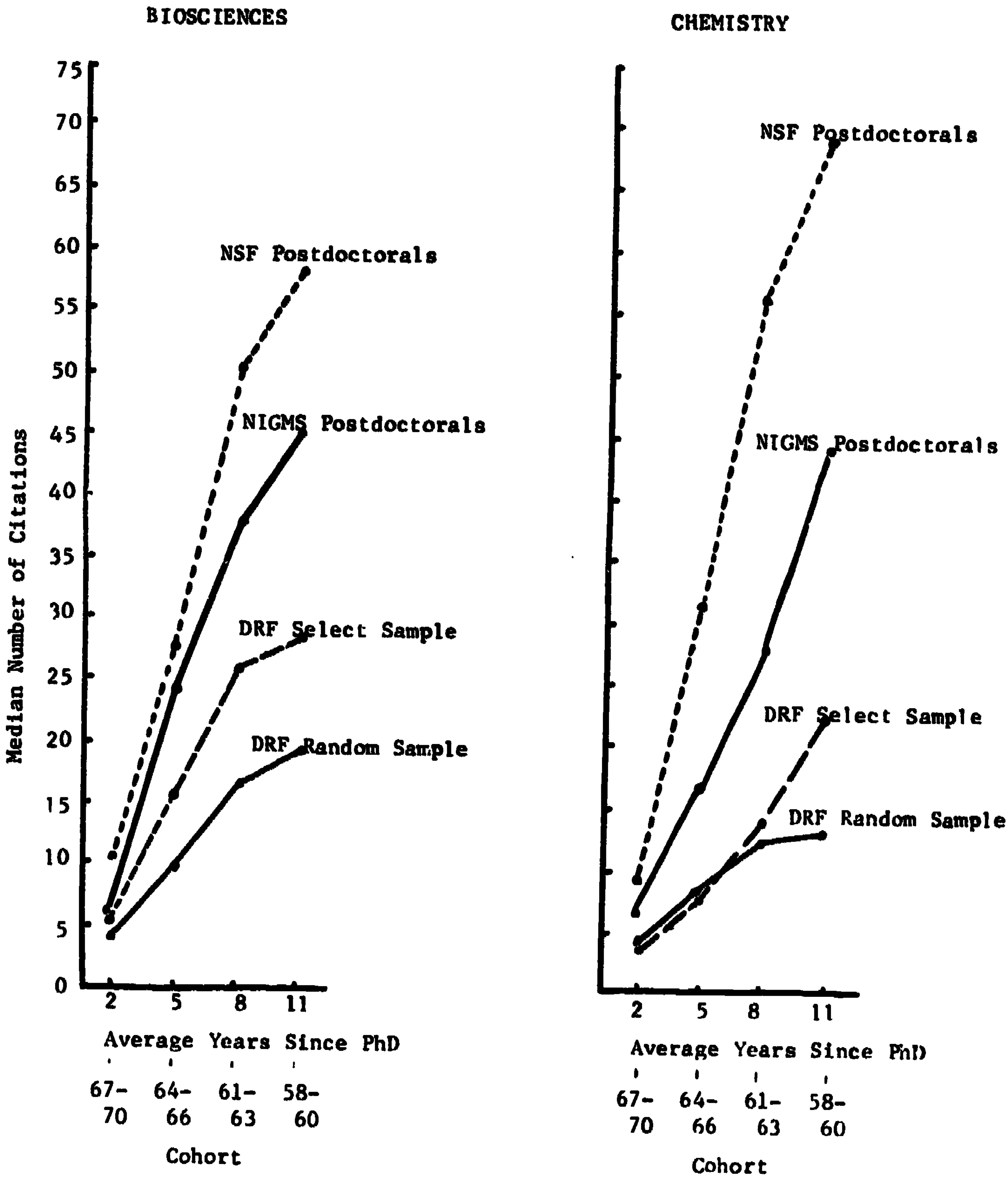


FIGURE 14

Median citation counts for NIGMS postdoctorals and comparison groups, by cohort, 1958-1970, in two field groups



"all other" group are omitted, as the purpose here is for general illustration only, showing a stage in the evolution of a procedure for data analysis. It is clear that there are group differences, but the differences between the NSF and NIGMS postdoctoral groups--probably based on different selection factors--were about as wide as the differences between the postdoctorals and the DRF samples. The latter samples are themselves quite clearly separated, again possibly on the basis of initial differences in backgrounds, ability, and orientation.

In the above publications and citations data there occurred people with names that duplicated other names in the file. As there was no way to distinguish between them, the data for the two or more individuals were averaged. Although this was satisfactory as a preliminary step, it was decided that it would be wiser to exclude such ambiguous cases altogether, and proceed with the unique names--those names which occurred only once in approximately a half-million cases in the OSP file that was matched with the computerized data from the Institute for Scientific Information. This results in the inclusion only of those cases where one could have reasonable assurance that the counts were for the individual under consideration and not for someone else with the same name, or for a combination of the given individual's works with those of another or several other persons. About one quarter of the cases were those of multi-person names; the unique names comprised about 73% of the file. While the numbers of cases were cut down in the several groups, it was judged that the reduction in ambiguity of the data more than compensated for the numbers. Details of this procedure are described in Appendix B.

Another limitation of these data is the fact that further statistical analysis is almost precluded by the statistics used. Medians are excellent for the purpose of portraying final results, and for interpretation of group differences in the case of skewed distributions such as are found with the publications and citations data. But they do not lend themselves to any further analysis. The usual statistical techniques are designed to work with normally-distributed variables, and do not work well with highly skewed distributions, such as citation and publication counts. In order to perform further analyses using conventional techniques, it was necessary, therefore, to convert the raw counts to a normally distributed scale. The procedure used for this conversion is described in Appendix C. The results, expressed in standard scores, were then converted back to the original counts of publications and citations for purposes of interpretation. This statistical route, through normalization and re-conversion, is important to keep in mind, as the results would be quantitatively different if the analyses had been made directly in terms of the original counts. The major effect of this conversion process is to reduce the importance of the cases with extremely high counts - analogous to reducing the effect of a few millionaires in calculation of average incomes of several groups of people. A small group with a single millionaire might thereby have its average income doubled, masking the significance of the rest of the cases in the group. A similar effect in the publication and citation counts is avoided by the normalization process.

Mean Publication Counts

The publications data for the NIGMS postdoctorals and the several comparison groups were assembled in terms of the transmuted mean counts, as described above. These data must be considered on a cohort-by-cohort basis because, if the data for all graduation cohorts are considered together, the heavier weighting of the later cohorts in the postdoctoral data provides a serious distorting element, as the later graduates have, of course, had less time to publish than the earlier graduates. The data are also broken out by field, as there are important variations from field to field in publication practices. Only three field breaks appear justified: biosciences, chemistry, and all other fields combined. The latter is an extremely heterogeneous group, including the physical sciences, mathematics, engineering, and the social sciences. However, none of these constituent groups is large enough for reliable data by itself. The combined data are, therefore, presented more for the sake of completeness than for any clearly interpretable results.

Table 16 provides the mean counts for each of the three fields described above, for each cohort, and for the total of all cohorts combined. There are eleven columns, representing the NIGMS postdoctoral trainees, fellows, and the combination of the two; the random sample derived from the Doctorate Records File (DRF), sorted into those planning postdoctoral training and those who did not, and the combined total; and corresponding data for the select sample drawn from the DRF to match the NIGMS postdoctorals as nearly as possible. Finally, the two columns at the far right represent the data for postdoctorals in two other government-sponsored programs: the National Science Foundation Postdoctoral Research Program sponsored by the Air Force Office of Scientific Research. The latter program was very small in numbers, but the recipients were very highly selected. As a result, data are missing in many of the cells, but the totals for all cohorts combined are available. No data have been entered for cell means based on fewer than 20 cases; means based on fewer than 75 cases are entered in parentheses to indicate that they are not as reliably determined as are the others.

TABLE 16

Mean Number of Publications for NIGMS Postdoctorals and Comparison Groups, by Field and Cohort

Field & Cohort	NIGMS			Samples from Doctorate Records File						NSF Post-Docs	AFOSR Post-Docs
				Random			Select				
	Trainees	Fellows	Total	Post-Docs.	Empl	Total	Post-Docs	Empl	Total		
Bioscience											
Pre-1958	5.1	13.4	9.0	-	3.8	3.9	-	4.1	4.3	-	-
1958-60	5.7	(7.9)	6.[illegible]	(7.9)	4.5	4.9	6.7	4.1	5.0	(9.7)	-
1961-63	6.0	7.6	6.7	7.1	4.1	4.9	7.1	4.2	5.4	(7.2)	-
1964-66	5.9	6.4	6.0	5.6	3.2	3.8	6.1	3.5	4.7	7.7	-
1967-70	3.2	3.6	3.4	2.9	2.2	2.5	3.5	2.3	3.0	4.7	-
Total All Years	4.8	6.1	5.4	4.3	3.3	3.5	4.9	3.5	4.1	6.8	8.0
Chemistry											
Pre-1958	-	(18.0)	(13.5)	-	2.8	2.8	-	(3.7)	(3.7)	-	-
1958-60	-	(12.5)	(9.8)	(7.0)	2.4	2.9	(8.1)	(4.5)	(6.0)	(11.8)	-
1961-63	(4.9)	(7.5)	6.7	(5.3)	3.0	3.4	5.3	(3.8)	4.8	11.0	-
1964-66	(6.5)	6.8	6.7	4.3	2.6	3.0	5.7	(3.2)	4.6	8.7	-
1967-70	(2.9)	4.3	3.9	3.4	2.0	2.4	3.0	(3.3)	3.1	(4.1)	-
Total All Years	4.3	6.7	6.0	4.1	2.5	2.8	4.4	3.6	4.0	8.1	(9.4)
All Other Fields											
Pre-1958	6.9	(10.0)	7.8	-	1.5	1.5	-	(2.1)	(2.2)	4.3	-
1958-60	(7.7)	-	7.4	(4.8)	1.9	2.0	-	(2.7)	(3.1)	8.6	-
1961-63	5.2	-	5.5	6.7	1.8	2.1	-	(1.9)	(3.3)	7.1	-
1964-66	5.1	(5.1)	5.1	5.2	1.9	2.2	(6.9)	(1.8)	(3.7)	6.1	-
1967-70	2.5	(1.9)	2.3	3.0	1.1	1.3	(4.3)	(1.7)	2.5	3.8	-
Total All Years	5.4	4.6	5.1	4.0	1.5	1.6	6.4	1.9	2.9	5.6	(6.0)

\- Means based on fewer than 20 cases are omitted.

() Means based on fewer than 75 cases are in parenthesis.

Taking the first columns of the bioscience data, one can note that the NIGMS fellows come out with generally higher mean publication counts than do the NIGMS trainees, although in some instances the differences are not large. The same is true for the other fields, shown in the same columns farther down the page. However, the combined total for the NIGMS fellows and trainees is not reliably distinguished from the means for the other groups of postdoctorals. The NSF postdoctorals generally have higher mean counts than do the NIGMS postdoctorals, with a single exception in the heterogeneous "all other" field. This is probably a matter of selection ratio; that is, a smaller proportion of the NSF applicants were awarded fellowships, and the resulting more severe competition probably resulted in an overall higher level of qualification of the awardees. What is clearly apparent, however, is that the people who held postdoctorals are, with one insignificant exception, higher in mean publication counts than are those who did not hold postdoctorals. This includes both those in the matching select sample and the random sample drawn from the Doctorate Records File. Among the non-postdoctorals, these two groups--select and random--are not always reliably distinguished from each other.

The fact that postdoctorals, regardless of source of support, exceed the nonpostdoctorals, strongly suggests that the training, as such, was important in causing the difference. However, there are important caveats in this regard, especially in light of the fact that the more selective programs are generally related to higher scores. It could be, on the basis of the evidence up to this point, that all the differences found are the result of selective factors. Before pursuing this question further, it will be useful to view the corresponding data on citations, particularly because the citation data are generally regarded as more crucial than publication counts with respect to contributions to the body of science.

Mean Citation Counts for NIGMS and Comparison Groups

The data on mean citation counts are presented in Table 17, with columns and rows arranged exactly as in Table 16. The NIGMS fellows, in both biosciences and chemistry, achieve higher mean citation counts than do the NIGMS trainees. The NIGMS fellows are almost equal to the NSF fellows, in fact exceeding the NSF average once (biosciences, 1964-1966). The average of the NIGMS postdoctorals

TABLE 17

Mean Number of Citations for NIGMS Postdoctorals and Comparison Groups, by Field and Cohort

Field & Cohort	NIGMS			Samples from Doctorate Records File						NSF	AFOSR
				Random			Select				
	Trainees	Fellows	Total	Post-Docs.	Empl	Total	Post-Docs.	Empl	Total	Post-Docs	Post-Docs
Bioscience											
Pre-58	31.5	83.0	59.0	-	14.7	15.3	-	20.0	22.0	-	-
1958-60	24.3	(41.0)	29.5	(54.0)	11.0	13.0	44.0	14.0	22.0	(60.0)	-
1961-63	22.0	30.0	25.3	21.5	9.4	12.0	29.0	12.2	18.0	(30.0)	-
1964-66	14.7	22.0	17.0	13.5	4.4	6.3	17.0	6.7	11.2	18.3	-
1967-70	2.7	4.1	3.2	2.6	1.5	1.8	3.5	1.5	2.7	8.0	-
Total All Years	10.5	17.0	13.0	7.3	5.6	6.0	10.3	7.9	9.0	20.5	(46.0)
Chemistry											
Pre-58	-	(130.0)	(94.0)	-	10.0	10.0	-	(15.0)	(14.7)	-	-
1958-60	-	(55.0)	(44.0)	(24.3)	7.9	9.2	(40.0)	(15.3)	(25.3)	(55.0)	-
1961-63	(15.7)	(24.3)	21.0	(11.2)	7.7	8.4	14.7	(8.4)	12.5	55.0	-
1964-66	(10.5)	16.0	14.7	7.7	3.8	4.9	9.0	(6.0)	7.5	24.3	-
1967-70	(2.8)	4.5	4.0	2.7	1.3	1.7	2.1	(3.1)	2.4	(5.2)	-
Total All Years	8.4	14.7	13.0	5.9	4.6	4.9	6.5	7.5	6.9	25.3	(20.5)
All Other Fields											
Pre-58	24.7	(52.5)	29.0	-	4.3	4.3	-	(10.8)	(11.2)	9.6	-
1958-60	(24.3)	-	22.5	(9.8)	4.6	4.8	-	(8.4)	(11.0)	34.0	-
1961-63	13.5	-	14.3	15.0	3.7	4.3	-	(2.7)	(6.1)	22.5	-
1964-66	11.0	(6.7)	10.0	8.2	2.5	2.9	(12.0)	(2.3)	(5.6)	12.5	-
1967-70	2.1	(1.0)	1.6	2.4	1.0	1.0	(5.3)	(1.1)	2.1	3.9	-
Total All Years	12.7	6.7	11.0	5.0	1.9	2.1	12.2	3.7	5.4	12.5	(13.5)

\- Means based on fewer than 20 cases are omitted.
() Means based on fewer than 75 cases are in parenthesis

however, is not reliably distinguished from the two postdoctoral samples drawn from the Doctorate Records File. These two latter groups, also, are not always clearly distinguished from each other, although both of them are quite obviously higher in mean citation counts than are those who entered employment immediately after graduation. This finding is similar to that for the mean publication counts and raises again the question as to whether the pattern of group differences found is primarily a matter of the effects of training at the postdoctoral level, or of initial differences between the groups that are related to explicit selection, or self-selection to have the training in the first place. Accordingly, attention was perforce turned to the possibility of controlling for these initial differences, in order that the effects of postdoctoral training per se may be distinguished from the selection factors that determine which people receive such training and which do not.

Deriving Corrected Mean Counts

The general strategy for correcting the publication and citation counts to allow for the differential effects of initial ability, motivation, and graduate school environment is to find measures that correlate with these variables and with the publications and citations data. Then, by means of a regression equation which "predicts" the publications or citations from the ability and environmental data, one can estimate how much of the variation that is observed is due to these factors, and hence how much remains to be explained by the effects of postdoctoral training as such. That is, one subtracts out of the actually obtained score that portion which is due to the unwanted factors, leaving a residual by which to calculate the training effects we most want to observe. This strategy requires that we find variables that constitute reasonably good approximations to the ability, motivation, and environmental factors we wish to eliminate in our "corrected counts". It was decided to pursue this approach only with the bioscience fields, where the numbers are adequate and where the concern of this study is concentrated.

It would be desirable to analyze initial ability differences in terms of test scores, for example, or grade point averages, but the necessary data are not available. Attention then turns to surrogate scores. The only datum universally available that is known to correlate (although negatively and not strongly) with ability, is age at PhD. This variable, readily computed from the Doctorate Records File, may well be supposed to be compounded of ability, drive, and a number of accidental environmental factors, all of which, however, predate the postdoctoral training. It was decided to try out this measure to see the extent to which it correlated with publications and citations.

It may well be that environmental differences related to the institution of PhD are important in influencing publications and citations. It may further be assumed that both self-selection or choice of graduate school and selection by the graduate school on the basis of ability will relate to publications and subsequent citations of those publications. Attention then turned to means for assessment of the graduate school environment that might be useful for the purpose of equating the postdoctoral and non-postdoctoral groups so as to isolate the influence of the postdoctoral training from the selection and environmental correlates of graduate training.

The best-known measure of graduate school environment is the set of ratings developed by Roose and Andersen of the American Council on Education[7]. The mean R-A rating for all the bioscience departments in each institution was computed as we did not know the actual department in which each individual had received his graduate training, although his field, of course, was known. These average ratings were therefore included in the analysis to determine whether they would help sharpen up the particular differences with which this study was concerned. It proved possible, also, to derive from the data of the study itself another set of environmental measures that it was throught might be more directly related to the question of subsequent publications and citations. These measures were derived through the following rationale (performed on transmuted standard scores, later re-interpreted as publication or citation counts):

(1) An important part of the graduate school environment is that furnished by the other graduate students.
(2) We can measure empirically the propensity for these other students to "get into the scientific literature" via their publications and citations, earned in the years subsequent to graduation.
(3) By calculating the mean of the publication scores and citation scores of the bioscience PhD graduates of a given institution, within a given field, one can infer the nature of the graduate school environment in which any bioscience graduate student of the period had his training--at least the fellow-student portion of this milieu.

Following this rationale, the mean citation score and publication score was computed for all the bioscience graduates of the 1958-70 period in each of the

[7] Kenneth D. Roose and Charles J. Anderson, A Rating of Graduate Programs, (Washington, D. C.: American Council on Education, 1970).

institutions which awarded bioscience PhD's during this period. Institutions having fewer than sixteen graduates for whom such mean scores were available were excluded, so that the resulting scores would not unduly reflect the influence of a few exceptional individuals, who would in turn be characterized as influenced by the environment which they themselves had created. The requirement of a minimum of sixteen cases largely avoided this circularity. Two scores, it is to be noted, are derived for each school in this manner - one based on the mean publication score, the other on the mean citation score. Each PhD was then "tagged" with these institutional indices for his own PhD institution.

How was the influence of these measures, assumed to be possibly influential in determining publications and citations, to be assessed? Four measures existed: (1) age at PhD graduation; (2) the average Roose-Andersen rating of the bioscience departments of the institution of PhD; (3) the institutional mean publication index; and (4) the institutional mean citation index. The assessment procedure was quite direct: Each individual in the bioscience PhD population of the 1958-70 period was assigned as independent variables the appropriate predictor scores (1) to (4) above and as dependent variables his own achievement scores (publications and citations). All of the intercorrelations were computed, separately for each sex, and multiple regression equations were computed to predict the individual's publication and citation scores.

What the multiple regression equation does is to take into account all of the variables used as predictors (in this case age at PhD and the institutional environmental factors), and the inter-relations of these predictors, in influencing the outcome variable (publication and citation scores in this case). It turned out that age at PhD was indeed a valuable predictor of later publications and citations, although not a strong one. The Roose-Andersen ratings were even better predictors. The best predictors of all, however, were those derived from the later achievements of the graduate students themselves. In fact, these latter indices performed in such a way as to subsume the effects of the R-A ratings, so that the final regression formulas - the ones with the greatest predictive significance - included only the age at PhD and the relevant graduate student index. The mean publications index, in other words, was most important in predicting the individual's publications, and the mean citation index was most important in predicting the individual's citations. Because the regression equations were separately computed for men and for women, the sex differences, both in the relationships between the variables and in average publications and citations, are automatically included in the formulae. The actual regression formulae, and the specific details of this procedure are described in Appendix D.

The exercise described above was undertaken to help highlight the influence of the postdoctoral experience itself, apart from the influence of pre-existing conditions within the individual or attributable to his prior experience. The result of the technique was to produce a "predicted citation score" and a "predicted publication score" based on the combined influence of the factors which it was desired to exclude. When this predicted score is subtracted from the actual score, one thereby removes, insofar as is possible with the data at hand, the unwanted influences. The difference between the average of the residual scores (actual minus predicted) of those with and those without postdoctoral training shows the effect of the postdoctoral training, insofar as one can determine it. It is important to note the inclusion in both of the statements above the qualifier "insofar as possible". One cannot remove the effects of abilities or environmental factors for which we have no measures, except insofar as they correlate with the measures which we do have. With this qualifier firmly in mind, we are ready to assess the effect of the postdoctoral training on the career outcome measures derived from the publication and citation counts.

Corrected Mean Counts for NIGMS and Comparison Groups

The corrected mean counts (actual minus predicted) for publications are given in Table 18 and for citations in Table 19. In both tables, data are given for each graduation cohort separately, and for the total of all cohorts combined. In examining the data summed directly across all cohorts, it was found that the effect of a rapidly increasing percentage of bioscientists taking postdoctoral training was producing a spurious effect. That is, the later cohorts, whose members had not had much time to publish, and even less time to be cited, are most heavily weighted in the postdoctoral group. The spurious effect, then, is to lower the summed postdoctoral publications and citations scores, as compared with the non-postdoctorals, who on the average had graduated earlier. The solution to this is to consider each cohort separately, and this is done in Figures 15 and 16, which show the corrected mean counts by cohort for the NIGMS postdoctorals and the comparison groups. There is also shown on these two figures a kind of cohort average, derived from taking the unweighted average of the mean counts across all four graduation cohorts. These unweighted averages are given also in Tables 18 and 19, in the bottom line of each table. As can be seen by comparing with the scores for the 1958-70 group taken as a single cohort, these "cohort averages" are uniformly higher because they do not reflect the heavier weighting of the later cohorts with less time to get into the scientific literature.

In Figures 15 and 16 there are curves showing the "DRF Postdoctorals" and "DRF Immediate Employment" groups, with no separation of the random and select samples. The data shown are the weighted averages of the two sets of data. The reason these two groups are not separated is apparent in Tables 18 and 19. The two sets of scores, when corrected as described earlier, are too close together to make separate plotting feasible, and in fact are seldom different by a statistically significant amount, even though the numbers are quite large. On the other hand, there is a rather clear separation between the curves for those who have had postdoctoral training, whatever the source of support, from those who have not had such training. The NIGMS curve crosses that of the DRF postdoctorals and that of the NSF postdoctorals again and again; the several curves are not reliably distinguished. The heavy dashed line in Figures 15 and 16 represent the general average, i.e., the mean expected score after the corrective factors have been applied. It is weighted, of course, toward the

TABLE 18

Mean Publication Counts, Corrected for Ability and Graduate School Differences, for NIGMS and Comparison Bioscientists, by PhD Cohort

PhD Cohort	NIGMS Postdoctorals			DRF Postdoctorals		DRF Immediate Employment		AFOSR Post-doctoral	NSF Post-doctoral
	Trainees	Fellows	Total	Random	Select	Random	Select		
1958-60	3.8	4.5	4.1	(4.7)	3.8	2.9	3.0	-	(4.9)
1961-63	3.7	4.3	3.9	4.0	4.1	2.7	2.6	-	(3.7)
1964-66	3.5	3.6	3.5	3.4	3.7	1.8	2.0	-	3.8
1967-70	1.7	1.7	1.7	1.5	1.8	1.3	1.6	-	2.1
1958-70*	2.8	2.9	2.9	2.4	2.8	1.8	2.2	(3.7)	3.4
Cohort Average**	3.1	3.4	3.2	3.2	3.3	2.1	2.3	-	3.6

* The total 1958-70 cohort gives heavier weight to the larger, and more recent, cohorts.
** Cohort Average is the unweighted average of the cohort scores.
() Parentheses denote means based on fewer than 75 cases.
\- Means based on fewer than 20 cases are omitted.

more numerous recent cohorts; no cohort correction was applied. It is noteworthy that the actual-expected difference increases progressively over time, i.e., the effects of postdoctoral training are progressive--the investment pays increasing dividends as careers mature.

In comparing the data of Tables 18 and 19 with the corresponding figures, it will be noted that in the latter the combined data for fellows and trainees are shown, whereas the data both separate and combined are given in the tables. The "cohort average" data are shown in the illustrations, at the far right, with the fellows and trainees distinguished. It is possible to distinguish some differences between these two groups, particularly in the early cohorts. This is probably because of selection differences that are not fully accounted for in the correction formulae. A hint of this is provided by the data for the NSF postdoctorals and that for the AFOSR cases also. These two groups, particularly the AFOSR postdoctorals, are very highly selected. Over a period of time these differences in selection rigor may be expected to have an effect, and the greatest effect, given sufficient time, in the citation counts, where quality differences count most heavily.

FIGURE 15

Mean "corrected" publication counts for NIGMS postdoctorals and comparison groups in bioscience fields, by cohort

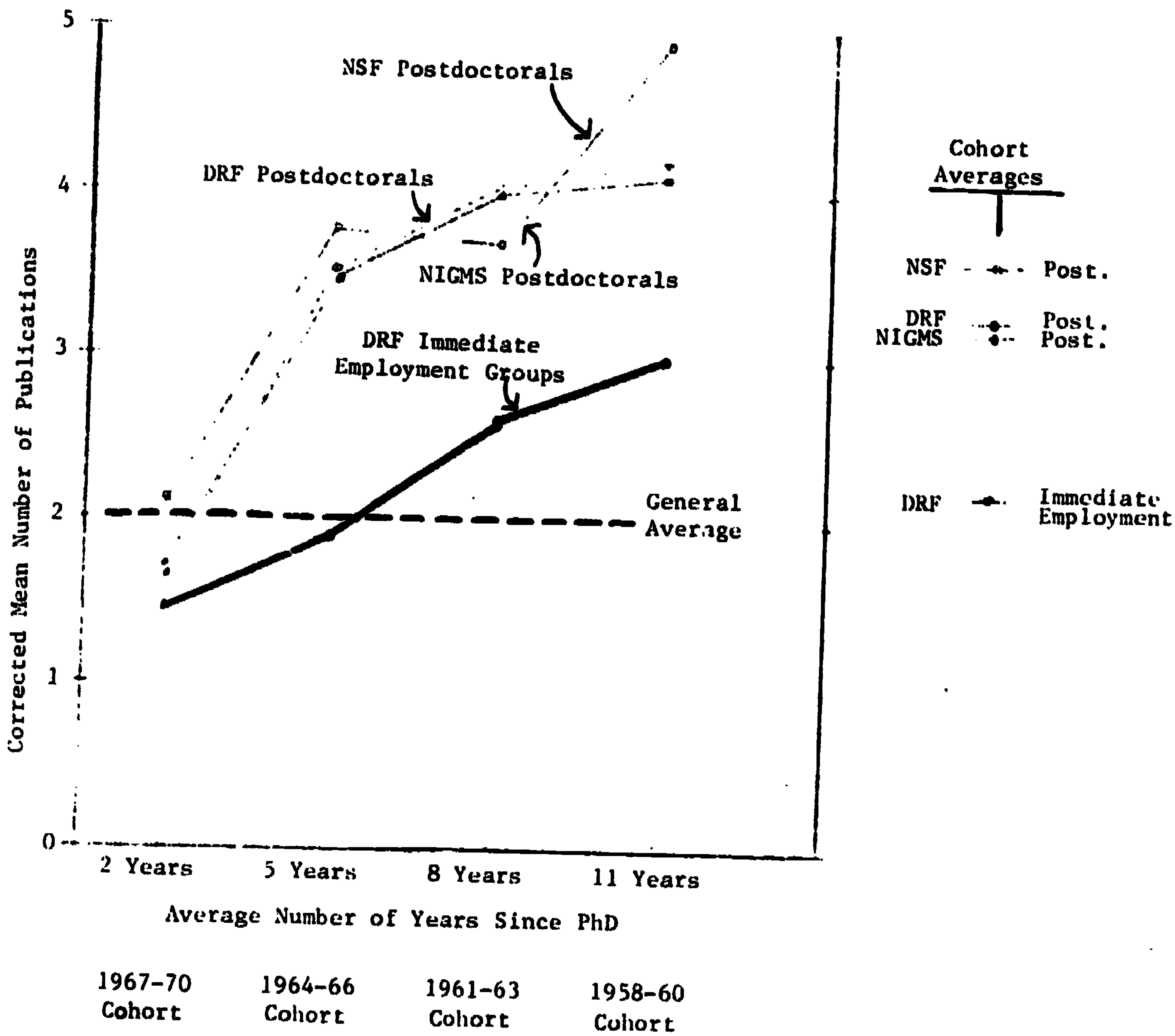


TABLE .9

Mean Citation Counts, Corrected for Ability and Graduate School Differences, for NIGMS and Comparison Bioscientists, by PhD Cohort

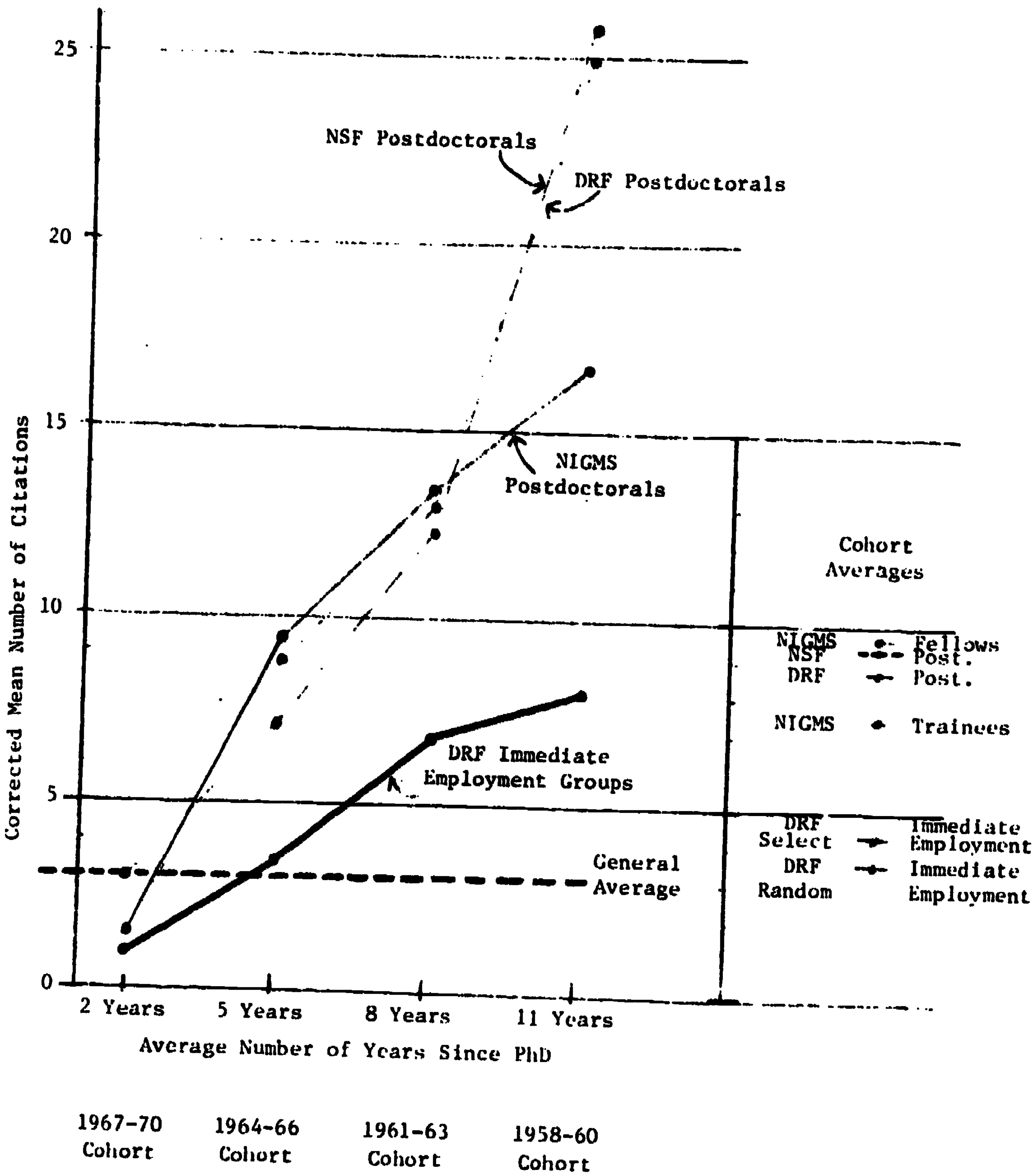
PhD Cohort	NIGMS Postdoctorals			DRF Postdoctorals		DRF Immediate Employment		AFOSR Post-doctoral	NSF Post-doctoral
	Trainees	Fellows	Total	Random	Select	Random	Select		
1958-60	15.0	20.0	16.7	(28.0)	(22.5)	6.6	9.4	-	(25.8)
1961-63	12.7	14.7	13.5	11.0	14.3	6.6	6.9	-	(12.2)
1964-66	8.0	11.7	9.4	7.9	9.8	3.2	3.8	-	7.1
1967-70	1.5	1.7	1.6	1.3	1.6	1.0	1.1	-	2.9
1958-70*	5.7	6.5	6.1	4.0	5.4	2.7	3.8	(16.0)	8.2
Cohort Average**	7.5	9.6	8.2	8.2	9.2	3.7	4.4	-	9.4

* The total 1958-70 cohort gives heavier weight to the larger, and more recent, cohorts.
** Cohort Average is the unweighted average of the cohort scores.
() Parentheses denote means based on fewer than 75 cases.
\- Means based on fewer than 20 cases are omitted.

The above observations may be summed rather succinctly. They show that, over the period of time provided by these data, there are significant differences between postdoctorals and those who have not had postdoctoral training, with respect to both publications and citations, when all allowances possible from available data have been made for initial differences between the groups. These differences increase with time since graduation, so that we have only the beginnings of differences in achievements that may reasonably be expected to mount progressively as careers advance. The data also show, somewhat less clearly, that the allowances made by the correction formulae, while effective, are imperfect, and that there remain some differences, as yet unanalyzable, in selectivity in the various groups. These selectivity differences, although minimized, still have some effect on ability to get into the scientific literature, and particularly to write papers that are most likely to be cited by other scientists.

FIGURE 16

Mean "corrected" citation counts for NIGMS postdoctorals and comparison groups in bioscience fields, by cohort



A Broader Context

The foregoing data with respect to the career performance of the NIGMS postdoctorals and comparison groups appear to be rather consistent and reasonably definitive. That is, the influence of postdoctoral training, whether sponsored by the NIGMS or another agency, is clearly in line with the objectives of the sponsoring agencies. These objectives are to increase the supply of highly qualified researchers, for both research and teaching functions, because it is only those who are fully qualified in research who can teach the techniques and points of view essential for the advancement of science. The data indicate that the postdoctorals do more research than those without such training, that more of them are employed in academic positions, that they win more competitive research grants, that they contribute more to the scientific literature and that they are cited more frequently by their fellow scientists. The latter effects hold even when account is taken of the fact that they have initial advantages in terms of ability and environmental influences. The comparison groups chosen for analysis of these effects show the results rather clearly. It was felt, however, that additional data might be very useful in providing a broader context in which to interpret the findings, definitive though they might be with respect to the NIGMS postdoctoral programs.

The broader context for interpretation of the effects of postdoctoral training was obtained by consideration of all bioscience postdoctorals, regardless of the mode of support, and comparing their performance and career lines with the whole bioscience PhD population, using the same 1958-1970 PhD cohorts in the biosciences that have been referred to before in describing the correction process to discount the effects of selection for postdoctoral training. The full account of the findings of this more extensive survey are given in Appendix E. However, one of the highlights, showing the effect of postdoctoral training on citation counts, is given below.

The career lines of postdoctorals and of the general bioscience PhD population were studied, and the individuals were sorted out according to the major type of work performed and their institutions of employment in 1970, as shown in the National Register of Scientific and Technical Personnel. This had the effect of supplying another control variable - work context - to supplement the controls supplied by the "correction formula" which reduced or eliminated the effect of ability and predoctoral environmental factors. Those in academic settings were sorted according to the Roose-Andersen rating averages for the bioscience departments. Those in institutions for which no Roose-Andersen ratings were available were sorted according to the highest level of degree granted, and the un-rated PhD-granting institutions were combined for this purpose with the masters-granting institutions. In this way, the effect of major type of work activity and type of employer are controlled, so that the difference between the postdoctorals and the general PhD population may be compared, as another way of measuring the effect of the postdoctoral experience. The data given in Figure 17 are for corrected citation counts, which eliminate, insofar as possible, the effects of ability and graduate school environment. They include data for the 1958-66 cohorts only, because members of the most recent cohort had not had time for their publications to be cited. At the bottom of Figure 17, the citation counts (re-transmuted from the standard scores) are given. It is apparent that there are consistent differences, wider in the academically-employed than in the nonacademic groups, between the postdoctorals and the general norm, holding constant present employment as well as ability and predoctoral environment.

In Figure 17 the profile of citation counts by type of institution and by type of work activity within the postdoctoral group parallels the profile of the general bioscience PhD population, and is of importance in itself. "Researchers",[8] regardless of background, obviously have higher citations counts, and "teachers"[8] have lower citation counts than either the researchers or the miscellaneous "all other" groups. Those employed in research-oriented universities, particularly the higher-rated institutions, score above those in the lower-rated and less research oriented universities and colleges. But the distinguishing features of the postdoctoral groups are most manifest in the masters-granting, baccalaureate-granting, and non-research settings. It appears from this that, regardless of ultimate employment context, those who have had postdoctoral training are more likely to be cited frequently than are those without postdoctoral training. Put in another way, the differences within the several postdoctoral groups are smaller than within the general population, and less affected by the type of employment. This information, combined with the fact that the postdoctoral vs. general population difference increases over time, leads one to the conclusion that the effects of such training on research output and contributions to science are just beginning to be measured, and will in all likelihood be enhanced as time goes on. The costs have been incurred, but the benefits are only beginning to be felt at the present time.

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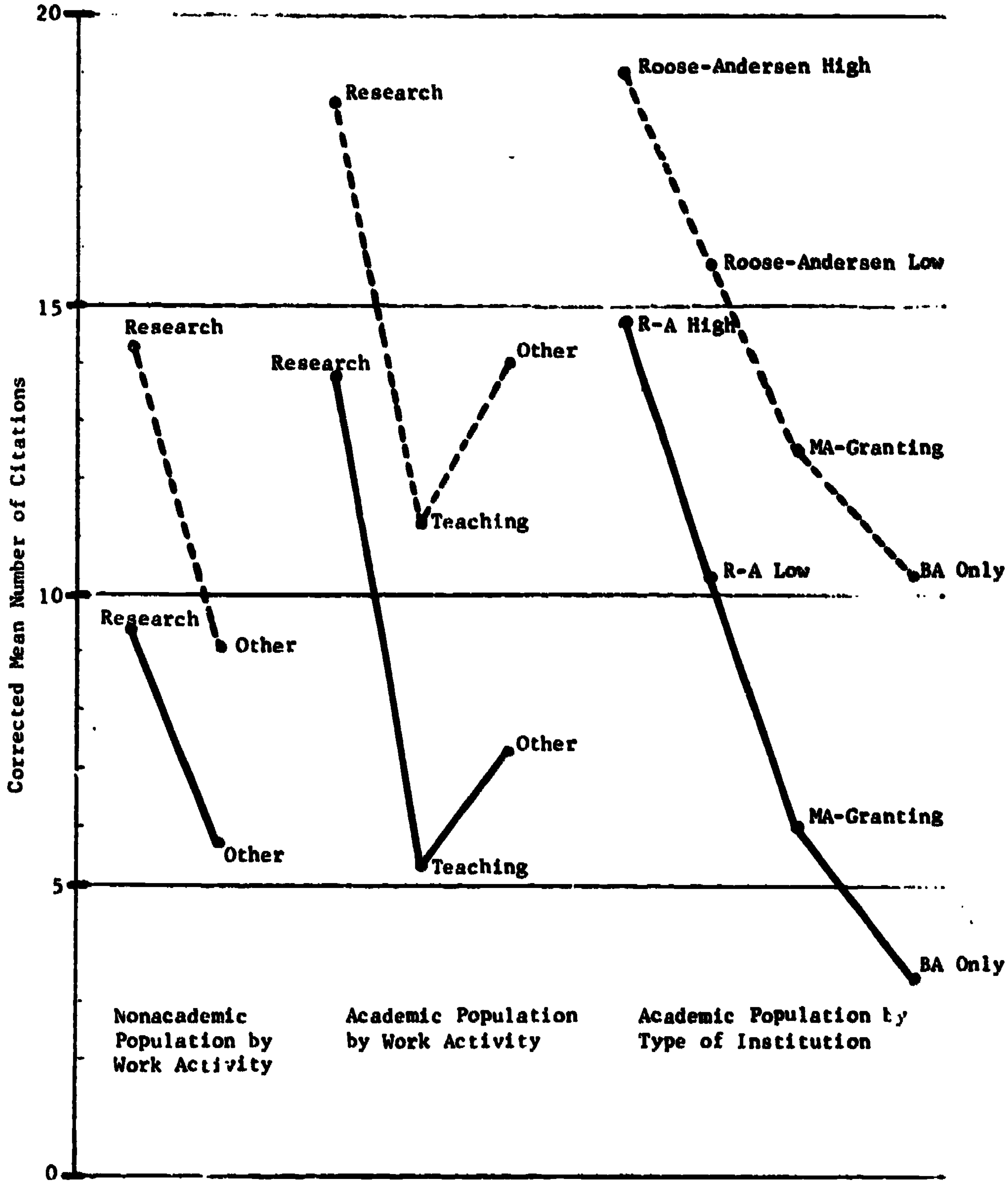
8 Many "researchers" also teach, and "teachers" also do research, as secondary work activities. These categories are based on primary work activity only.

FIGURE 17

Comparison of corrected citation counts of postdoctoral bioscientists and general bioscience PhD population, by work activity and institution type, average of 1958-1966 cohorts



14.3	9.1	18.7	11.2	14.0	19.0	15.7	12.4	10.3	Postdoc.
9.4	5.7	13.8	5.3	7.3	14.7	10.3	5.9	3.4	Grand Total

– – – – – Bioscience postdoctorals ——— General bioscience PhD population

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Summary

This study was undertaken at the request of the National Institute of General Medical Sciences, to examine and evaluate the program of postdoctoral training grants and fellowships sponsored by that Institute over the period since 1958. The objectives of the program were to improve the supply of highly-trained bioscientists and research-oriented physicians, to the end that the biomedical manpower trained in the nation's medical schools and graduate schools might develop more scientific knowledge of medicine and hence deliver better medical care to the nation's populace. The present study was to concentrate on the effects of postdoctoral training on the careers of those who had been so sponsored; the institutional effects of training grants had been s .died by an earlier committee.

The Committee sought evidence directly from former NIGMS postdoctorals and from present mentors and postdoctorals themselves, by conducting site visits to biomedical laboratories across the country. These investigations showed that postdoctoral training furnishes the research orientation essential for physicians who will enter academic medicine, and is increasingly required by the medical schools for the hiring of new faculty. It was found also that the opportunity for research-oriented PhD's and clinically-oriented physicians to receive postdoctoral training together is invaluable in extending the competence and effectiveness of members of both groups. For the PhD's, the opportunity through postdoctoral training to sharpen research tools, to increase flexibility, to allow for changes of field to meet new challenges, and to develop research independence and confidence, is essential to the best preparation for teaching and research in strong graduate schools and laboratories. Those responding to the Committee's inquiries, who have had the advantage of such training in the past, are unanimous with respect to its value, and feel that it should not be eliminated in favor of other methods of support. They regard the flexibility of the several modes of support as essential to the most efficient operation of the research and teaching establishment.

A set of operational criteria were developed by which to evaluate, in a quantitative manner, the career effects of postdoctoral training. These criteria included (1) engagement in research as a primary activity, (2) employment by medical schools and graduate schools, particularly the research-oriented institutions, (3) advancement up the academic ladder in these institutions,

(4) the winning of competitive awards of research grants offered by the National Science Foundation and the National Institutes of Health, and (5) contributions to the advancement of science as measured by publications in the scientific literature and, particularly, by citations of one's publications by other scientists.

To test the effectiveness of the program against each of these criteria, comparison groups were set up as standards against which the NIGMS trainees and fellows might be evaluated. For the post-MD's, the comparison group was a random sample of physicians graduating over approximately the same period of time as those whose postdoctoral training was sponsored by the NIGMS. For the post-PhD's, several comparison groups were drawn up: a random sample of PhD's from approximately the same graduation cohorts; a select sample from these cohorts, matched with the postdoctorals in terms of field of specialization, institution of doctorate, and sex; and two groups of postdoctorals sponsored by other agencies.

The career patterns of the NIGMS fellows and trainees, and their career achievements as outlined above, were compared on all available dimensions with those of the members of the comparison groups. The results may be rather succinctly summarized:

The Post-MD's

Career Patterns: MD's who have taken NIGMS postdoctoral training are headed for careers in academic medicine and research, and achieve these career goals in numbers quite clearly in line with the objectives of the program that sponsored them.

Career Achievements: Measures of career achievement show that NIGMS post-MD's obtain research grants in a competitive atmosphere in numbers far beyond those of a random sample of physicians, become faculty members in the nation's more prestigious medical schools, and rapidly advance up the academic ladder in this rigorously competitive environment. The proportion of this group which publishes research papers is far larger than the corresponding proportion of a random sample of physicians; on the average, they publish far more papers, and are cited far more often by other scientists, indicating significant contributions to the growth of science.

Evaluation: The medical schools, on the basis of experience, and through analysis of their own needs for highly qualified staff, have turned increasingly to postdoctorals--both post-MD's and post-PhD's, to fill their teaching and research positions. They are highly dependent upon people trained to this level for the advance of medical science and practice. The opportunity to train MD's and PhD's together in a research atmosphere, thus combining clinical and research approaches in the attack on medical problems, has become a keystone in the structure of medical progress.

The Post-PhD's

Career Patterns: Those who seek postdoctoral training differ in their career goals, motivations, graduate school environments, and career patterns from PhD's who do not seek postdoctoral training. Postdoctorals in general, and the NIGMS postdoctorals as a particular group, follow more definitely research-oriented careers, and are found more frequently in academic institutions, than non-postdoctoral PhD's.

Career Achievements: NIGMS postdoctorals in academic institutions attain thesis adviser status more rapidly than do non-postdoctorals, and are found with graater frequency in the more prestigious graduate schools and research-oriented medical schools. They far exceed the research grant award rates of PhD's who have not had postdoctoral training.

The most rigorous measures of research achievement--number of publications and citations to these publications--were more extensively analyzed. Postdoctoral fellows tend to be far more productive in these respects than those PhD's who go directly into employment. This superiority increases with time since the PhD; this indicates that an even greater measure of contribution due to postdoctoral training is to be anticipated in the future, as careers advance.

Even when allowances are made for individual differences in ability (insofar as it could be estimated) and graduate school environment, the superiority of the achievement of the postdoctorals was maintained, although diminished in degree. For most groups, the superiority was maintained even when the type of employer and primary work activity are also taken into consideration. These results provide strong evidence for concluding that experiences as postdoctoral fellows or trainees tend to produce superior researchers.

Within the several groups of postdoctorals, there were differences that seemed to be related to the selectivity of the programs - those in the programs in which the participants were selected in the most rigorous competition and by the most universalistic criteria tended to excel over those in the less competitive programs. For example, NSF and AFOSR postdoctoral fellows attain thesis adviser status more rapidly than do those of the less competitive NIGMS program. All of these groups, however, exceed the attainments of the PhD's who enter employment without postdoctoral training.

Evaluation: The NIGMS postdoctorals, both fellows and trainees, followed career lines, achieved career goals, and made scientific contributions clearly in line with the objectives of the NIGMS postdoctoral program. While no formal cost-benefit analyses were attempted by the Committee, it was noted that the whole NIGMS postdoctoral program could be paid for by an amount equal to about one penny per month for each of the country's wage-earners. The benefit to tax-paying wage earners is a question left for the reader to answer.

Conclusions

Research-oriented physicians, who have acquired the ability to apply the disciplines of basic research to the solutions of clinical problems, constitute an indispensable segment of our medical school faculties. It is only through them that the important discoveries that flow from the basic science laboratories and from the clinical laboratories, can be interpreted to medical students and practicing physicians and thus applied for the benefit of mankind. There is no other group that can provide this important function. It is one of the most important functions of our medical schools if we are to envision future improvement in the quality of medical care delivered to our people.

The faculties of our medical schools must be regarded as a most important national resource. The impact upon this total resource of cutting back the medical school postdoctoral training programs could be disastrous within a relatively few years, because it would dry up the pool of young research-oriented physicians - those educated at the current frontiers of research. Only about 5% of all medical school graduates end up as full-time academic faculty people and, of these, only a few can be currently labeled as "research-oriented". Thus, the demand for postdoctoral MD research training comes from a small, but very important, group of young physicians. Unlike the PhD, the MD graduate has many avenues open to him besides the more difficult one of following a career in research. The extra opportunity and incentive provided by the postdoctoral program is thus essential to maintain the flow of these key persons into academic medicine.

Continued progress in basic and applied research in the biomedical sciences is based more upon the continuing supply of highly-trained manpower than upon any other single factor. Research in many areas of the biomedical sciences today requires a command of a broader range of knowledge and techniques than can normally be acquired in the course of doctoral education alone. This is the result of a continued high rate of increase of knowledge and the fact that many of the most important areas of research are at the margins of two or more scientific disciplines. Thus, education beyond the doctorate is becoming a necessary condition for the accomplishment of high-quality research in the biomedical areas, even by those with excellent graduate education.

The rapid advances in the biomedical sciences in the last decade and a half have been facilitated by postdoctoral fellowship programs in a number of ways. One of the most important among them is the rapid diffusion of new techniques. Providing scientists with research opportunities in the laboratories of internationally eminent researchers is essential to diffusion of many techniques which cannot be transmitted adequately by the printed page alone. Furthermore, the phenomenon of "critical mass" is important - the provision of large enough research groups of competent people of diverse skills and backgrounds so that their interaction generates creative accomplishment; postdoctorals contribute enthusiasm and fresh skills, as well as numbers, to such groups. Finally, these fellowship programs promote a healthy spirit of competition among young American scientists and provide the mobility whereby they reach positions where they can be most effective. Continued advances in the biomedical sciences will depend in large part upon the diffusion of ideas and skills, the mobility of personnel, the group formation, and the open competition that have been fostered by postdoctoral fellowship programs in the past. Their discontinuation would have very serious adverse effects on the progress of biomedical science.

The result of greatly reducing the postdoctoral training of scientists holding the PhD would have adverse effects not only on the graduate departments, but also on the medical schools. It is from this group that the majority of the faculty members of the preclinical departments of our medical schools are drawn. They cannot be effectively replaced by scientists whose only research experience is the work of their doctoral dissertation. It is through the postdoctoral training that the young scientist acquires the breadth and versatility that are absolutely necessary for high-quality teaching at the graduate level. The Committee concurs in the opinion of the bioscientists contacted in the course of this study that a balanced program of support, including fellowships, traineeships, individual research grants, and institutional grants is essential to the continued improvement of the total system of science and practice essential to the nation's health. Although no data from actual experience could, of course, be adduced from the present study, the Committee believes that elimination of any single branch of the system of support of biomedical science, on the premise that it is less cost-effective than some other branch, would merely diminish the effectiveness of those areas that are to be maintained. The Committee recommends a balanced system, with gradual, rather than sudden changes in emphasis or program, and feels that a retention of fellowships and traineeships is essential to the future of the nation's health system.

The impact of advanced research training on actual delivery of improved health care could not be examined by this committee. The belief in the importance of such research training to health care delivery rests on the sound premise that better training results in better physicians. The direct measurement of this effect must await development of accepted measures of the quality of physician performance. This task was beyond the scope of the present committee. It is felt to be a matter of great importance, and one that should provide quantitative and objective evidence where at present the case must rest on the evidence of informed opinion.

APPENDIX A

A Research-Orientation for Medical Schools

In the absence of any nationally-recognized system for determination of the research-orientation of medical schools, a scale was set up that incorporated elements that related most directly to the objectives of the present study. Published data were available regarding three quantitative measures for most of the medical schools. These three measures were combined in an arbitrarily-weighted system, with the weights arranged so that no single one would affect the rankings more heavily than the average of the other two. The measures used, and their weights in the formula for this scale were as follows: percentage of the alumni who passed one or more U. S. Specialty Boards (weight = 1);percentage of the alumni who were later employed as medical school faculty (weight = 3); percentage of the whole student body who were graduate students or postdoctorals (weight =0.3). Inasmuch as these three factors were positively correlated, the weights might be changed somewhat without greatly altering the positions of the various medical schools in the resulting list. In any case, it is only the final grouping of the schools into six categories, rather than the exact position, that is significant, and it was the average across groups of schools that was used in the further statistical work, so that even the category into which a given school might fall would not have a profound weight in the final result. The several groups of schools, and the list of those for whom insufficient data were available for a determination, are given in Table A-1.

TABLE A-1

Research-Orientation Scale for Medical Schools

Group A; Score = 6

Harvard, Chicago, Johns Hopkins, Yale, Columbia

Group B; Score = 5

Cornell, Rochester, Washington University (St. Louis), New York University, Vanderbilt, Duke, University of Pennsylvania, Case-Western Reserve, Stanford

Group C; Score = 4

University of Virginia, Emory, Boston University, State University of New York at Syracuse, Wisconsin, Minnesota, Michigan, George Washington University, University of California - San Francisco, State University of New York at Brooklyn, Northwestern, State University of New York at Buffalo, University of Washington (Seattle), Tulane, Vermont, University of California at Los Angeles, University of Utah, University of Cincinnati, Eins[illegible]-Yeshiva

Group D; Score = 3

University of Illinois, University of Iowa, Temple, Gray-Wake Forest, University of Southern California, Tufts, St. Louis University, University of Maryland, Baylor, University of Oregon, Georgetown, Pittsburgh, Albany Medical Union, Jefferson Medical College, University of Colorado, Medical College of Virginia, New York Medical College, University of Kansas, Marquette, University of Nebraska, University of Texas, Wayne State University, Ohio State University, University of Oklahoma, Medical College of South Carolina, Women's Medical College (Pa.)

Group E; Score = 2

Indiana University, University of Louisville, University of Arkansas, Loyola, University of Puerto Rico, Hahnemann Medical College, Louisiana State University, Creighton University, University of Tennessee, Chicago Medical School, University of Southwest Texas, University of Alabama, University of Mississippi

Group F; Score = 1

Medical College of Georgia, University of Missouri, Loma Linda University, Howard University, Meharry Medical College

Unrated Schools

University of Arizona, University of California-Davis, University of California-San Diego, University of Connecticut, Florida State School of Medicine, University of Florida, University of Miami, University of South Florida, Southern Illinois University, Rush Medical College, University of Kentucky, University of Massachusetts, University of North Carolina, University of North Dakota, University of South Dakota, West Virginia University, Dartmouth Medical School, University of Nevada School of Medicine, College of Medicine and Dentistry of New Jersey-Newark, College of Medicine and Dentistry of New Jersey-Rutgers, University of New Mexico, State University of New York at Stony Brook, Mount Sinai, Medical College of Ohio-Toledo, Texas Technological University-Lubbock, University of Texas Medical Branch-Galveston, University of Texas Medical School-Houston, Eastern Virginia Medical School

APPENDIX B

Publication and Citation Counts as a Function of Name Frequency

As mentioned in the main body of the report, it was found that it was possible to use with confidence the publication and citation counts only for those persons whose names appeared only once in the list compiled by the Office of Scientific Personnel (OSP) that was matched with the computer tape from the Institute for Scientific Information. This decision was made after an attempt to correct for the frequency with which a given name appeared in the OSP list. In the tabulations that were initially made from the ISI tape, the counts for any given name were divided by the number of times that name appeared in the OSP file. That is, if J. J. Jones appeared ten times in the OSP files, and the total publications count was 120, the number of publications credited to J. J. Jones was 12 - on the basis that we had no way of knowing which publications belonged to which Jones, and that an equal distribution among all the Joneses was the only equitable assignment. As the data were examined, however, it was found that this allotment of the many contributions by persons with the same name would add "more noise than signal" to the analysis, and it was decided to include in the analysis only those whose names appeared once in the files.

The distribution of publication counts for the persons in the file with unique names, and for those whose names appeared two, three, or more time, are given in Table B01. Histograms illustrating these distribution are provided in figure B-1. It is apparent that there is a classical Lazy-J curve for the unique name frequency distribution, and that this curve tends toward the normal form as the name frequency increases. It is reasonable to assume that the counts provided in the unique name column are as nearly accurate as it is possible to get from this source, using the computer techniques that had to be employed for the very large number of cases involved. Thus it appears that about 30% of the people have no publications during the period listed (1961 and 1964-70). However, for the two-person names, there are only 14% with no publications. About half of those with no publications are therefore credited with a publication by someone else having the same name, and that person is accordingly not credited with his own publication, by the "equal division" procedure that was employed. For the three-person names, the number with zero publications falls to about 12%, and for those names appearing four or five times, the zero-publication count falls

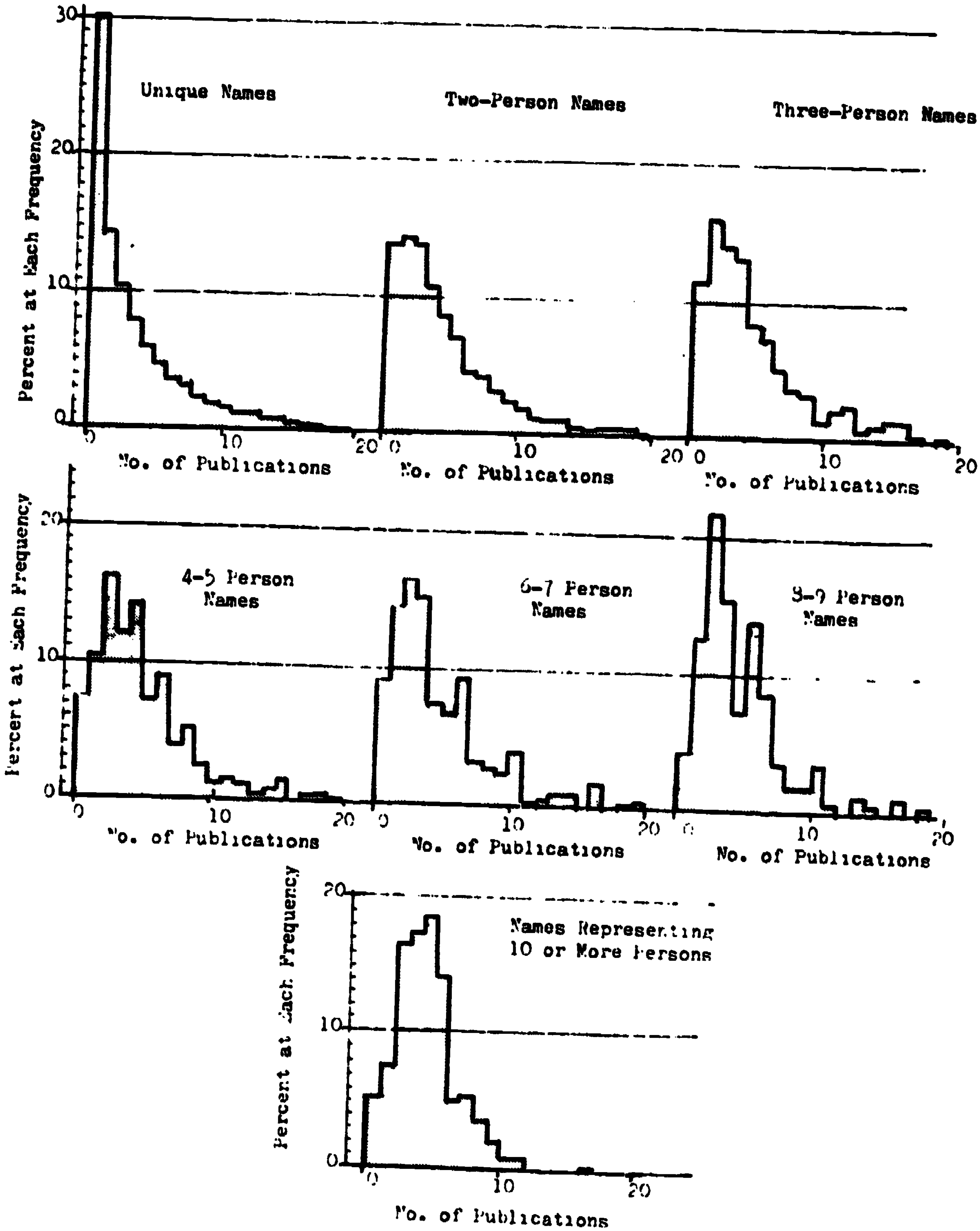
TABLE B-1

Percentage Distributions of Publication Counts as a Function of Name Frequency

Number of Publications	Name Frequency (in percentages) 1	2	3	4 & 5	6 & 7	8 & 9	10 % & over
0	30.5	14.2	11.8	7.3	9.2	4.2	5.5
1	14.4	14.5	16.3	11.3	14.7	12.7	7.6
2	10.4	14.2	14.3	16.2	16.8	21.8	16.8
3	7.8	10.9	13.4	12.2	15.4	15.7	17.6
4	6.0	8.7	8.5	14.2	7.5	7.3	18.7
5	4.7	7.2	7.6	7.3	6.8	13.9	14.5
6	3.8	4.8	5.4	9.0	9.6	8.5	5.3
7	3.3	4.4	3.9	4.0	3.4	3.6	5.5
8	2.6	3.3	3.8	5.2	3.1	1.8	3.7
9	1.9	2.7	1.6	2.9	2.7	1.8	2.4
10	1.8	2.2	2.4	1.4	4.1	3.6	1.1
11	1.4	1.5	2.6	1.7	.3	.6	1.1
12	1.4	1.5	.9	1.4	.7	-	-
13	1.0	1.5	1.1	6	1.0	1.2	-
14	1.0	.9	1.6	.9	1.0	.6	-
15	.8	.9	1.6	1.7	-	-	-
16	.7	.9	.7	.2	2.1	1.2	.3
17	.6	.8	-	.5	-	-	-
18	.7	.8	.3	.6	.3	.6	-
19	.5	.3	.1	.3	.3	-	-
20-29	2.9	2.3	1.8	1.2	.3	.6	-
30-39	1.1	1.0	.1	-	-	-	-
40-49	.4	.3	.1	-	.3	-	-
50-59	.6	.5	-	-	-	-	-
Total Number of Cases	11,616	1,856	761	655	292	165	380

FIGURE B-1

Frequency distributions of publication counts by multiple name-frequency



to 7%. Thus, increasingly, the people with more common names who do not publish are credited with the publications of others with the same name who do publish. In examining the distributions, it should be kept in mind that the exact percentages are less and less reliable as the number of cases decreases from 11,616 unique names to 1,856 two-person names, to 380 names appearing ten or more times. The general trend, however, is quite evident; the assignment at random of publications to persons with common names adds random error to a rather clear-cut distribution curve that is highly skewed in its original form. As the random error increases with larger and larger numbers of persons with the same name, the distribution moves toward the "normal curve of error", as is to be expected. The decision was, therefore, to eliminate this source of random error, and to proceed with those counts that could be relied upon with greatest confidence - those for persons whose names appeared only once in the OSP files.

Data regarding the citation distributions were similar in form, but even more highly skewed. These data are not presented here, but the form of the distribution curve may be observed from the raw count-to-standard score conversion table presented in Appendix C.

Notes on citation counts and citation indexing:

1. For a general review of the process of citation indexing, with bibliography, see Citation Indexes, by Melvin Weinstock, Institute for Scientific Information, 35 Chestnut St., Philadelphia, Pa. 19106, reprinted from Encyclopedia of Library and Information Science, Vol. 5, pages 16-40, Marcel Dekker, N.Y. 1971.

2. For studies of the validity of the citation index, see:

   a. A. E. Bayer and J. Folger, "Some Correlates of a Citation Measure of Productivity in Science," Sociology of Education, 39 (4), 382-390 (1966)

   b. S. Cole and J. R. Cole, "Scientific Output and Recognition: A Study in the Operation of the Reward System in Science," American Sociological Review, 32 (3), 377-390 (1967).

   c. J. Cole and S. Cole, "The Ortega Hypothesis," Science, 27 October 1972, pages 368-375.

APPENDIX C

Converting Raw Publication and Citation Counts to Standard Scores

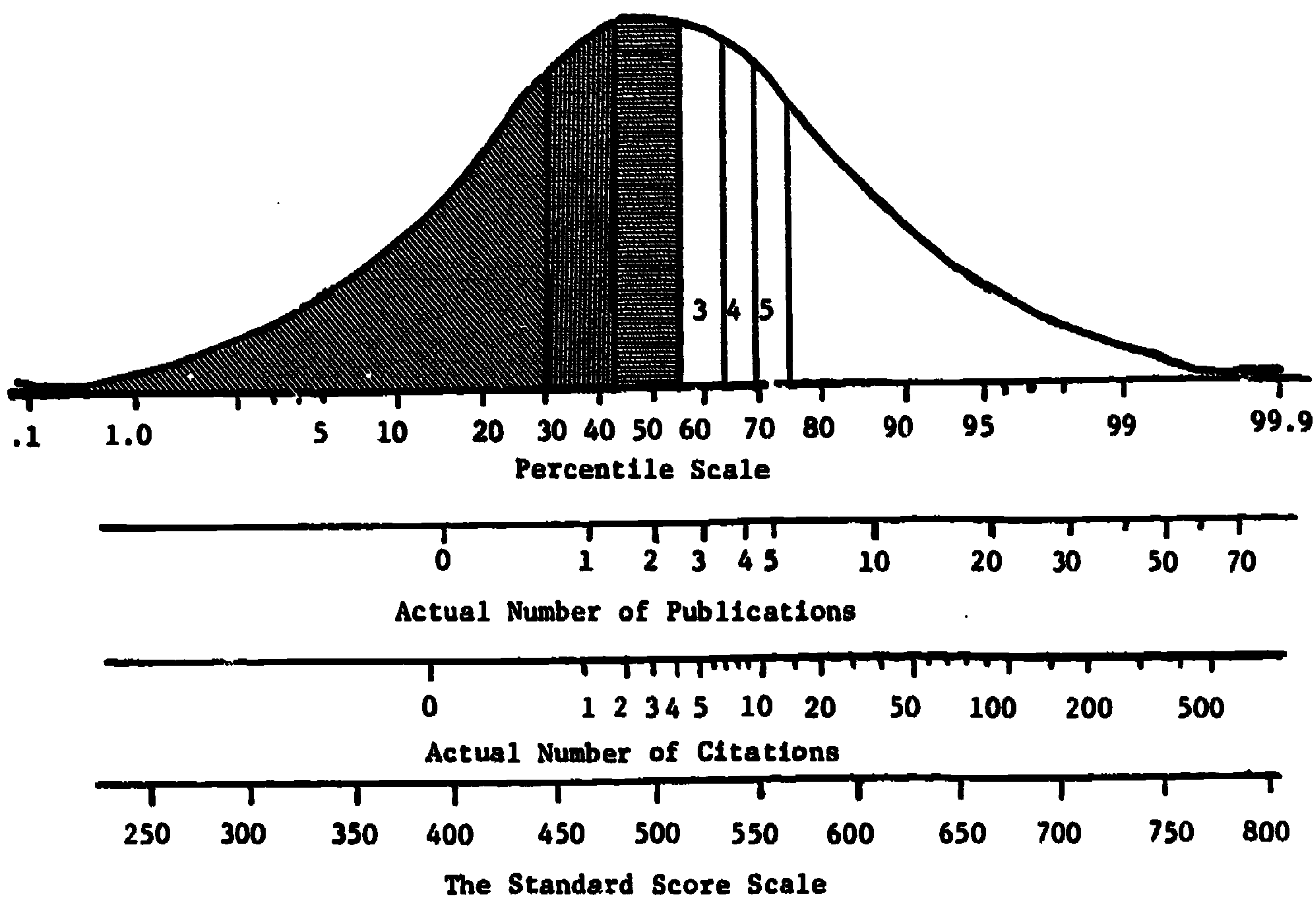
The main body of the report refers briefly to the conversion of the original publication and citation counts to standard scores for the purpose of statistical analysis. This appendix provides some more detail on the procedure by which this conversion, and the re-conversion back to publication and citation counts was made. The population used for this normalization process (18,935 cases) consisted of all of the 1958-1970 bioscience PhD's with unique names, except those of foreign origin who either emigrated or who were uncertain of their plans to stay in the United States.

Whenever one attempts to analyze highly skewed distributions, he must deal with the fact that our standard statistical tools are designed for variables that are normally distributed. In many situations with only a minor degree of skew, the departure from normality can be ignored. In the present case, however, as shown in Appendix B, the skew is extreme and cannot be ignored without serious danger of distorting the final results. Frequently, when skewed distributions such as this are encountered, recourse is had to the logarithms of the values, and means calculated on these logarithms. The result is a geometric mean, and that is quite understandable as such. In the present case, however, 30% of the cases had zero counts for publications and citations. The logarithm of zero is indeterminate, and this alone renders the log conversion unacceptable. Accordingly, another method was chosen - that of converting to standard scores by the assumption that the standard tables relating percentiles to standard scores in the normal distribution will provide suitable values. The results suggest that this conversion process and the subsequent analyses provide meaningful data. For final interpretation of the standard score results, a re-conversion to publication and citation counts was made, using the same table in reverse that was used for the original transmutation. The details of this process are described below.

Figure C-1 on the following page shows the standard normal curve of distribution. It is marked off in the familiar percentile terms - half of the cases fall below and half fall above the central point of the distribution, and the percentiles are spread out toward either tail of the distribution. This normal distribution curve is used here for conversion of the publications and citations counts.

FIGURE C-1

The Normal Curve of Distribution for Converting Publication and Citation Counts to Percentiles and Standard Scores



In the two lines below the percentile scale, the actual number of publications and citations are entered to show the frequency with which they occur. Let us examine the publications scale first. Of all the scientists in the unique-name random sample, 30.5% had no publications of record. This is the largest single group, and is indicated by diagonal shading on the curve. The mid-point of this group would of course be at about the 15th percentile, so zero is entered at this point on the scale for actual number of publications. Next, a zone for the 14.4% with one publication is shown with vertical ruling; it is centered above the 38th percentile point. The zone for two publications is centered on the 50th percentile, or median. Beyond this, the zones are not shaded, but are marked off to incidate the relationship of percentiles to number of publications, up to five. From this point on, the zones are too narrow for graphic illustration, but follow the same logic, and one can see that about 90% had fewer than a dozen publications, and only one in a hundred had over 35 publications.

The same set of steps is used to convert from "raw" citation counts to citation percentiles. It is noteworthy here that, although the zero point and single citation point are at nearly the same positions as the corresponding points for the publication counts, the scale from there on upward is much more compressed. Ten publications and thirty-five citations fall at about the same point (86th percentile), twenty-two publications and one hundred citations fall at about the 96th percentile; while thirty-four publications = 210 citations = 98.5 percentile. The interpretation is clear: few people were cited in the scientific literature during the decade 1961-1970 who had not published during that decade. There are exceptions, of course--Aristotle is still cited occasionally-but the exceptions seem to prove the rule. For the great bulk of cases, in numbers quite sufficient for statistical analysis, citation frequency goes up more rapidly than publications. The correlation between the two counts (described elsewhere in this report) shows that the people who publish most are not only cited most often, but their ratio of citations to publications is higher than that of those who publish infrequently. Again, there are exceptions, but the general tendency is quite clear.

Standard Score Scale

The normalization process referred to earlier involves use of the bottom scale, marked Standard Score Scale (frequently abbreviated to SS). This scale is based on the arbitrary designation of the mean as 500 and the standard deviation as 100. The scale thus provided is familiar to many through its use with a number of standardized tests, such as the Graduate Record Examination. One can, using these scales, convert from raw score to percentile to standard score. The raw score-to-percentile transformation is an empirical one; the second step is based on standard statistical tables. The result, omitting the intermediate percentile step, results in a conversion scheme which is fed into the computer, so that henceforth in the analytical steps one deals with standard scores. The conversion table is presented in Table C-1. For interpretation of the significance of final results, one can re-convert any given standard score to the original count to arrive at an average number of publications or citations for any group - always remembering the statistical route by which such a mean was in fact derived.

TABLE C-1

Table for Converting Publication and Citation Counts to Standard Scores

Publications Count	SS	Publications Count	SS	Citations Count	SS	Citations Count	SS	Citations Count	SS
0	397	40	734	0	390	40	617	80	657
1	468	41	736	1	466	41	618	82	658
2	500	42	738	2	487	42	619	84	659
3	523	43	740	3	500	43	620	86	660
4	541	44	742	4	511	44	621	88	661
5	556	45	744	5	519	45	622	90	662
6	570	46	746	6	527	46	623	92	663
7	581	47	748	7	534	47	624	94	664
8	592	48	750	8	540	48	625	96	665
9	600	49	752	9	545	49	626	98	666
10	608	50	754	10	550	50	627	100	667
11	616	51	756	11	554	51	628	102	668
12	623	52	758	12	558	52	629	104	669
13	630	53	760	13	562	53	630	106	670
14	636	54	762	14	566	54	631	108	671
15	642	55	764	15	569	55	632	110	672
16	648	56	766	16	572	56	633	112	673
17	653	57	768	17	575	57	634	114	675
18	658	58	770	18	578	58	635	116	676
19	663	59	772	19	581	59	636	118	677
20	667	60	774	20	583	60	637	120	678
21	671	61	776	21	585	61	638	122	679
22	675	62	778	22	587	62	639	124	680
23	679	63	780	23	589	63	640	126	682
24	683	64	782	24	591	64	641	128	684
25	687	65	784	25	593	65	642	130	686
26	691	66	786	26	595	66	643	132	687
27	695	67	788	27	596	67	644	134	688
28	699	68	790	28	598	68	645	136	689
29	702	69	792	29	600	69	646	138	690
30	705	70	794	30	602	70	647	140	691
31	708	71	796	31	604	71	648	142	692
32	711	72	798	32	606	72	649	144	694
33	714	73	800	33	608	73	650	146	696
34	717	74	802	34	610	74	651	148	697
35	720	75	804	35	612	75	652	150	698
36	723	76	806	36	613	76	653	152	699
37	726	77	808	37	614	77	654	154	700
38	729	78	810	38	615	78	655	156	701
39	732	79	812	39	616	79	656	158	703

For Publication counts over 79, use: 812 + 2X Publications

For higher citation counts:

$>158<200$: SS = 703 + (Cit-158)/2

$\geq 200<300$: SS = 716 + (Cit-200)/4

$\geq 300<500$: SS = 741 + (Cit-300)/6

$\geq 500<1000$: SS = 775 + (Cit-500)/10

≥ 1000 : SS = 824 + (Cit-1000)/20

APPENDIX D

Correction of Publication and Citation Scores for Environmental and Ability Differences Existing Prior to the PhD

As mentioned in the main body of the report, the differences between the postdoctorals and those not having postdoctoral training was found to be related to variables other than the training as such. It was also related to a measure of ability and/or motivation, and environmental differences existing in the predoctoral period. This appendix describes in somewhat more detail the procedures used to estimate the influence of these correlated variables and to eliminate their effect via the derivation of "corrected scores." All of the statistical procedures described here were performed on the standard scores described in Appendix C. The final results tabulated in the body of the report were re-transformed back to the original publication and citation counts from the corrected standard scores derived as described below, using the standard score transformation table given in Appendix C.

The statistical analyses were originally performed on the data for the two sexes separately, using a series of eight predictor variables for each dependent variable - publication standard score and citation standard score, respectively. As the data given in the following tables show, it was found that only two of these predictors were needed for each dependent variable - the rest contributed negligibly to prediction. Age at PhD came out in both regression formulae, but with a minor weight. It is assumed to be a simple expression of a complex variable involving ability, motivation, and opportunity factors. For predicting the individual's publication standard score, the mean publication standard score (Pub SS Mean) for the individual's institution of PhD was the most valid predictor; for predicting citation standard score the corresponding institutional mean citation standard score (Cit SS Mean) was the most valid predictor. Both of these variables were derived from the publication and citation standard scores earned by the bioscience graduates of the several PhD-granting institutions. They therefore reflected a variable relating to the potentiality of the graduate student body at the respective institutions, and thus an environmental variable for any graduate student in biosciences in those institutions. Because no institutional mean standard scores were used which were based on fewer than sixteen cases (many institutional means were based on over 100 cases) the individual's influence on the standard score for his own institution was negligible. These institutional mean standard scores for publications and citations are given in Table D-1.

The eight predictors used in the regression analyses were as follows:

1. Age at PhD
2. RAM (Roose-Andersen Mean ratings for bioscience departments of the institution from which the individual graduated)
3. Pub SS Mean (Mean publication standard score for the institution of PhD)
4. Cit SS Mean (Mean citation score for the institution of PhD)
5. Cit SS/Pub SS Mean (Mean of the ratio of citation standard score to publication standard score for the alumni of the institution of PhD)
6. Pub SS SD (Standard deviation of publication standard score for institution)
7. Cit SS SD (Standard deviation of citation standard score for institution)
8. Cit SS/Pub SS SD (Standard deviation of the ratios of citation standard score to publication standard score for the alumni, by institution)

The ratio variables, as shown in the regression tables, proved to be insignificant, and have been eliminated. The standard deviation indices also were found to have very low validity, and were eliminated from the final regression formula. The Roose-Andersen mean ratings were found to provide no additional valid variance beyond that furnished by the institutional publication standard score or citation standard score, and thus fell out of the regression formula. The formula finally used to provide each "corrected standard score" was as follows:

Original Standard Score + 500 - Predicted Standard Score

For the several predicted standard scores, the formulae are as follows:

Pub SS, Male:	Age at PhD x -2.[illegible]	+ Pub SS Mean x .10	+ 78.31
Pub SS, Female:	Age at PhD x - .[illegible]	+ Pub SS Mean x .06	+ 152.98
Cit SS, Male:	Age at PhD x -1.09	+ Cit SS Mean x .10	+ 22.29
Cit SS, Female:	Age at PhD x - .55	+ Cit SS Mean x .07	+ 102.54

For those who wish to study the detail of the statistical analysis, Table D-2 provides the statistical constants for the four regressions; Table D-3 provides the intercorrelation tables for the publications, for males and females; Table D-4 provides the intercorrelation tables for citations, for males and females. These are reporductions of the computer printouts, as are the four remaining tables, which give the step-wise development of the regressions. Table D-5 gives the regression data for males on publications, Table D-6 for females on publications, Table D-7 for males on citations, and Table D-8 for females on citations.

TABLE D-1

Institutional Mean Indices Based on Publication and Citation Standard Scores of Bioscience PhD's Graduating 1958-1970

Institution Name	Bioscience PhD's	Institutional Mean Pub SS	Institutional Mean Cit SS
Alabama, Univ. of, Ala.	49	533	505
Arizona State Univ., Arizona	22	482	468
Arizona Univ. of, Arizona	119	506	484
Arkansas, Univ. of, Ark.	29	490	477
Auburn Univ., Alabama	67	506	482
Baylor University - Texas	67	525	497
Boston Univ., Mass.	111	500	483
Brandeis Univ., Mass.	65	544	561
Brown Univ., R. I.	60	531	526
Bryn Mawr College, Pa.	18	463	460
Calif. Inst. of Tech., Cal.	71	562	591
California, U. of, Berkeley	722	542	542
California, Univ. of, Davis	386	552	536
Calif., U. of, Los Angeles	426	541	530
Calif., U. of, Riverside	71	508	468
Calif., U. of, San Diego	44	539	520
Calif., U. of, Santa Barbara	27	514	482
Calif., U. of, San Francisco	87	528	520
Case Western Reserve U., Ohio	114	534	531
Catholic U. of America, D. C.	87	466	467
Chicago, Univ. of, Ill.	315	546	550
Cincinnati, Univ. of, Ohio	91	517	495
City Univ. of New York, N. Y.	22	543	503
Clemson Univ., S. C.	18	512	480
Colorado State Univ., Colo.	130	510	491
Colorado, Univ. of, Colo.	109	507	513
Columbia Univ., N. Y.	254	534	538
Connecticut, Univ. of, Conn.	137	529	501
Cornell Univ., New York	481	541	525
Delaware, Univ. of, Delaware	49	523	508
Duke Univ., N. C.	217	529	523
Emory Univ., Georgia	69	518	514
Florida State Univ., Florida	67	517	517
Florida, Univ. of, Florida	148	530	520
Fordham Univ., N. Y.	77	497	484
George Washington Univ., D. C.	109	566	559
Georgetown Univ., D. C.	92	548	542
Georgia, Univ. of, Ga.	133	518	497
Hahnemann Med. Coll/Hos., Pa.	40	533	518
Harvard Univ., Mass.	374	551	562
Hawaii, Univ. of, Hawaii	70	530	508

Institution Name	Bioscience PhD's	Institutional Mean Pub SS	Institutional Mean Cit SS
Howard Univ., D. C.	24	505	476
Illinois Inst. of Tech., Ill.	30	494	474
Illinois, Univ. of, Ill.	658	535	[illegible]
Indiana Univ., Indiana	231	519	513
Iowa State Univ., Iowa	340	518	499
Iowa, Univ. of, Iowa	228	532	513
Johns Hopkins Univ., Md.	274	538	546
Kansas St. U. of Ag&ApSc., Kan.	152	522	502
Kansas, Univ. of, Kansas	211	514	501
Kentucky, Univ. of, Ky.	51	533	487
Lehigh Univ., Pa.	16	523	500
La. St. U. & Ag&Mech. Col., La.	135	509	496
Louisville, Univ. of, Ky.	55	540	505
Loyola Univ., Illinois	66	534	497
Marquette Univ., Wis.	52	546	501
Maryland, Univ. of, Md.	247	525	521
Mass. Inst. of Tech., Mass.	91	540	569
Massachusetts, Univ. of, Mass.	97	522	487
Miami, Univ. of, Florida	76	526	520
Michigan State Univ., Mich.	341	526	513
Michigan, Univ. of, Mich.	448	530	527
Minnesota, Univ. of, Minn.	583	559	536
Mississippi State Univ., Miss.	37	501	468
Mississippi, Univ. of, Miss.	73	548	517
Missouri, Univ. of, Columbia	152	520	498
Montana State Univ., Montana	59	510	503
Nebraska, Univ. of, Nebr.	118	510	483
New Hampshire, Univ. of, N. H.	44	523	503
New Mexico, Univ. of - N.M.	16	508	498
New York Univ., New York	244	536	525
N.C. State Univ., Raleigh	176	537	514
North Carolina, Univ. of, N.C.	185	503	493
North Dakota State Univ., N.D.	26	469	457
North Dakota, Univ. of, N.D.	33	538	514
Northwestern Univ., Ill.	155	535	520
Notre Dame Univ., Ind.	53	496	498
Ohio State Univ., Ohio	398	521	505
Oklahoma State Univ., Okla.	129	504	494
Oklahoma, Univ. of, Okla.	169	511	497
Oregon State Univ., Ore.	261	514	499
Oregon, Univ. of, Ore.	101	521	514

TABLE D-1 Continued

Institution Name	No.	Institutional Mean Pub SS	Institutional Mean Cit SS
Pennsylvania State Univ., Pa.	216	525	508
Pennsylvania, Univ. of, Pa.	232	546	541
Philadelphia Col. Phar&Sci.,Pa.	18	552	535
Pittsburgh, Univ. of, Pa.	198	519	510
Princeton Univ., N. J.	59	539	553
Purdue Univ., Ind.	594	517	509
Rhode Island, Univ. of, R. I.	53	507	488
Rice Univ., Texas	27	513	483
Rochester, Univ. of, N. Y.	168	537	528
Rockefeller Univ., N. Y.	105	587	612
Rutgers, The State Univ., N.J.	363	519	510
St. Bonaventure Univ., N.Y.	22	459	439
St. Johns Univ., N.Y.	57	493	458
St. Louis Univ., Mo.	76	541	516
South Dakota, Univ. of, S.D.	23	521	471
So. California, Univ. of, Cal.	133	532	527
Southern Illinois Univ., Ill.	39	520	481
Stanford Univ., Cal.	186	534	528
SUNY Col. at Syracuse, N.Y.	17	501	486
SUNY Med. Center Downst., N.Y.	43	570	524
SUNY at Buffalo, New York	153	539	500
SUNY Med. Center Upstate, N.Y.	33	557	538
Syracuse Univ., N.Y.	81	519	521
Temple Univ., Pa.	62	527	514
Tennessee, Univ. of, Tenn.	159	522	509
Texas A & M Univ., Texas	178	528	495
Texas, Univ. of, Texas	338	532	526
Thomas Jefferson Univ., Pa.	58	536	483
Tufts Univ., Mass.	43	554	542
Tulane Univ. of La., La.	171	526	501
Utah State U. Of Ag&ApSc.,Utah	61	519	491
Utah, Univ. of, Utah	128	522	521
Vanderbilt Univ., Tenn.	77	520	512
Vt., U. of, St. Agr. Col., Vt.	33	509	499
Va. Commonwealth U. Med., Va.	37	564	507
Virginia Polytech. Inst., Va.	81	508	487
Virginia, Univ. of, Va.	39	478	471
Washington State Univ., Wash.	116	522	504
Washington Univ., Mo.	73	524	508
Washington, Univ. of, Wash.	231	543	542
Wayne State Univ., Mich.	85	526	494
West Virginia Univ., W. Va.	98	522	492
Wisconsin, Univ. of, Wis.	874	543	538
Wyoming, Univ. of, Wyo.	33	474	445
Yale University Conn.	226	546	554
Yeshiva Univ., New York	27	578	557

TABLE D-2

Statistical Constants for Regression Analyses of Bioscience PhD's

Variable	Males N = 15,135		Females N = 2,622	
Regression on Publications Standard Score				
	Mean	SD	Mean	SD
1. Publications SS	537.2	93.4	490.0	83.8
2. Age at PhD	31.5	4.9	32.3	6.5
3. Roose-Andersen Mean	290.9	74.9	295.3	77.8
4. Publications SS Mean	5303.2	160.0	5302.7	176.1
5. Citations SS Mean	5194.7	221.0	5217.6	233.6
6. Cit. SS/Pub. SS Mean	986.9	21.7	990.7	21.6
7. Publications SS S.D.	920.5	82.0	919.3	76.3
8. Citations SS S.D.	928.6	81.0	947.8	82.3
9. Cit. SS/Pub. SS S.D.	139.0	10.0	139.6	10.7
Regression on Citation Standard Score				
	Mean	SD	Mean	SD
1. Citations SS	524.7	95.6	490.8	92.4
2. Age at PhD	31.5	4.9	32.3	6.5
3. Roose-Andersen Mean	290.9	74.9	295.3	77.8
4. Publications SS Mean	5303.2	160.0	5302.7	176.1
5. Citations SS Mean	5194.7	221.0	5217.6	233.6
6. Cit. SS/Pub. SS Mean	986.9	21.7	990.7	21.6
7. Publications SS S.D.	920.5	82.0	919.3	76.3
8. Citations SS S.D.	928.6	81.0	947.8	82.3
9. Cit. SS/Pub. SS S.D.	139.0	10.0	139.6	10.7

TABLE D-3

Correlation Matrices for Males and Females, for Prediction of Individual Publication Standard Scores

STANDARD ERROR OF ZERO R (N USED = 15135) = .0081 - MALE

Variable	1	2	3	4	5	6	7	8	9
1 PUB SS	1.0000	-.1373	.1161	.1809	.1620	.0603	.1024	.1307	-.011[illegible]
2 AGE AT PHD	-.1373	1.0000	-.1090	-.0650	-.0995	-.0920	.0167	-.0549	.0163
3 RAN	.1161	-.1090	1.0000	.5994	.7222	.5578	.3576	.4970	.0355
4 PUB SS MEAN	.1809	-.0650	.5994	1.0000	.8597	.2728	.5600	.6408	-.0736
5 CIT SS MEAN	.1620	-.0995	.7222	.8597	1.0000	.7208	.4933	.7417	.0456
6 CIT SS/PUB SS MEAN	.0603	-.0920	.5578	.2728	.7208	1.0000	.2473	.4998	.2742
7 PUB SS S.D.	.1024	.0167	.3576	.5600	.4933	.2473	1.0000	.5960	.2806
8 CIT SS S.D.	.1307	-.0549	.4970	.6408	.7417	.4998	.5960	1.0000	.0439
9 CIT SS/PUB SS S.D.	-.011[illegible]	.0163	.0355	-.0736	.0456	.2742	.2806	.0439	1.0000

FEMALE : STANDARD ERROR OF ZERO R (N USED = 2622) = .0195

Variable	1	2	3	4	5	6	7	8	9
1 PUB SS	1.0000	-.0641	.0931	.1470	.1382	.0508	.0510	.1001	-.0270
2 AGE AT PHD	-.0641	1.0000	-.1587	-.1549	-.1558	-.0718	-.0639	-.1224	.0393
3 RAN	.0731	-.1587	1.0000	.6220	.7357	.5417	.3469	.4575	-.0481
4 PUB SS MEAN	.1470	-.1549	.6220	1.0000	.8767	.2456	.5119	.5885	-.1909
5 CIT SS MEAN	.1382	-.1558	.7357	.8767	1.0000	.6768	.4722	.6913	-.0503
6 CIT SS/PUB SS MEAN	.0508	-.0718	.5417	.2456	.6768	1.0000	.2335	.4533	.2763
7 PUB SS S.D.	.0510	-.0639	.3469	.5119	.4722	.2335	1.0000	.5834	.1949
8 CIT SS S.D.	.1001	-.1224	.4575	.5885	.6913	.4533	.5834	1.0000	-.0226
9 CIT SS/PUB SS S.D.	-.0273	.0393	-.0481	-.1909	-.0503	.2763	.1949	-.0226	1.0000

TABLE D-4

Correlation Matrices for Males and Females, for Prediction of Individual Citation Standard Scores

MALE

Variable	1	2	3	4	5	6	7	8	9
1 CIT SS	1.0000	-.0803	.1802	.2091	.2447	.1779	.1184	.1896	.0077
2 AGE AT PHD	-.0803	1.0000	-.1090	-.0650	-.0995	-.0920	.0167	-.0549	-.0163
3 RAM	.1802	-.1090	1.0000	.5994	.7222	.5578	.3576	.4970	.0355
4 PUB SS MEAN	.2091	-.0650	.5994	1.0000	.8597	.2728	.5600	.6408	-.0736
5 CIT SS MEAN	.2447	-.0995	.7222	.8597	1.0000	.7208	.4933	.7417	.0456
6 CIT SS/PUB SS MEAN	.1779	-.0920	.5578	.2728	.7208	1.0000	.2473	.4998	.2742
7 PUB SS S.D.	.1184	.0167	.3576	.4630	.4933	.2473	1.0000	.5960	.2806
8 CIT SS S.D.	.1896	-.0549	.4970	.6408	.7417	.4998	.5960	1.0000	.0439
9 CIT SS/PUB SS S.D.	.0077	.0163	.0355	-.0736	.0456	.2742	.2806	.0439	1.0000

FEMALE

Variable	1	2	3	4	5	6	7	8	9
1 CIT SS	1.0000	-.0703	.1549	.1640	.2031	.1595	.0807	.1382	.0231
2 AGE AT PHD	-.0703	1.0000	-.1587	-.1549	-.1558	-.0718	-.0639	-.1224	.0393
3 RAM	.1547	-.1587	1.0000	.6220	.7357	.5417	.3469	.4575	-.0481
4 PUB SS MEAN	.1649	-.1549	.6220	1.0000	.8767	.2456	.5119	.5895	-.1909
5 CIT SS MEAN	.2031	-.1558	.7357	.8767	1.0000	.6768	.4722	.6913	-.0503
6 CIT SS/PUB SS MEAN	.1595	-.0718	.5417	.2456	.6768	1.0000	.2335	.4533	.2763
7 PUB SS S.D.	.0807	-.0639	.3469	.5119	.4722	.2335	1.0000	.5834	.1349
8 CIT SS S.D.	.1382	-.1224	.4575	.5895	.6513	.4533	.5834	1.0000	-.0226
9 CIT SS/PUB SS S.D.	.0731	.0393	-.0481	-.1909	-.0503	.2763	.1349	-.0226	1.0000

TABLE D-5

Stepwise Computation of Multiple Regression of Predictor Variables on Publication Standard Score - Males

MULTIPLE R — INDIVIDUAL PUBLICATIONS SS

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
0 PUB SS	.0000	.0000	.0000	.000	1, 15134	.000	0, 15134	93.419

VARIABLE		COEFF	BETA
PUB SS	0	537.2579	

F-COEFF LEVEL OF SIGNIFICANCE =1.000 F-TOT LEVEL OF SIGNIFICANCE =1.000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
4 PUB SS MEAN	.0327	.1809	.1809	511.799	1, 15133	511.799	1, 15133	91.878

VARIABLE		COEFF	BETA
PUB SS	0	-22.5702	
PUB SS MEAN	4	.1056	.1809

F-COEFF LEVEL OF SIGNIFICANCE = .000 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
2 AGE AT PHD	.0485	.2203	.1279	251.542	1, 15132	385.908	2, 15132	91.124

VARIABLE		COEFF	BETA
PUB SS	0	78.3162	
AGE AT PHD	2	-2.3311	-.1260
PUB SS MEAN	4	.1008	.1727

F-COEFF LEVEL OF SIGNIFICANCE = .000 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
8 CIT SS S.D.	.0488	.2210	.0176	4.672	1, 15131	258.891	3, 15131	91.110

VARIABLE		COEFF	BETA
PUB SS	0	98.4705	
AGE AT PHD	2	-2.3855	-.1257
PUB SS MEAN	4	.0924	.1584
CIT SS S.D.	8	.0257	.0223

F-COEFF LEVEL OF SIGNIFICANCE = .031 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
5 CIT SS MEAN	.0489	.2211	.0074	.827	1, 15130	194.373	4, 15130	91.108

VARIABLE		COEFF	BETA
PUB SS	0	96.2104	
AGE AT PHD	2	-2.3976	-.1264
PUB SS MEAN	4	.0966	.1609
CIT SS MEAN	5	-.0069	-.0162
CIT SS S.D.	8	.0318	.0276

F-COEFF LEVEL OF SIGNIFICANCE = .363 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
6 CIT SS/PUB SS MEAN	.0489	.2211	.0039	.226	1, 15129	155.536	5, 15129	91.107

VARIABLE		COEFF	BETA
PUB SS	0	-24.1829	
AGE AT PHD	2	-2.4022	-.1266
PUB SS MEAN	4	.1207	.2068
CIT SS MEAN	5	-.0299	-.0708
CIT SS/PUB SS MEAN	6	.1226	.0225
CIT SS S.D.	8	.0340	.0295

F-COEFF LEVEL OF SIGNIFICANCE = .635 F-TOT LEVEL OF SIGNIFICANCE = .000

TABLE D-6

Stepwise Computation of Multiple Regression of Predictor Variables on Publication Standard Score - Females

MULTIPLE R — INDIVIDUAL PUBLICATIONS SS

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY	VARIABLE	COEFF	BETA
0 PUB SS	.0000	.0000	.0000	.000	1, 2621	.000	0, 2621	83.882	PUB SS 0	490.0568	

F-COEFF LEVEL OF SIGNIFICANCE =1.000 F-TOT LEVEL OF SIGNIFICANCE =1.000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY	VARIABLE	COEFF	BETA
4 PUB SS MEAN	.0216	.1470	.1470	57.892	1, 2620	57.892	1, 2620	82.970	PUB SS 0	118.8784	
									PUB SS MEAN 4	.0700	.1470

F-COEFF LEVEL OF SIGNIFICANCE = .000 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY	VARIABLE	COEFF	BETA
2 AGE AT PHD	.0234	.1529	.0423	4.700	1, 2619	31.337	2, 2619	82.896	PUB SS 0	152.9212	
									AGE AT PHD 2	-.5423	-.0424
									PUB SS MEAN 4	.0669	.1405

F-COEFF LEVEL OF SIGNIFICANCE = .030 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY	VARIABLE	COEFF	BETA
7 PUB SS S.D.	.0241	.1553	.0278	2.031	1, 2618	21.577	3, 2618	82.864	PUB SS 0	143.5326	
									AGE AT PHD 2	-.5359	-.0419
									PUB SS MEAN 4	.0747	.1569
									PUB SS S.D. 7	-.0352	-.0320

F-COEFF LEVEL OF SIGNIFICANCE = .154 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY	VARIABLE	COEFF	BETA
8 CIT SS S.D.	.0250	.1580	.0293	2.247	1, 2617	16.752	4, 2617	82.828	PUB SS 0	158.4876	
									AGE AT PHD 2	-.5168	-.0404
									PUB SS MEAN 4	.0675	.1418
									PUB SS S.D. 7	-.0517	-.0471
									CIT SS S.D. 8	.0399	.0392

F-COEFF LEVEL OF SIGNIFICANCE = .134 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY	VARIABLE	COEFF	BETA
9 CIT SS/PUB SS S.D.	.0251	.1585	.0123	.396	1, 2616	13.478	5, 2616	82.822	PUB SS 0	136.5996	
									AGE AT PHD 2	-.5172	-.0404
									PUB SS MEAN 4	.0698	.1467
									PUB SS S.D. 7	-.0574	-.0523
									CIT SS S.D. 8	.0404	.0397
									CIT SS/PUB SS S.D. 9	.1027	.0131

F-COEFF LEVEL OF SIGNIFICANCE = .529 F-TOT LEVEL OF SIGNIFICANCE = .000

TABLE D-7

Stepwise Computation of Multiple Regression of Predictor Variables on Citation Standard Score - Males

MULTIPLE R — INDIVIDUAL CITATIONS SS

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
0 CIT SS	.0000	.0000	.0000	.000	1, 15134	.000	0, 15134	95.619

VARIABLE		COEFF	BETA
CIT SS	0	524.7066	

F-COEFF LEVEL OF SIGNIFICANCE =1.000 F-TOT LEVEL OF SIGNIFICANCE =1.000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
5 CIT SS MEAN	.0599	.2447	.2447	963.748	1, 15133	963.748	1, 15133	92.713

VARIABLE		COEFF	BETA
CIT SS	0	-25.0322	
CIT SS MEAN	5	.1058	.2447

F-COEFF LEVEL OF SIGNIFICANCE = .000 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
2 AGE AT PHD	.0630	.2511	.0580	51.126	1, 15132	509.033	2, 15132	92.556

VARIABLE		COEFF	BETA
CIT SS	0	22.2946	
AGE AT PHD	2	-1.0981	-.0565
CIT SS MEAN	5	.1034	.2391

F-COEFF LEVEL OF SIGNIFICANCE = .000 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
8 CIT SS S.D.	.0632	.2514	.0141	3.021	1, 15131	340.408	3, 15131	92.547

VARIABLE		COEFF	BETA
CIT SS	0	34.2636	
AGE AT PHD	2	-1.1056	-.0569
CIT SS MEAN	5	.0968	.2239
CIT SS S.D.	8	.0241	.0204

F-COEFF LEVEL OF SIGNIFICANCE = .082 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
7 PUB SS S.D.	.0632	.2515	.0043	.274	1, 15130	255.362	4, 15130	92.546

VARIABLE		COEFF	BETA
CIT SS	0	35.3333	
AGE AT PHD	2	-1.0999	-.0566
CIT SS MEAN	5	.0971	.2245
PUB SS S.D.	7	-.0060	-.0052
CIT SS S.D.	8	.0272	.0230

F-COEFF LEVEL OF SIGNIFICANCE = .601 F-TOT LEVEL OF SIGNIFICANCE = .000

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
3 RAN	.0633	.2515	.0034	.176	1, 15129	204.314	5, 15129	92.546

VARIABLE		COEFF	BETA
CIT SS	0	41.4615	
AGE AT PHD	2	-1.0964	-.0565
RAP	3	.0061	.0048
CIT SS MEAN	5	.0955	.2208
PUB SS S.D.	7	-.0062	-.0053
CIT SS S.D.	8	.0277	.0235

F-COEFF LEVEL OF SIGNIFICANCE = .675 F-TOT LEVEL OF SIGNIFICANCE = .000

TABLE D-8

Stepwise Computation of Multiple Regression of Predictor Variables on Citation Standard Score - Females

MULTIPLE R — - - - — INDIVIDUAL CITATIONS SS

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
0 CIT SS	.0000	.0000	.0000	.000	1, 2621	.000	0, 2621	92.421

F-COEFF LEVEL OF SIGNIFICANCE =1.000 F-TOT LEVEL OF SIGNIFICANCE =1.000

VARIABLE		COEFF	BETA
CIT SS	0	490.8345	

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
5 CIT SS MEAN	.0412	.2031	.2031	112.668	1, 2620	112.668	1, 2620	90.456

F-COEFF LEVEL OF SIGNIFICANCE = .000 F-TOT LEVEL OF SIGNIFICANCE = .000

VARIABLE		COEFF	BETA
CIT SS	0	71.7617	
CIT SS MEAN	5	.0803	.2031

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
2 AGE AT PHD	.0428	.2068	.0399	4.186	1, 2619	58.496	2, 2619	90.424

F-COEFF LEVEL OF SIGNIFICANCE = .041 F-TOT LEVEL OF SIGNIFICANCE = .000

VARIABLE		COEFF	BETA
CIT SS	0	102.5434	
AGE AT PHD	2	-.5534	-.0396
CIT SS MEAN	5	.0779	.1969

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
9 CIT SS/PUB SS S.D.	.0440	.2097	.0353	3.275	1, 2618	40.123	3, 2618	90.367

F-COEFF LEVEL OF SIGNIFICANCE = .070 F-TOT LEVEL OF SIGNIFICANCE = .000

VARIABLE		COEFF	BETA
CIT SS	0	58.1249	
AGE AT PHD	2	-.5741	-.0407
CIT SS MEAN	5	.0735	.1965
CIT SS/PUB SS S.D.	9	.2926	.0346

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
7 PUB SS S.D.	.0446	.2112	.0263	1.809	1, 2617	30.554	4, 2617	90.336

F-COEFF LEVEL OF SIGNIFICANCE = .179 F-TOT LEVEL OF SIGNIFICANCE = .000

VARIABLE		COEFF	BETA
CIT SS	0	53.5555	
AGE AT PHD	2	-.5729	-.0406
CIT SS MEAN	5	.0842	.2132
PUB SS S.D.	7	-.0363	-.0300
CIT SS/PUB SS S.D.	9	.3526	.0459

ENTER	R**2	R	PART. R	F-COEFF	N1, N2 DF	F-TOT	N1, N2 DF	SY
4 PUB SS MEAN	.0448	.2117	.0137	.493	1, 2616	24.537	5, 2616	90.328

F-COEFF LEVEL OF SIGNIFICANCE = .482 F-TOT LEVEL OF SIGNIFICANCE = .000

VARIABLE		COEFF	BETA
CIT SS	0	91.1960	
AGE AT PHD	2	-.5792	-.0411
PUB SS MEAN	4	-.0113	-.0310
CIT SS MEAN	5	.0938	.2312
PUB SS S.D.	7	-.0237	-.0246
CIT SS/PUB SS S.D.	9	.3036	.0352

APPENDIX E

A Broader Context for Interpretation of the Effects of Postdoctoral Training on the Career Lines and Career Achievements of Bioscientists

The main portion of this report deals with the effects of NIGMS postdoctoral training, and provides some comparison groups by means of which the effects of the fellowships and traineeships may be evaluated. It was felt important, however, to look beyond the NIGMS programs alone, to seek to determine whether postdoctoral training, however supported, had important career effects. The means for this broader outlook were provided by the procedures necessary for the study of the NIGMS cases. As described in Appendixes C and D, the entire 1958-1970 bioscience PhD population was available for analysis; all that was required was information about their post-PhD careers. The first post-PhD datum was that provided by the Survey of Earned Doctorates/Doctorate Records File, regarding plans for the first year after graduation. Other data were provided by the 1970 National Register of Scientific and Technical Personnel, and by the 1970 National Faculty Directory. The combined data were analyzed to provide answers to such questions as:

1. What are the career streams upon which the NIGMS program is imposed, and which in turn are modified by the NIGMS programs of support?

2. How many people are involved in these various patterns, including postdoctorals?

3. What is the quantitative relationship between predoctoral and postdoctoral fellowship programs in the staffing of colleges and universities?

4. What are the quantitative relationships between career patterns or roles, and publication and citation achievements?

For these analyses, the 1958-1970 PhD bioscientists who were clearly identified by the "unique name" procedure described in Appendix B, were selected. Excluded from the analysis were those PhD's of foreign origin who either went abroad after completion of the PhD, or who were uncertain as to their postdoctoral plans (many of whom may be expected to have returned to their home countries). This left a population of 18,935 bioscientists whose careers were analyzed in terms of the kinds of data that could be secured about them from the Doctorate Records File, the National Register, the National Faculty Directory, and the Institute for Scientific Information. The career achievement data for this analysis were limited to the corrected publication and citation standard scores for people pursuing various career lines. Because the data collected by the Doctorate Records File changed from time to time, all of the desired data were not available for the earliest cohorts. However, for the period 1961-1970, there were a total of 16,191 bioscience PhD's for whom all the needed data were available, including important data regarding activity in the predoctoral year which provided a somewhat longer view of the career lines of these people.

Career Lines of Bioscientists

It was found, by sorting the new PhD's by activity in the predoctoral year, that some of the career patterns that later became important were clearly foreshadowed prior to the doctorate. For example, a significant proportion of the graduates had been employed by colleges or universities in faculty positions before the doctorate was earned. This group was already heavily committed to teaching--not exclusively, but in far larger proportion than were PhD's as a whole. Another important set of factors is that related to holding of a predoctoral fellowship. All those on fellowships, from whatever source, were grouped and their subsequent careers analyzed. They, too, showed a different pattern from PhD's as a whole--one more heavily committed to research. To bring out and quantify these differences, the 16,191 bioscience PhD's of the period from 1961-70, (the only years for which the necessary data were available) were sorted into three categories based on experience in the predoctoral year: those on fellow-ships, those working full-time in colleges or universities, and all others. The results are shown in Table E-1 and Figure E-1. Here the data for the whole 1961-70 period are combined, and both sexes included, as only minor sex differences appeared in these data. (The data on predoctoral year experience and plans at PhD were gathered from the Survey of Earned Doctorates, as mentioned above, while the data on employer categories in 1970 were obtained from the National Register and the National Faculty Directory.)

Constancy of Career Patterns

Table E-1 and Figure E-1 show quite dramatically the constancy of career patterns over time. At the left in both table and figure, the total of the 16,191 bioscientists are broken out according to their principal activity in the year preceding the doctorate. Of the total, 34.4% held fellowships, 14% were academically employed, and 51.6% were in all other categories. Progressing across the page, we find these three groups broken out by categories of plans at the time of PhD graduation (middle of page), and finally, at the right, the categories of employment actually found on follow-up through the 1970 National Register of Scientific and Technical Personnel and the National Faculty Directory.

Plans at the time of graduation tend to follow the actual activity categories of the predoctoral year. That is, of those on fellowships, the majority (51%) planned to continue with postdoctoral fellowships, traineeships, or other types of training. About 30% planned immediate academic employment, and about 18% planned to enter nonacademic employment. Slightly over 1% were uncertain of their plans; this percentage goes up fractionally with the other groups. Of those who were already employed full time in academic work at the time of graduation, three quarters planned to continue such employment, 13% planned postdoctoral training, and only 11% planned nonacademic employment. For the rest of the graduates, with their various types of support during the predoctoral year, the percentages in the three categories of plans were nearly equal--roughly one third planned further training and a third each academic and nonacademic employment.

Moving on to the actual employment in 1970, we note a continuation of the same patterns. Among the holders of predoctoral fellowships, academic employment is found for half of the cases, nonacademic employment for one

TABLE E-1

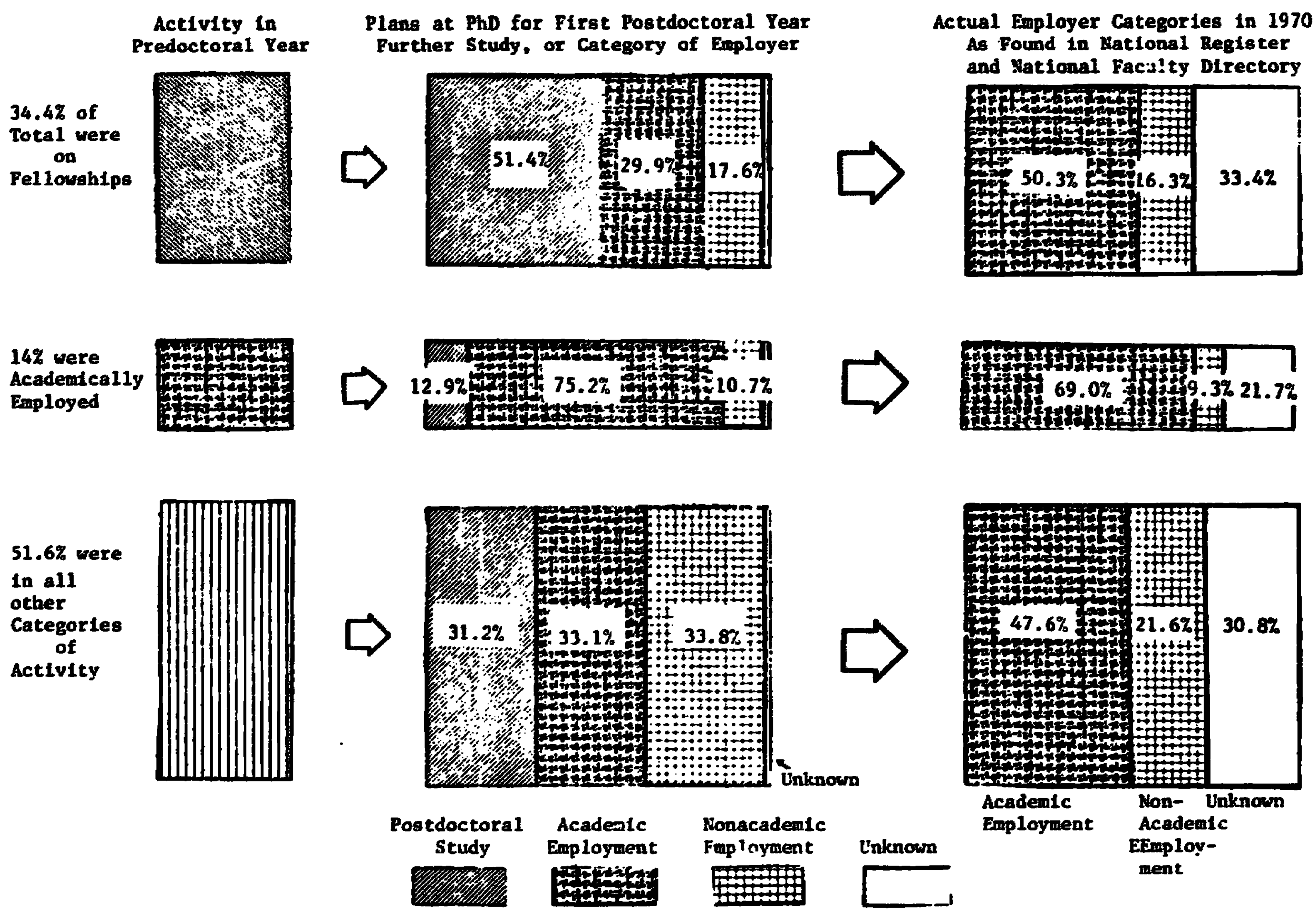
Plans at PhD and Later Employment of Bioscientists, Sorted by Activity in the Predoctoral Year (1961-1970 Graduation Cohorts, Men and Women Combined)

Category of Activity in Predoctoral Year	Plans at PhD Graduation								Employment in 1970*					
	Postdoctoral Training		Immediate Employment				Unknown		Academic		Nonacademic		Unknown	
			Academic		Nonacademic									
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Total = 16,191	5759	35.6	6132	37.9	4042	25.[illegible]	258	1.6	8340	51.5	2924	18.1	4927	30.4
Fellowship Holders N = 5566 (34.4%)	2861 (49.7)	51.4	1662 (27.1)	29.9	977 (24.2)	17.6	66 (25.6)	1.2	2799 (33.6)	50.3	910 (31.1)	16.3	1857 (37.7)	33.4
Full-Time Employed in Colleges and Universities N = 2266 (14.0%)	292 (5.1)	12.9	1703 (27.8)	75.2	242 (6.0)	10.7	29 (11.2)	1.3	1563 (18.7)	69.0	211 (7.2)	9.3	492 (10.0)	21.7
All Other Activities N = 8359 (51.6%)	2606 (45.3)	31.2	2767 (45.1)	33.1	2823 (69.8)	33.8	163 (63.2)	1.9	3978 (47.7)	47.6	1803 (61.7)	21.6	2578 (52.3)	30.8

* Note: The percentages in parentheses show the proportion of the column total in each row.

FIGURE E-1

Constancy of Career Plans, bioscience PhD's of 1961-1970



sixth, and for the remaining third, actual employment could not be determined because the people could not be identified in the available data banks. Turning to those who originally were employed in colleges and universities, we see that 69% are still so employed, while only 9% are employed in non-academic positions, and employment could not be determined for 22%. Finally, for the "all other" category, we find academic employment for 48%, nonacademic employment for 22%, while for 31% employer category could not be determined.

Another way of looking at the same data is to consider the column percentages. That is, Table E-1 shows that although fellowship holders constituted only 34% of the entire group, they constituted approximately half of those who went into postdoctoral training, while the 14% who were employed in academic positions in the predoctoral year constituted only 5% of the postdoctoral fellows. Going on to 1970 employment, the divisions are more nearly equal, but it is still apparent that the 14% employed in academe in the predoctoral year constituted 18.7% of all those so employed in 1970.

The data of Table E-1 and Figure E-1 give only one of several possible aspects of the career continuity picture. One can also begin with plans at PhD and follow up to the data available in 1970. Using the same 1961-70 bioscientists, Table E-2 and Figure E-2 show data on the constancy of career patterns from this perspective. They indicate the extent to which plans at the time of graduation are an indicator of actual career outcomes in later years. Do individuals carry out their plans, and continue in the same patterns, or do career patterns change significantly in the period following the degree?

In Table E-2, the top row gives the data for the total of all bioscience cases in the 1961-70 group for whom data were available from the National Register regarding 1970 employment. There were 8,797 total cases in this group; of this total, 5,924 (67%) were found to be in academic jobs, and 2,873 (33%) in nonacademic jobs. The academically-employed are further broken out into those primarily in research (32% of grand total), teaching (31%) and all other (5%). The nonacademic 33% is divided into those engaged primarily in research (22%) and all others. Each row of the table is similarly subdivided. The grand total shown in the top row is divided in the rows below according to plans at PhD: postdoctoral training (35%) vs. immediate employment (65%), in the second and third rows, respectively. Those planning immediate employment are divided into the academics (40%, row 4) and nonacademic (25%, row 8). The plans for employment are then subdivided in the same way as the actual employment: the academics into research, teaching, and all other; the nonacademics into research and all other. The table thus permits a direct evaluation of the extent to which plans at PhD are translated into the realities of employment several years later. Figure E-2 shc ne same data graphically: The top diagram shows the employment outcome .. those who planned postdoctoral training; the middle diagram shows the e. oyment outcomes for those who planned academic employment; and the bottom diagram shows the outcomes for those who planned nonacademic employment. Within each of these three diagrams, the total number of cases is shown, in percentage terms, broken into the same five categories of employment as shown in Table E-2: academic research, teaching, and other; and nonacademic research and all other.

The constancy of career patterns, or carry-over of plans into actions, is clearly visible in Table E-2 and Figure E-2, in particular with respect to academic vs. nonacademic employment. Of those planning academic employment, 89% are so employed, and 54% in teaching, primarily. Of those planning nonacademic employment, only 28% are later found in academe and only 13% in teaching. For this group, research in a nonacademic setting employs 48%, other nonacademic work, 24%. Of the postdoctorals, who constitute the main focus of concern here, 72% are found in academic employment (52% in research and 17% in teaching) while the 28% in nonacademic employment are divided 22% in

TABLE E-2

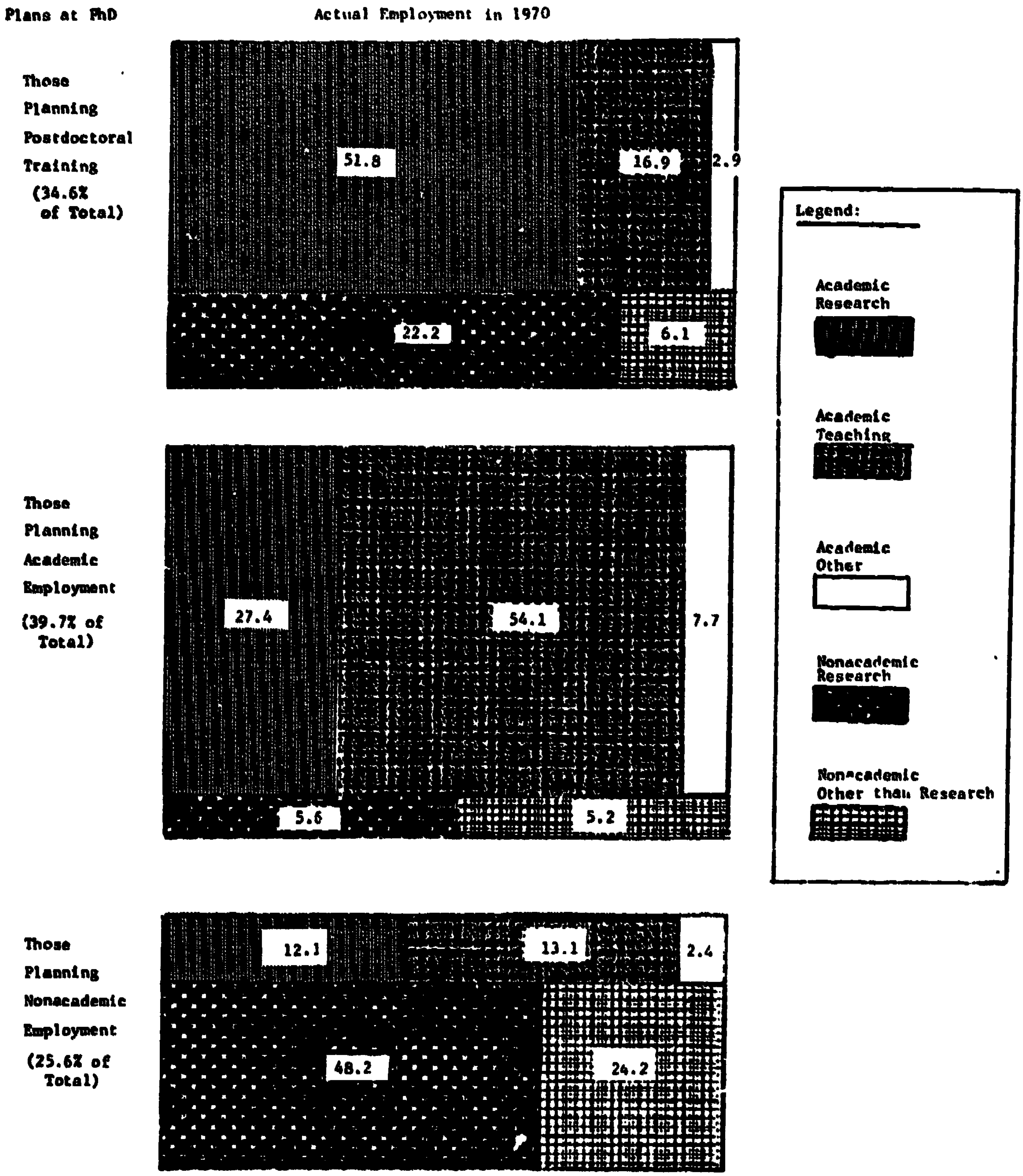
Actual 1970 Employment* of 1961-1970 Bioscientists, Sorted by Plans at PhD (Men and Women Combined)

Plans at PhD		Grand Total	Academic: Total Academic	Academic: Research	Academic: Teaching	Academic: All Other	Non-Academic: Total Non-Academic	Non-Academic: Research	Non-Academic: All Other
Grand Total	N	8797	5924	2809	2703	412	2873	1962	911
	H %	100.0	67.3	31.9	30.7	4.7	32.7	22.3	10.4
	V %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Postdoctoral Training	N	3048	[illegible]	1580	516	89	863	678	185
	H %	100.0	71.7	51.8	16.9	2.9	28.3	22.2	6.1
	V %	34.6	36.9	56.2	19.1	21.6	30.0	34.6	20.3
Immediate Employment	N	5749	3739	1229	2187	323	2010	1284	726
	H %	100.0	65.0	21.4	38.0	5.6	35.0	22.3	12.6
	V %	65.4	63.1	43.8	80.9	78.4	70.0	65.4	79.7
Academic Employment	N	3494	3117	956	1892	269	377	196	181
	H %	100.0	89.2	27.4	54.1	7.7	10.8	5.6	5.2
	V %	39.7	52.6	[illegible]	[illegible]	65.3	13.1	10.0	19.9
Research	N	1266	1063	647	320	96	203	120	83
	H %	100.0	84.0	51.1	25.3	7.6	16.0	9.5	6.6
	V %	14.4	17.9	23.0	11.8	23.3	7.1	6.1	9.1
Teaching	N	1776	1667	178	1388	101	109	48	61
	H %	100.0	93.9	10.0	78.2	5.7	6.1	2.7	3.4
	V %	20.2	28.1	6.3	51.4	24.5	3.8	2.4	6.7
Other	N	452	387	131	184	72	65	28	37
	H %	100.0	85.6	29.0	40.7	15.9	14.4	6.2	8.2
	V %	5.1	6.5	4.7	6.8	17.5	2.3	1.4	4.1
Non-Academic Employment	N	2255	622	273	295	54	1633	1088	545
	H %	100.0	27.6	12.1	13.1	2.4	72.4	48.2	24.2
	V %	25.6	10.5	9.7	10.9	13.1	56.8	55.5	59.8
Research	N	1394	265	141	107	17	1129	852	277
	H %	100.0	19.0	10.1	7.7	1.2	81.0	61.1	19.9
	V %	15.8	4.5	5.0	4.0	4.1	39.3	43.4	30.4
Other	N	861	357	132	188	37	504	236	268
	H %	100.0	41.5	15.3	21.8	4.3	58.5	27.4	31.1
	V %	9.8	6.0	4.7	7.0	9.0	17.5	12.0	29.4

* The data of this table include only those bioscience PhD's found in the 1970 National Register with employment data given.

FIGURE E-2

Actual employment in 1970 for bioscience PhD's, 1961-1970 with varying plans for immediate postdoctoral period



research vs. 6% in all other types of activity. Academic research, then is the majority outcome for the postdoctorals, however supported, with nonacademic research in second position and teaching, as a primary activity, third. All non-research and non-teaching activities comprise only 9% for the postdoctoral group, as compared with 13% for the group planning academic employment and 27% for the group planning nonacademic employment.

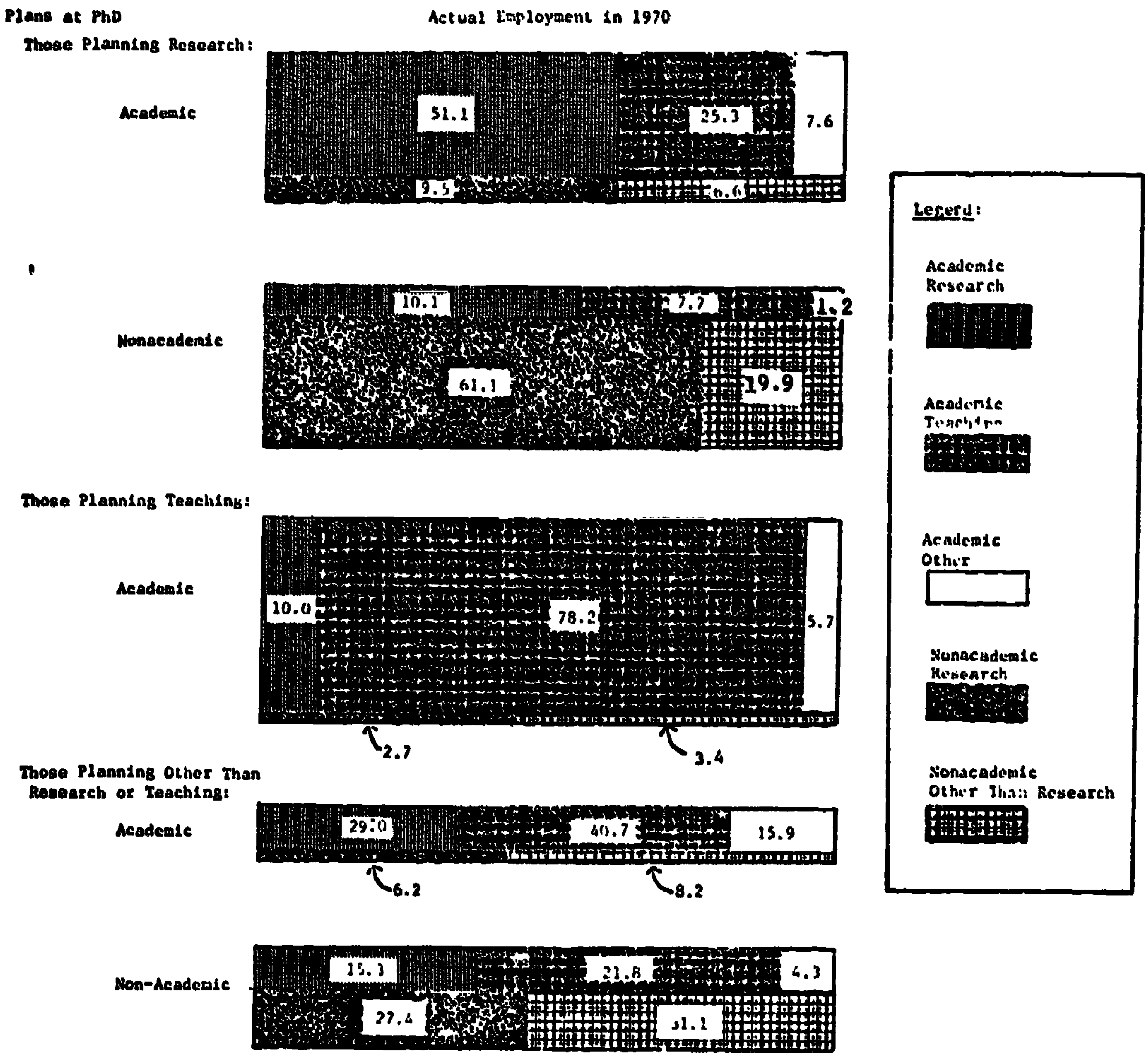
Do Later Jobs Accord with Plans at PhD?

The "plans at PhD" divisions shown in Figure E-2 concern employer categories only. Table E-2, however, also shows the breakouts in terms of planned type of postdoctoral activity, within employer category. These data are portrayed graphically in Figure E-3. The topmost diagram shows the employment in 1970 of those planning academic research: 51% are primarily engaged in research in 1970, while 25% are engaged primarily in teaching and 16% have left academe, going primarily into research in other settings. The second diagram shows outcomes for those planning research careers in nonacademic settings; 61% are so engaged in 1970, and 20%, while in nonacademic employment, are in other than research as a primary activity. It should be noted in all these data that we have been observing primary work activity; many of those who are now primarily in non-research work may still be doing some research in a secondary capacity, and those primarily in research may also do some teaching.

Turning to those planning teaching (all in academic settings, of course), we find that 78% are actually engaged primarily in teaching in 1970, while 10% are primarily engaged in research. The three other categories of activity engage the remaining 12%, divided almost evenly between "academic, other" and all types of nonacademic activity. Finally, the groups with plans for other than research or teaching as a primary activity are shown in the bottom two diagrams. Within these groups, the setting (academic or nonacademic) remains in accordance with plans for the majority of cases. For work activity, this is not true; teaching and research are found to be the primary activities of the vast majority, with percentage distributions among the various types of activity roughly equal for both the academic and nonacademic plans groups.

FIGURE E-3

Actual employment in 1970 for bioscience PhD's, 1961-1970 with varying plans for immediate employment at the time of PhD graduation



Postdoctoral Training and Academic Employer Categories

Up to this point, we have been concerned with academic employment without differentiating the type of institution. Yet there are important variations, and these variations are related to the reasons for and need for postdoctoral training. Postdoctoral training, including but not limited to that sponsored by the NIGMS, is intended primarily to prepare people to serve on the faculties of colleges and universities where a research orientation is important. There will be, as we have seen and as postdoctoral sponsors expect, nonacademic employers also. For the analysis to follow, all these nonacademic employers are grouped into a single category. Within the academic realm, the categories of institutions are arranged as was done earlier in the main body of the report with respect to the comparison groups. That is, they are sorted by level of highest degree granted, and the PhD-granting level is sub-sorted according to the Roose-Andersen ratings. The ratings used here comprised the average ratings of the bioscience departments, as the individual departments of employment were unknown. The method of analysis was to separate the bioscience PhD's planning postdoctoral training from all the others, and to compare the academic and other employer categories of these postdoctorals with the norm of all bioscience PhD's.

Table E-3 gives the data by cohort, and for all cohorts combined, for the total of all bioscience PhD's of the 1958-1970 period, and for the subset of those bioscientists who have had postdoctoral training. The cohort differences are minimal, except for the most recent cohort, for which a larger proportion of outcomes are unknown --many no doubt being still in postdoctoral training. The data for this table were derived from the National Register of Scientific and Technical Personnel for 1970, and the National Faculty Directory for the same year. In both sources, institution of employment was given; the academic institutions were than sub-sorted as described above, by level of highest degree and by Roose-Andersen ratings. Only two categories of Roose-Andersen ratings were used for this purpose; about 40% fell in the "high" category, and 60% in the low category. PhD-granting institutions for

TABLE E-3

Employer Categories for All Bioscience PhD's and Bioscience Postdoctorals, by Cohort, with Comparison of 1958-1966 Postdoctorals and Non-Postdoctorals and Percentages of Postdoctorals by Employer Category and Cohort

Cohort of PhD	Plans at PhD		Total, All Employer Categories	Employer Category in 1970 Academic Institutions: R-A High	R-A Low	MA	BA	Non-Academic	Unknown
Total, All Cohorts									
	All PhD's	N	18,935	2,061	3,034	3,102	1,605	3,531	5,602
		%	100.0	10.9	16.0	16.4	8.5	18.6	29.6
	Postdoctorals	N	6,181	991	992	726	334	930	2,208
		%	100.0	16.0	16.0	11.7	5.4	15.0	35.7
1958-1960									
	All PhD's	N	2,744	292	507	456	207	607	675
		%	100.0	10.6	18.5	16.6	7.5	22.1	24.6
	Postdoctorals	N	422	64	89	69	19	67	114
		%	100.0	15.2	21.1	16.4	4.5	15.9	27.0
1961-1963									
	All PhD's	N	3,126	356	547	552	256	624	791
		%	100.0	11.4	17.5	17.7	8.2	20.0	25.3
	Postdoctorals	N	886	157	178	123	51	137	240
		%	100.0	17.7	20.1	13.9	5.8	15.5	27.1
1964-1966									
	All PhD's	N	4,263	513	801	801	346	815	987
		%	100.00	12.0	18.8	18.8	8.1	19.1	23.2
	Postdoctorals	N	1,356	239	282	224	76	221	314
		%	100.0	17.6	20.8	16.5	5.6	16.3	23.2
1967-1970									
	All PhD's	N	8,802	900	1,179	1,293	796	1,485	3,149
		%	100.0	10.2	13.4	14.7	9.0	16.9	35.8
	Postdoctorals	N	3,517	531	443	310	188	505	1,540
		%	100.0	15.1	12.6	8.8	5.3	14.4	43.8
1958-1966									
	Postdoctorals	N	2,664	460	549	416	146	425	668
		%	100.0	17.2	20.6	15.6	5.4	15.9	25.0
	Non-postdoctorals	N	7,469	701	1,306	1,393	663	1,621	1,785
		%	100.0	9.3	17.4	18.6	8.8	21.7	23.8
			Percentage of Total with Postdoctorals						
Total		%	32.6	48.1	32.7	23.4	20.8	26.3	39.4
1958-1960		%	15.4	21.9	17.6	15.1	9.2	11.0	16.9
1961-1963		%	28.3	44.1	32.5	22.3	19.9	22.0	30.3
1964-1966		%	31.8	46.6	35.2	28.0	22.0	27.1	31.8
1967-1970		%	40.0	59.0	37.6	24.0	23.6	34.0	48.9

which no R-A ratings were available were grouped with the masters granting schools into a single category. Those schools which grant baccalaureate degrees only constituted the fourth academic-employment category.

Near the bottom of Table E-3, the data for the 1958-1966 cohorts (which varied only slightly) have been collected in two categories - postdoctorals and non-postdoctorals - to show most clearly the contrast in employer categories of these two groups. The most recent cohort was omitted because of the large proportion of cases for whom data were missing. In the combined 1958-1966 data, as for each of the first three cohorts separately, it will be noted that the proportion in "high" Roose-Andersen rated schools is almost twice as high for postdoctorals as for those without such training. Postdoctorals are present in a slightly larger proportion even in the "low" Roose-Andersen rated institutions, but in the remaining categories the proportion of postdoctorals is smaller. These relationships are depicted graphically in Figure E-4, where the area of each portion of the graph is made proportional to the number of cases in the group - postdoctorals and non-postdoctorals. At the bottom ot Table E-3, the percentages of postdoctorals in each employer category, in each cohort, are given.

Figure E-5, based on data at the bottom of Table E-3, demonstrates quite clearly that the importance of postdoctoral training to employment in the more advanced institutions increased sharply over the period 1958-1970. The four institutional categories are clearly distinguished at all cohorts, and for the cohort averages shown at the right of the figure. Only 22% of the bioscientists from the earliest cohort who were, in 1970, employed by high-rated PhD-granting institutions had postdoctoral training. This increased steadily to 59% for the most recent cohort. Similar, though less sharp increases are shown for the lower-rated PhD institutions, and even for the baccalaureate-granting colleges. The data for the MA-granting schools show a rise through three cohorts, with a drop in the most recent; the drop may not be statistically significant, because the data are not all available for this cohort, as mentioned earlier.

FIGURE E-4

Comparison of Employer Categories of Postdoctorals and Non-Postdoctorals, bioscience PhD's of 1958-1966

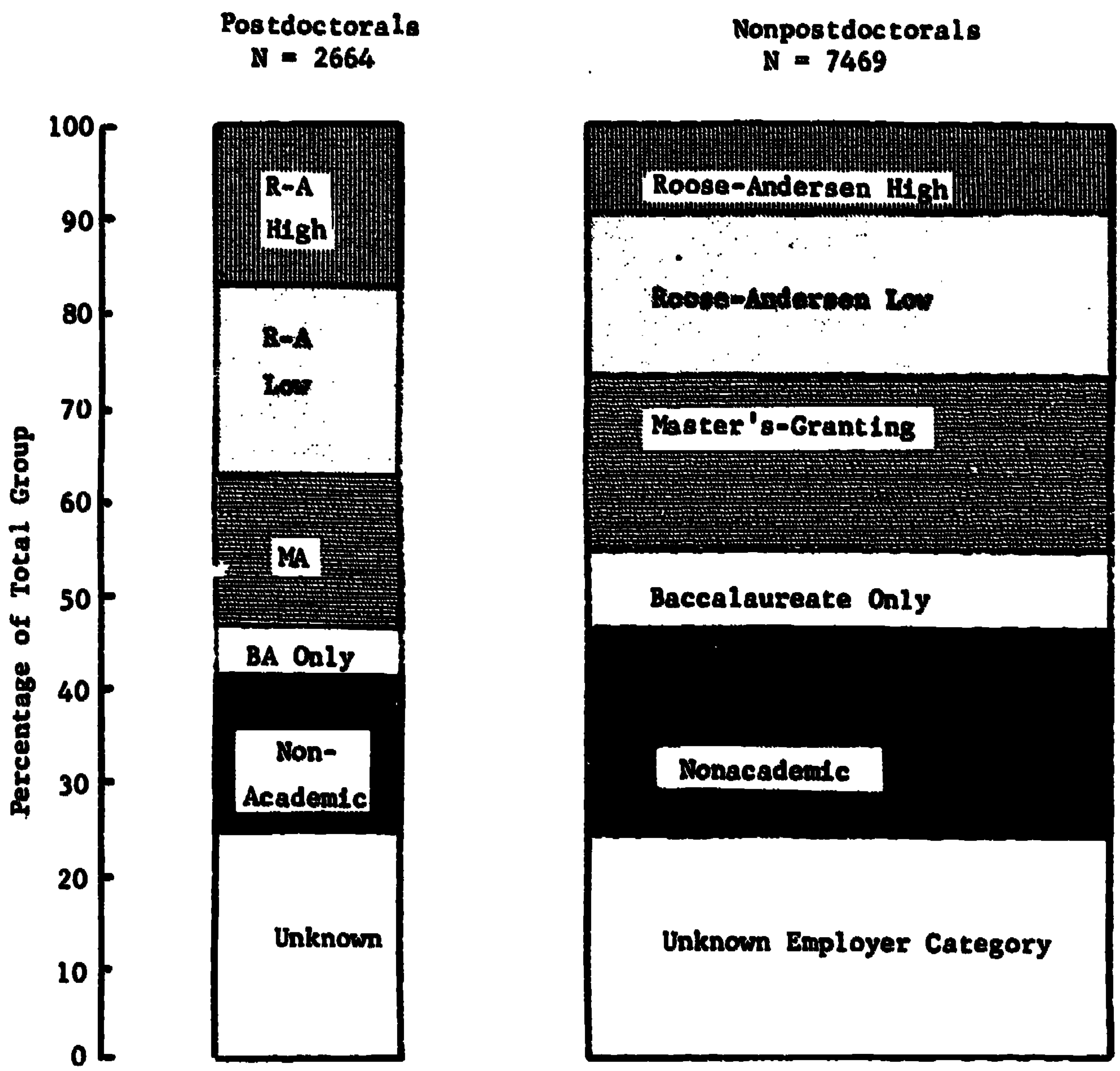
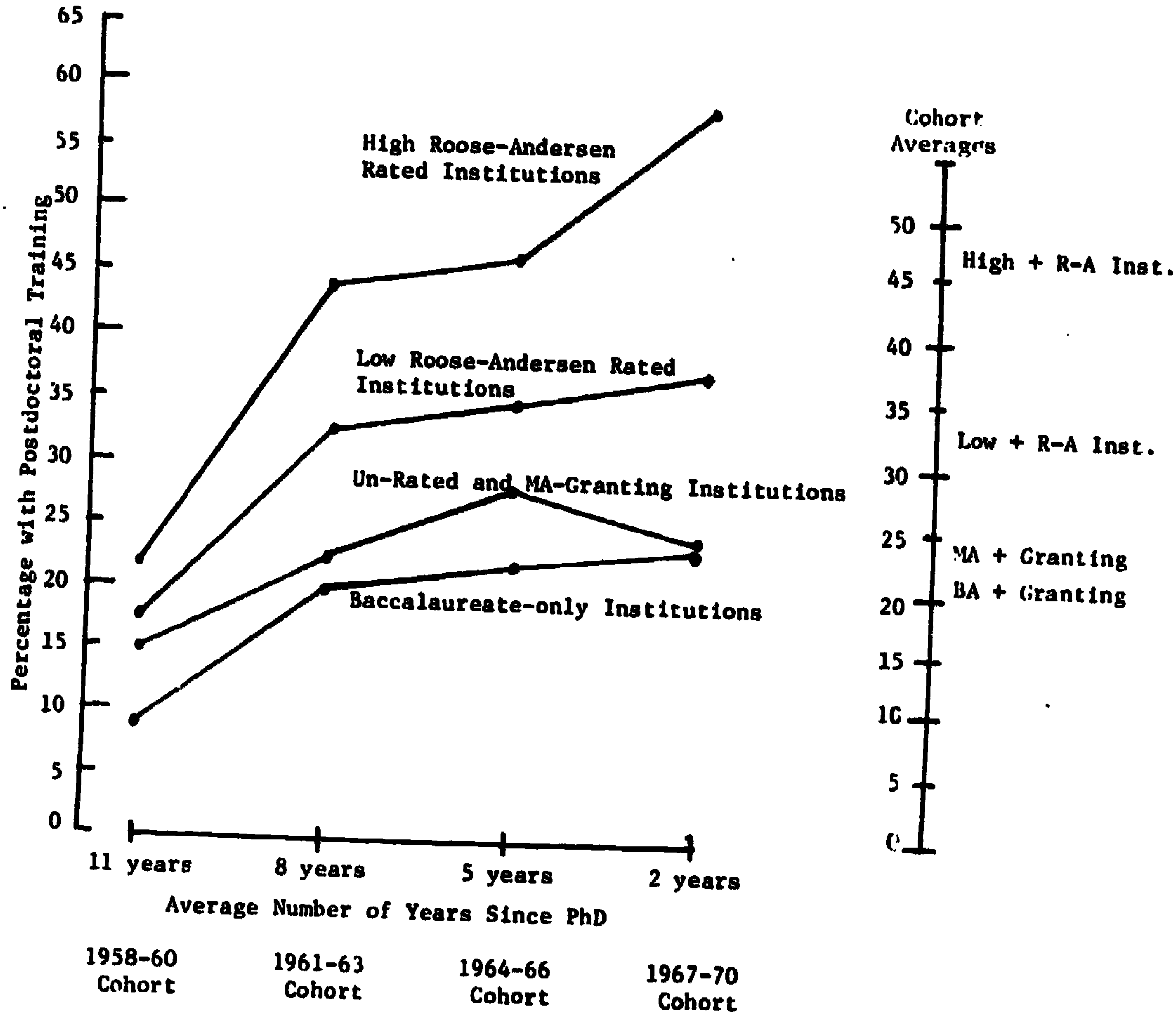


FIGURE E-5

Percentage of Bioscience Doctoral Faculty Members with Postdoctoral Training, by Type of Employing Institution, by PhD Cohort



Summary Regarding Plans and Actual Employment

A brief summary of the degree of agreement between plans for the first postdoctoral year and actual employment several years later, for the bioscientists earning PhD's over the 1961-70 period is that by and large the plans are fulfilled, and that the passage of time changes career lines, but not drastically. Those planning academic careers follow them, and for the most part are found primarily in teaching several years later. Those planning nonacademic careers stay for the most part in nonacademic settings, and are engaged primarily in research. The postdoctorals wind up mostly in academic positions, and, by about a 3-to-1 majority, in research activity. The plans themselves tend to follow from activities in the predoctoral year: fellows tend to opt for more training; those already in academic positions remain in academe; while all others--that is, students otherwise supported--divide their plans almost equally between postdoctoral training, academic employment, and nonacademic employment, but are found on follow-up to be primarily academically employed, in institutions granting advanced degrees, and differentially in institutions with the higher Roose-Andersen ratings.

What of Career Achievements?

The descriptions, figures, and tables above describe employment outcomes. But what of career achievements? Is there any relationship between postdoctoral training, for this general group of bioscientists, and measures of success or effectiveness, as these were briefly outlined earlier? Do the postdoctorals contribute more than others to the scientific literature, in this broader sample? This appears to be the most central of all the questions that refer to career achievements, and it will be explored, both with respect to publications and citations, using the corrected standard scores described earlier.

Publications and Citations of Bioscientists

The career lines of the bioscientists have given evidence of strongly-determined patterns of a kind related to those found in the comparison group studies. The question was whether these same patterns of achievement, as measured by publications and citations, would be evident for the whole bioscience population when those who planned postdoctoral training immediately after the PhD were compared with the norm of all bioscientists. In particular, we wished to know whether, considering the actual employment as found in 1970, the achievement pattern of postdoctorals was different from the norm. In the data of Table E-4 we see that there is a difference (even after allowing for initial differences in ability and environment, as described earlier). The bioscientists who planned immediate postdoctorals come out ahead in almost all of the comparisons with the general norm. A summary of the data is shown graphically in Figure E-6, which is worthy of some detailed examination.

In examining Table E-4, it will be noticed that the difference between the postdoctorals and the general norm increases over time; the earliest cohort shows the greatest difference; the most recent shows practically no difference. In fact, many of the most recent cohort have not had time since the PhD to get any articles into print; the scores of all groups are low. It was decided, therefore, to compute an unweighted average across the earlier cohorts, which had had time to publish research papers. This unweighted average of the standard scores for each of the employer category groups, summing across the three earliest cohorts, is shown in the bottom pair of rows in Table E-4, and is depicted in Figure E-6. The overall average for the entire group is shown as a solid horizontal line at standard score 517. The corresponding average for the postdoctorals is shown by a dashed horizontal line at standard score 534. Thus there is an average difference, for these cohorts, of 17 standard score points, after allowing, as the corrected scores do, for initial ability and environmental differences.

TABLE E-4

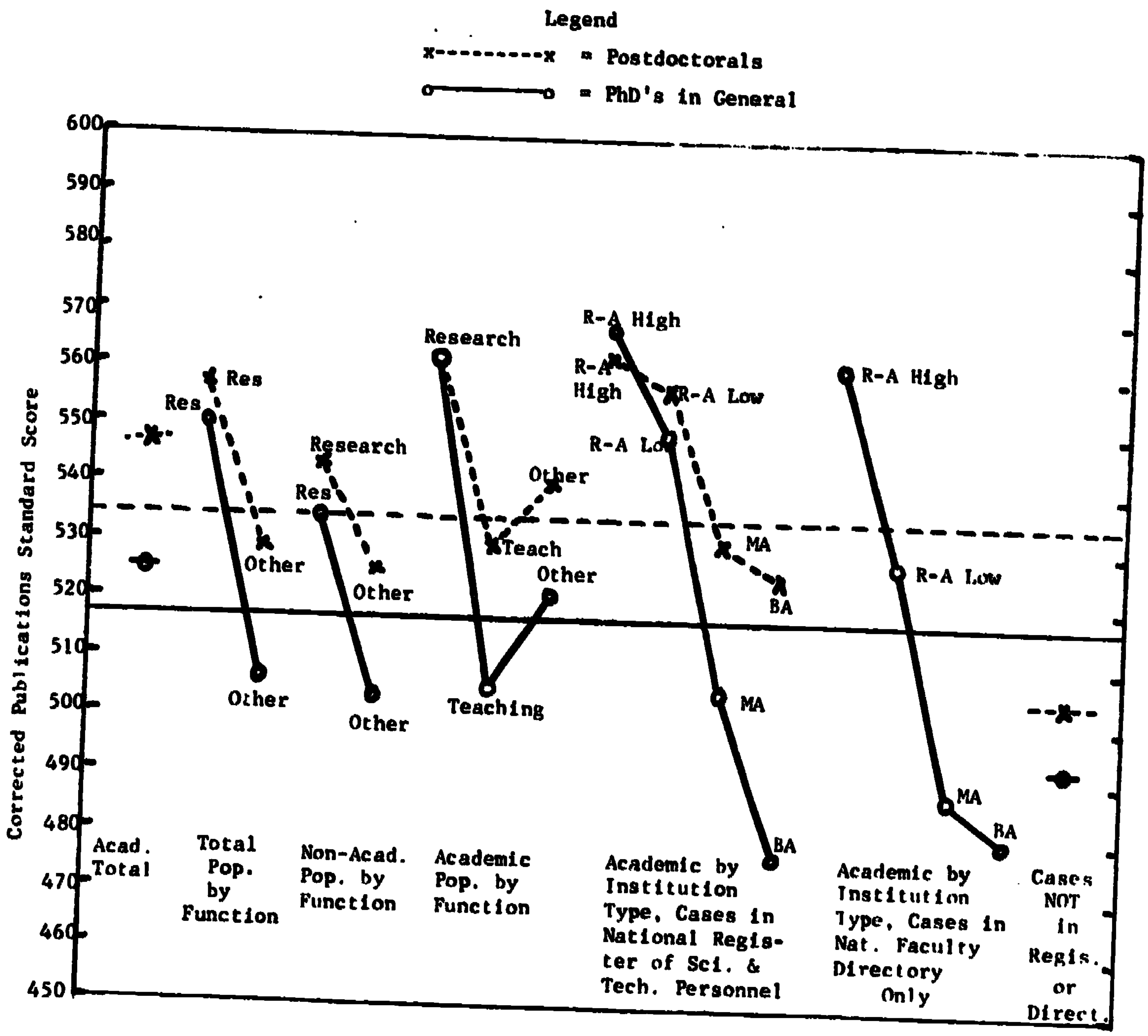
Corrected Publication Standard Scores for Bioscience PhD's and Postdoctorals by Categories of 1970 Employment, by Cohort 1958-1970, with 1958-1966 Average*

	Grand Total	All Rsrch	Other Empl	Non-Univ. Rsrch	Non-Univ. Other	Acad. Total	Univ. Rsrch	Univ. Teach	Univ. Other	Cases in National Register: RA High	RA Low	MA, RA-X	BA	Cases in Faculty Directory Only: RA High	RA Low	MA, RA-X	BA	Non-Regis. and Non-Direc.
Cohort 58-60																		
Grand Total	519	566	510	542	499	535	582	514	522	592	562	515	471	(572)	536	490	465	479
Postdoctorals	539	579	542	(555)	-	563	589	(552)	-	(589)	582	(544)	-	-	-	(507)	-	486
Cohort 61-63																		
Grand Total	516	548	507	534	505	523	560	503	527	564	550	501	476	577	525	474	477	496
Postdoctorals	533	550	525	541	(532)	543	553	521	(536)	559	551	519	(497)	(602)	(525)	(519)	-	511
Cohort 64-66																		
Grand Total	513	537	502	525	504	518	545	499	515	545	536	500	484	534	520	497	499	504
Postdoctorals	530	541	521	533	(530)	534	544	515	(549)	537	539	528	(530)	(535)	(543)	(516)	(529)	516
Cohort 67-70																		
Grand Total	481	495	476	493	477	484	497	473	498	495	497	476	473	497	487	472	455	473
Postdoctorals	485	492	495	492	479	494	492	504	(492)	491	496	489	505	(487)	(494)	503	(477)	474
Average 58-66																		
Grand Total	517	550	506	534	503	525	562	505	521	567	549	505	477	561	527	487	480	493
Postdoctorals	534	557	529	543	525	547	562	529	(540)	562	557	530	524	-	-	-	-	504

* Unweighted mean of standard scores for cohorts 58-60, 61-63, 64-66.
() Less than 75 cases.
\- Less than 20 cases.

FIGURE E-6

Corrected publication standard scores for bioscience PhD's and postdoctorals, 1958-1966, by categories of employment in 1970



The sharp differences displayed by the postdoctorals, shown in Figure E-6, are greater for the academic groups than for the nonacademic. This overall difference is shown by the first pair of symbols: a circle with a line through it for the general academic norm, and an "x" with a dotted line through it for the academic postdoctorals. The difference is 22 standard score points. In the next section of the chart, all of the people, regardless of employer category, who are doing research are compared with all those doing other types of work. The superiority of the postdoctorals in research is reduced to seven points; those in non-research activites show a difference of 23 points. It seems probable that many of those who, in 1970, were not primarily engaged in research, had been promoted to administrative positions; others were from the beginning primarily engaged in teaching. Going on to the third set of figures, or pair of profiles, we see the non-academic researchers compared with non-academic "others". The same pattern persists, but both groups are lower on the profile than are the groups that include academicians. The third profile, consisting of three points, compares the postdoctoral and norm group academicians sorted into those primarily engaged in research (no difference between the postdoctorals and the norm group), teaching (with a 24-point advantage for the postdoctorals), and "all other" (where the postdoctorals are 19 points ahead). For those who are primarily research-oriented, the publication differential vanishes. Those postdoctorals who are teachers primarily are nevertheless well above the general norm on publications, while teachers as a whole are 12 points below the norm.

The next profile in Figure E-6 compares the academic postdoctorals and the general bioscience academic population by category of institution type, for those cases found in the National Register of Scientific and Technical Personnel. This stipulation appears to be important. The Register apparently picks up more of the research-oriented people; the publication standard scores of registrants are higher than those of people who do not enter the Register. The first point in this profile is for the institutions whose bioscience departments rated high in the Roose-Andersen ratings. Within this select group, the postdoctorals actually ranked slightly below the general norm, but still above the score of any other group in Figure E-6. People who win appointments in the high-rated institutions without having had postdoctoral training are probably exceptional people. Turning to the lower-rated PhD-producing institutions, we note that the score of the general norm group drops farther than does that of the postdoctorals; this difference is further enhanced when we go on to the masters-granting institutions, and is still greater when we turn to the baccalaureate-only colleges.

There is shown next in Figure E-6 the group of bioscientists who were located only through the National Faculty Directory; this group does not include those who may also have been found in the National Register. Here the postdoctoral group was too small for reliable statistics. For the general bioscience population, however, the profile is somewhat similar to that for those in the preceding profile who were found in the National Register. The high Roose-Andersen group scores almost as high, on the average, as does the Register group; for the low-rated Roose-Andersen group, and for the masters-granting schools, there is a strong difference in favor of the Register group. At the baccalaureate level, there is only an insignificant difference. Clearly, the differences between these two profiles reflect a greater research and publications orientation on the part of those found in the Register. Finally, at the extreme right of the page in Figure E-6 are the scores of those in both the postdoctoral and general bioscience populations who were found neither the Register nor the Directory. Their scores are low; nevertheless the postdoctorals, on the average, maintain a statistically significant superiority.

Corrected Citation Standard Scores

The difference between postdoctorals and the general norm of bioscientists is clear enough in the data relating to publications; it is striking when one turns to citations. The data of Table E-5 and Figure E-7 are entirely parallel in format to the corresponding data for publications, but the general averages are higher except for the most recent cohort, which has had even less opportunity to be cited than to have its papers published. As was the case for publications, the citation data for the 1967-70 cohort were omitted in the unweighted averages depicted in Figure E-7. Here, in every comparison, the postdoctorals rank higher than the general norm, and by a margin larger than for the publications data. It may be noted also, in Table E-5, that the increase in corrected citation standard scores from one cohort to the next is greater than was the case with corrected publications. The difference between the postdoctorals

TABLE E-5

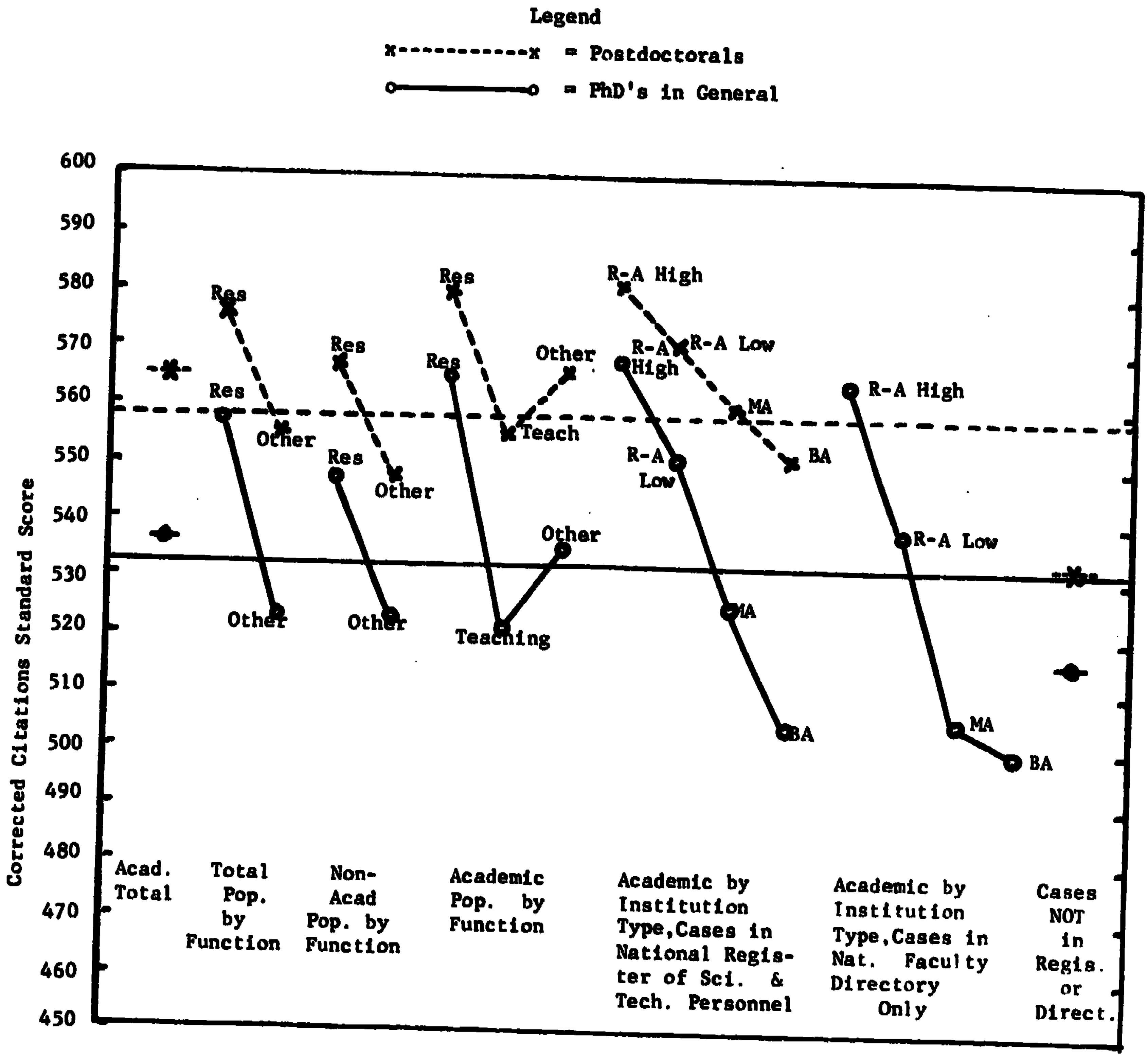
Corrected Citation Standard Scores for Bioscience PhD's and Postdoctorals, by Categories of 1970 Employment, by Cohort 1958-1970, with 1958-1966 Average*

	Grand Total	All Rsrch	Other Empl	Non-Univ. Rsrch	Non-Univ. Other	Acad. Total	Univ. Rsrch	Univ. Teach	Univ. Other	Cases in National Register: RA High	RA Low	MA, RA-X	BA	Cases in Faculty Directory Only: RA High	RA Low	MA, RA-X	BA	Non-Regis and Non-Direc
Cohort 58-60																		
Grand Total	543	578	536	568	535	551	585	536	539	590	567	541	511	(581)	548	519	496	516
Postdoctorals	574	607	577	(598)	-	593	611	(586)	-	(610)	602	(587)	-	-	-	(549)	-	530
Cohort 61-63																		
Grand Total	535	559	528	548	522	540	567	526	544	571	556	527	510	575	542	496	502	522
Postdoctorals	561	574	557	568	(561)	559	579	552	(574)	589	566	556	(530)	(602)	(558)	(565)	-	540
Cohort 64-66																		
Grand Total	518	535	505	525	514	518	542	501	521	543	529	508	492	537	523	499	501	511
Postdoctorals	538	546	531	536	(536)	543	550	526	(553)	544	544	537	(538)	(549)	(558)	(536)	(525)	529
Cohort 67-70																		
Grand Total	462	474	462	475	464	465	473	459	477	473	475	458	459	483	457	455	448	451
Postdoctorals	462	471	471	471	442	474	472	487	(459)	471	476	472	477	(490)	(464)	479	(457)	447
Average 58-66																		
Grand Total	532	557	523	547	524	536	565	521	535	568	551	525	504	564	538	505	500	516
Postdoctorals	558	576	555	567	547	565	580	555	(566)	581	571	560	551	-	-	-	-	533

* Unweighted mean of standard scores for cohorts 58-60, 61-63, 64-66.
() Less than 75 cases.
\- Less than 20 cases.

FIGURE E-7

Corrected citation standard scores for bioscience PhD's and postdoctorals, 1958-1966, by categories of employment in 1970



and the general norm also increases over time, indicating a cumulative effect of the postdoctoral experience. It is quite possible that this cumulative effect is mediated by the fact that postdoctorals get themselves into positions in which research is more important, and persist in research activities with more zeal and continuity. It is, in effect, another example of "As the twig is bent, so the tree is incline". An initial bent for research leads to postdoctoral training, which in turn leads on to a more strongly research-oriented career, more publications, and publications which are more often cited by other scientists. The effect seems, from the data of this appendix, to be a quite general one, not dependent upon the postdoctoral training program of any single government agency.

APPENDIX F

Some Topics for Further Research

This report was addressed to the description and evaluation of the NIGMS postdoctoral program, and it was found that it was possible to obtain relatively unambiguous answers to the questions proposed at the initiation of the study. A number of important questions remain, however, for those concerned with the training of high-level manpower and the support of research in the biomedical fields. The Committee has addressed itself to the need for further developments which might provide a more satisfactory systematic overview of scientific manpower supply and utilization, of which postdoctoral training is an integral part. Some of the Committee's suggestions for further research follow:

- What characteristics of institutions and of mentors are most highly related to the subsequent productivity and careers of postdoctorals? For example, is there an optimum size and mix of students?
- In what sub-fields of science is postdoctoral training most effective?
- What are the values of senior postdoctoral training, as compared to that for immediate post-PhD training? As the population of scientists ages, and as scientific knowledge and technology change more rapidly than do individual scientists, it would appear that training of senior postdoctorals might be very important in preventing scientific obsolescence and decline in research efficiency, and would permit switching to newer fields with higher pay-off potential than those some scientists are pursuing at any given time.
- As a larger and larger proportion of scientists may be expected in the future to be employed in nonacademic settings, what may we expect with regard to the value of postdoctoral training for these people in industry and government?
- Most important, from the overall standpoint, is the development of causal models of scientific productivity and status attainment. A satisfactory model would go far beyond the area of postdoctoral training alone, and would include both predoctoral education and later career development, and institutional relationships as well as individual careers. The availability

of really good causal models, and of the necessary indicators of causes and consequences would make possible more adequate assessments of programs of all sorts - the postdoctoral programs, grants in support of research, support of predoctoral students, etc.

In the absence of such a firm base for gauging the probable consequences of program changes, there is a tendency to regard any massive and/or precipitous changes in the volume and sources of research and training support as potentially very dangerous. Those involved in the training process feel that a social experiment with the scientific establishment may well produce results that would be disastrous, and whose long-term costs, as subsequent policy responds to correct the error, may well far overrun the cost of continuous support. They would cite, by way of analogy, the cost of tooling up again to make a supersonic transport, if that now defunct project, whose termination costs were very high, were to be revived. Similarly, they would argue, the pursuit of a scientific support program which causes research laboratories to close, training programs to shut down, and a field of inquiry to deteriorate, incurs, in the long run, costs to revitalize the area which outstrip the costs of continuous support. To meet this argument, a really adequate model of the scientific enterprise would allow a much more accurate estimate of the consequences of program modification or discontinuation than is possible at the present time.

The extensive data assembled for the present study provide a rich and unique opportunity to construct a model of the scientific career which would parallel in significant ways the Blau-Duncan model of status attainment in the society at large. Quite apart from its intrinsic intellectual interest, it would be a very important benchmark for evaluating the effects of various scientific manpower training programs. The construction of this model is regarded as first-order business for those concerned with scientific manpower and the sociology of science.