Postdoctoral Training in Bioscience: Allocation and Outcomes*

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ABSTRACT

The careers of 557 biochemists are studied in order to answer the following questions: Who gets postdoctoral training and why? How does such training affect subsequent employment opportunities? Does postdoctoral training increase later research productivity? Results show that predoctoral research productivity has no effect on who gets postdoctoral training or where one gets it. Getting postdoctoral training does not seem to affect one's chances of getting a prestigious job, but where the training occurred has a major impact on the prestige of subsequent jobs. In contrast, having had postdoctoral training seems to result in substantial increases in later citation rates, but where the training occurred makes little difference in citation rates. The modest effect of postdoctoral training on publication rates disappears when employment sector is held constant.

During the past two decades, postdoctoral training has become a significant component of science education in the U.S., especially in the biomedical sciences. Precise estimates of the number of scientists engaged in postdoctoral training are hard to come by, in part because the status, postdoctoral trainee, is so poorly defined and institutionalized in most universities (Curtis). Nevertheless, one recent study reported that between 1971 and 1975 over 55 percent of Ph.D. recipients in biomedical specialties took postdoctoral appointments within a year after receiving their doctorate. Moreover, by 1977 there were more than 6,000 postdoctoral trainees in biomedical fields, a number that grew at an annual rate of 12.5 percent since 1973 (Coggeshall et al.). This rapid growth has prompted concern that large numbers of new doctorates may be settling for temporary re-

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search positions in the face of diminishing opportunities for tenure-track appointments (National Research Council, d), and there is persuasive evidence that this is indeed the case (Coggeshall et al.).

A more fundamental concern is whether an investment of more than one hundred million dollars annually (National Research Council, d) can be justified on the basis of its outcomes. Unless it can be shown that postdoctoral training appointments are made wisely, that they are of some later value to the recipients, and that they generate measurable benefits to science, then it would be difficult to justify the investment as more than a remote and expensive form of unemployment compensation.

Aside from its importance for public policy, the postdoctoral training position provides a strategic site for the study of stratification and productivity in science (Reskin). Many postdoctoral positions—especially those that are called fellowships—confer prestige on their recipients. Even those with little prestige value may have important career benefits in the form of additional research experience and valuable credentials. Hence, to the extent that the norm of universalism obtains in science (Merton), one would expect these positions to be allocated on the basis of assessed ability or previous performance.

A related question is whether the university department in which a scientist receives postdoctoral training has an impact comparable to that of the doctoral department on later career chances. Many studies have documented the strong association between prestige of the doctoral department and prestige of subsequent academic affiliation (Berelson; Caplow and McGee; Cole and Cole; Crane; Hagstrom and Hargens; Hargens and Hagstrom), and recent studies have suggested that this effect is not explained by greater ability and/or performance of a department's graduates (Long; Long et al.). Does the same pattern hold for the postdoctoral department and, if so, does the postdoctoral department partially or entirely mediate the effect of the doctoral department? Finally, an examination of the relationship between postdoctoral training and later publication and citation patterns may help to answer more general questions about the effects of social contexts on scientific productivity.

To provide some tentative answers to these and other questions, we have studied the career histories of two cohorts of biochemists who received their doctorates in the late fifties and early sixties. The analyses reported here turn on three events in the early postdoctoral career. The first of these, getting a postdoctoral appointment, occurs within a year after receiving the Ph.D. degree. The second, entry into the regular labor force, ordinarily occurs during the same year for those who do not take postdoctoral training, but anywhere from one to four years later for those who do. The third consists of research productivity during the interval from eight to ten years following receipt of the doctoral degree.

Data

We collected biographic and bibliographic information, entirely from public data sources, about recipients of the Ph.D. in biochemistry from U.S. universities in fiscal years 1957, 1958, 1962, and 1963. Since no systematic differences among these cohorts were found, they are combined in all tables reported here. The list of doctorates was obtained from commencement rosters of individual universities and verified from separate sources.[1] Female biochemists were eliminated from the sample because their numbers were few and because biographic coverage was poor. The following analyses are thus restricted to 557 male biochemists for whom sufficient information could be obtained.[2]

Information about postdoctoral training was part of a career history gathered for each biochemist through 1972. Data were obtained from *American Men and Women of Science* (Cattel) and, where necessary, from a range of supplementary sources such as *American Doctoral Dissertations* (Xerox, a). No small problem in the study of postdoctoral appointments is their sheer identification. As our starting point, we accepted the National Research Council's (b) definition of a postdoctoral appointment as

> . . . a temporary appointment, the primary purpose of which is to provide for continued education or experience in research, usually, though not necessarily under the supervision of a senior mentor. Included are appointments in government and industrial laboratories which resemble in their character and objectives postdoctoral appointments in universities.

This definition corresponds almost precisely with that used by Curtis and Coggeshall et al.

Applying this definition to job titles listed in *American Men and Women of Science* led to certain ambiguities. The job titles we found fell into two classes:

1. There were 177 biochemists whose first jobs after receiving their doctorates were unambiguously described as "fellow," "postdoctoral fellow," or "trainee". Throughout the remainder of the paper we will refer to all such positions as simply fellowships and to the incumbents as fellows.

2. Another group had job titles such as "research associate," "research assistant," or "scientist." When jobs with these titles were held for less than five years, they were taken to be postdoctoral training appointments. There were 94 biochemists who held such appointments. Hereafter we will refer to these positions as research associateships.

In most of the analyses reported below, we combined these two groups into a single class described synonymously as postdoctoral trainees, trainees, appointees, or postdoctorals. Nevertheless, for each analysis we determined whether, in fact, it was appropriate to treat the two classes as functionally equivalent. Any differences will be noted below.

The prestige of the doctoral department was measured by the complete three-digit rating of faculty quality of biochemistry departments, a partial listing of which appeared in Cartter. These scores ranged from 1.00 for the least prestigious to 5.00 for the most prestigious. The prestige of the postdoctoral department and the department of the first subsequent job was more difficult to measure because the biochemists often held positions in departments other than biochemistry.[3] Accordingly, a "bioscience" prestige score for each university was constructed by taking a weighted average of the Roose and Andersen ratings of the departments of biochemistry (1/2), chemistry (1/4), physiology (1/12), microbiology/bacteriology (1/12), and pharmacology (1/12).[4] These scores also ranged from *1.00* to *5.00*.

For all but 8 of the biochemists, the name of the dissertation supervisor (hereafter referred to as the mentor) was obtained from *Dissertation Abstracts* (Xerox, b), *Directory of Graduate Research* (American Chemical Society), or a mail survey of graduate deans. A measure of the mentor's research accomplishments was obtained by counting citations to his or her first-authored publications in the 1961 *Science Citation Index* (Institute for Scientific Information). While these counts will be interpreted as a measure of eminence, it should be kept in mind that they may reflect both the performance of the scientist and his or her standing in the scientific community.

Biochemists' research productivity was measured by counts of published articles and citations to them. *Chemical Abstracts* was used to locate the articles, and counts of citations were obtained from several volumes of *Science Citation Index*. By counting citations to individual articles rather than to authors, we were able to obtain counts for *all* publications, not just those of which our biochemists were first author. For the analyses reported here, we used citation and publication counts for the three years ending in the year the doctorate was awarded (predoctoral productivity), and counts for the eighth through tenth years after receipt of the Ph.D. (For a detailed discussion of how these measures were constructed, see the appendix in Long). All of the analyses reported here used the natural logarithm of publication or citation counts. Before taking the logarithm, *0.5* was added to each count (Allison).

Beyond these key variables, we used Astin's measure of selectivity for each biochemist's undergraduate institution. This index has values ranging from 1 to 7, with 7 being the most selective. It has been interpreted by some to be a crude indicator of academic ability of baccalaureate recipients and by others as a measure of the quality of the undergraduate education. In any case, a number of studies have shown it to be a moderately good predictor of future success in science (e.g., Hagstrom and Hargens; Reskin).

Results

DETERMINANTS OF POSTDOCTORAL TRAINING

Relative to doctorate recipients in most scientific fields, biochemists are intensely committed to postdoctoral study. Among the biochemists studied, 49 percent pursued postdoctoral training within a year of earning the Ph.D. In this section, we examine those factors which had an impact in determining who did and who did not pursue postdoctoral training. The choice of variables for this analysis was guided, in part, by the expectation of universalism in science—that rewards should be allocated on the basis of meritorious behavior, or in anticipation of meritorious behavior at some time in the future. Accordingly, it was expected that predoctoral research productivity would have a substantial effect on the allocation of postdoctoral positions. We also anticipated that characteristics of the biochemists which could be interpreted as indicators of scientific ability might also have some impact. Such indicators include undergraduate selectivity, prestige of doctoral department, mentor's prestige, and age at which the biochemist received his doctorate.

Of course, to the extent that these characteristics are *not* valid indicators of ability, their influence can be interpreted as a failure of universalistic processes. In fact, they could also be seen as evidence for ascription. An additional ambiguity arises from the fact that, in order to have been a postdoctoral trainee, biochemists must have both applied for and accepted such positions. Thus, whatever factors appear to affect the allocation of postdoctoral positions may be more indicative of the preferences of new doctorates than the preferences of those who select among them. This is especially important in view of the fact that postdoctoral positions are not an unmitigated good: not only must the trainee incur the cost of temporarily forgoing a more permanent and usually better paid job, but there is also evidence that trainees lag behind non-trainees in salary for several years thereafter (Coggeshall et al.).

With these cautions in mind, let us turn to the results in Table 1. We first estimated a linear regression equation in which the dependent variable was a dummy variable coded 1 if the person was a postdoctoral trainee and 0 if not. As expected, biochemists from prestigious departments and with prestigious mentors were more likely to receive postdoctoral training, net of other variables. These effects are modest, however, and are dominated by the negative effect of age at the receipt of the doctorate, and by the fact that those who received their degree from schools of agriculture were much less likely to undertake postdoctoral training than those with degrees from arts colleges or medical colleges. Furthermore, those who were married when they received their doctorates were significantly less likely to have been postdoctoral trainees. Undergraduate selectivity has a positive

Table 1. ESTIMATES FOR LINEAR AND LOGIT MODELS PREDICTING ENTRY INTO POSTDOCTORAL TRAINING

	Linear Model			Logit Model	
Independent Variables	Metric Coeff.	Stand. Coeff.	t	Coeff.	t
Ph.D. in ag. school	-.226	-.22	-5.06	-1.017	-4.81
Married at Ph.D.	-.128	-.09	-2.25	-.594	-2.21
Ph.D. prestige	.0457	.09	2.21	.210	2.19
Age at Ph.D.	-.0200	-.15	-3.79	-.096	-3.76
Undergrad. selectivity	.0217	.08	1.89	.100	1.89
Mentor's citations	.0327	.10	2.19	.149	2.15
Publications	.0219	.03	.65	.087	.58
Citations	-.0213	-.04	-.82	-.096	-.81
R^2	.139				

effect that is statistically significant at the *.05* level with a one-tailed test but not with a two-tailed test.

Most surprisingly, the effects of the two predoctoral productivity measures are far from significant and, in the case of citations, the sign is opposite to that anticipated. To be sure that these null results were not a consequence of multicollinearity (the correlation between publication and citation counts exceeds *.60*), we reestimated the equation omitting one or the other of the two productivity measures. The coefficients were still far from reaching statistical significance. In a similar analysis for 231 male chemists, Reskin also failed to find a significant effect of predoctoral publications. Contrary to the results reported here, however, she also found no significant effects of undergraduate selectivity, prestige of doctoral department, counts of mentor's publications, and length of time between bachelor's degree and doctorate (which is highly correlated with age at Ph.D. in most samples).

These results could be called into question by the dubious legitimacy of using a dichotomous dependent variable with ordinary least-squares multiple regression. In particular, it is now well known that the use of a dichotomous dependent variable may lead to inconsistent standard error estimates and, hence, biased *t*-tests of the hypothesis that each coefficient is equal to zero (Hanushek and Jackson). To rule out this possibility, we estimated a logit model by the method of maximum likelihood. As seen in the last two columns of Table 1, the results are almost identical to those from the linear regression. (The coefficients are substantially higher, but that is an inherent feature of the logit specification.) The most meaningful comparison is the *t*-test for the hypothesis that a coefficient is equal to zero, and from Table 1 it can be seen that the logit and linear models produce remarkably similar t-statistics.

The most striking feature of these results is the absence of any effects of predoctoral publication and citation counts, a finding which clearly runs contrary to the hypothesis that postdoctoral training positions are awarded for meritorious behavior. This negative result cannot be dismissed on grounds of insufficient research productivity by the time of receipt of the doctorate. These biochemists had published as many as 16 papers by this stage in their careers, with a mean of 1.14 papers, and had received as many as 74 citations, with a mean of 2.64. So there was research productivity—some of it quite visible—which could have been used as at least one of the criteria for awarding postdoctoral positions. Moreover, in analyses reported elsewhere (Long et al.), we have shown that predoctoral publications are the single best predictor of citation counts made ten years later. These results are corroborated in Tables 6 and 7 of this paper. Thus, it cannot be argued that predoctoral productivity is a poor indicator of future productivity.

The positive effects of prestige of doctoral department, prestige of mentor, and undergraduate selectivity may be explained in at least three ways:

1. These origin statuses were used as indicators of ability in awarding postdoctoral positions.
2. Purely ascriptive processes determined which scientists got access to valued resources.
3. Those who scored high on all three measures were more motivated than others to seek out and accept postdoctoral training positions.

Without further data, there is no way to distinguish among these explanations. Age at Ph.D. can also be interpreted as an indicator of ability and, thus, its strong negative effect can be seen as consistent with the hypothesis of universalism. Precisely because the effect is so strong, however, we suspect that it is best explained in terms of individual motivations. Older Ph.D.s are undoubtedly more concerned about getting their careers started and have more to lose from investing additional years in poorly paid research training. The effect of marital status can be explained in the same way: those with responsibilities for family support may be less willing to take a monetary loss.

The much lower rates of postdoctoral training among agricultural biochemists may be due to the fact that agricultural science is generally oriented more toward mission and application than to basic research (Mayer and Mayer). As shown below, biochemists with agricultural doctorates were much more likely to take jobs outside of academia. The route of a postdoctoral training position, on the other hand, seems geared more toward basic research in an academic setting. A second explanation is that more postdoctoral positions were available to those whose research is medically rather than agriculturally oriented. Curtis (235) reported that over 60 percent of the postdoctoral fellowships in biochemistry were funded by the U.S. Public Health Service.

There is still one criticism that might be leveled at the analysis reported in Table 1. Reskin has argued that, for some new doctorates, a postdoctoral training position is an honor given for work well done and a stepping stone to a better job in the future. For other persons, however, such a position is just a job taken because no better job is available. She hypothesized that the processes leading people into postdoctoral positions and the consequences of having held such positions are very different depending on which of these two functions is paramount.

This argument suggests that lumping all temporary postdoctoral positions together may produce misleading results. To examine this possibility we divided the 271 postdoctorals into the two groups discussed earlier: 177 fellows and 94 research associates (RAs). We reasoned that fellowships would be more likely to emphasize the honorific functions while research associateships would have more of the character of jobs. Also relevant is the fact that fellowships were more likely to be awarded in nationwide competition while research associates were typically hired by sponsoring scientists who controlled a research grant. If there were any differences between these two groups, it was expected that fellowships would be allocated according to more universalistic criteria.

To test this hypothesis, we estimated a *multinomial* logit model (Hanushek and Jackson, 210–14) predicting whether a biochemist would fall into one of three categories: fellowship, research associateship, or no postdoctoral training. To make for easy comparison with Table 1, the results in Table 2 are presented as contrasts between each of the two postdoctoral training categories and the residual category of no training.

Only two of the differences between the two postdoctoral categories reach statistical significance. Age at Ph.D. has a very strong negative effect on getting a fellowship instead of no postdoctoral training; but virtually no effect on getting a research associateship rather than no postdoctoral training. This result may also be expressed somewhat differently: given that a person had postdoctoral training, age at Ph.D. had a significant effect ($t = 4.08$) on whether the training took the form of a fellowship or a research associateship. The other difference between the two training categories is in the effect of undergraduate selectivity: it is non-existent for RAs in contrast to non-trainees and positive for fellows compared to non-trainees. Although marital status appears to have a somewhat stronger negative effect for the fellow non-trainee contrast than for RAs versus non-trainees, the difference is not statistically significant. The effects of the other five variables are similar to those reported in Table 1. In particular, there is still no effect of predoctoral productivity for either of the two contrasts.

Table 2. MULTINOMIAL LOGIT MODEL DISTINGUISHING TWO TYPES OF POSTDOCTORAL TRAINING

	RAship vs. No Training		Fellowship vs. No Training		
Independent Variables	Coeff.	t	Coeff.	t	t test for Difference
Ph.D. in ag. school	-.990	-3.39	-1.03	-4.21	-.13
Married at Ph.D.	-.244	-.66	-.728	-2.49	-1.34
Ph.D. prestige	.191	1.49	.221	1.96	.21
Age at Ph.D.	-.0095	-.30	-.169	-5.04	-4.08
Undergrad. selectivity	.0002	.00	.167	2.64	2.21
Mentor's citations	.169	1.82	.140	1.73	-.28
Publications	.129	.65	.065	.38	-.30
Citations	-.068	-.44	-.124	-.91	-.33

While the differences in the two types of postdoctoral training are consistent with Reskin's claims, they do not undermine the conclusions drawn from Table 1. The fact that both age and marriage have substantial negative effects on getting a fellowship and very small negative effects on getting a research associateship seems quite reasonable in light of the economic explanation advanced earlier. To get a fellowship, one must typically enter a nationwide competition several months in advance. Thus, getting such a position requires effort and planning that would be expected only of someone who really wanted a fellowship and thought he would be qualified to get one. On the other hand, it seems plausible that the selection of research associateships would take place at a local level shortly before the position had to be filled. Then, when a new doctorate had exhausted all other possibilities, he might turn to a research associateship; older and married doctorates might be just as likely to do so as younger, single doctorates.

Of course, to the extent that age at Ph.D. is an indicator of scientific ability, these results could also be taken as evidence that merit is more important in the allocation of fellowships than in the allocation of research associateships. Adding weight to this interpretation is the fact that undergraduate selectivity—a less ambiguous indicator of ability than age at Ph.D. —affects the likelihood of getting a fellowship but not the likelihood of getting a research associateship. There does not appear to be any way to choose between these two interpretations with the data in hand. Nevertheless, the major finding holds: predoctoral productivity does not affect the probability of getting either type of postdoctoral position.

DETERMINANTS OF POSTDOCTORAL PRESTIGE

Postdoctoral training positions also vary in other ways. While nearly all of the postdoctoral positions were in academic settings (a few were at NIH), there was substantial variation in the prestige of the academic institutions. Since prestige is both rewarding in itself and is also an indicator of other desirable features of departments (Cartter; Hagstrom), it is natural to ask whether it was allocated among postdoctoral trainees according to universalistic criteria. In other words, one might expect to find that the most able and productive Ph.D.s get their postdoctoral training in the most desirable places.

In some respects, this is a better site to examine the operation of universalism than the mere receipt or non-receipt of a postdoctoral position. Once a new biochemist has decided to seek postdoctoral training, it makes sense to aim for a position in the most desirable location in terms of career advancement. And since there are few costs in choosing a prestigious institution over one that is not so prestigious, it is reasonable to assume that candidates will seek out and choose the most prestigious institutions. As a consequence, those factors which determine postdoctoral prestige ought to be more indicative of the preferences of those awarding the positions than the preferences of those seeking the positions.

The evidence for those preferences is shown in Table 3, which gives the results of regressing postdoctoral prestige on the same independent variables found in previous tables. Only two of the variables attain significance at the *.05* level, prestige of the doctoral department and the dummy variable indicating a degree from an agricultural school.[5] Again, predoctoral productivity has virtually no impact. This differs somewhat from Reskin's results. She found that not only doctoral prestige but also undergraduate selectivity and predoctoral publications had significant effects on postdoctoral prestige. However, Reskin's measure of prestige was based on the title and funding source of the postdoctoral position itself rather than on the department in which the position was located.

It appears then that many more factors influence whether a biochemist had a postdoctoral position than influence the prestige of that position. Moreover, Long found that for a subgroup of 136 biochemists (those who went on to tenure-track positions) the effect of doctoral prestige on postdoctoral prestige was largely explained by the fact that many individuals had their doctoral and postdoctoral training in the same institution. When these inbred scientists were excluded from the sample, the correlation virtually disappeared. In short, the allocation of postdoctorals among different institutions seems almost random, following neither universalistic nor ascriptive criteria. Nevertheless, as we shall see shortly, that allocation had major consequences for subsequent career chances.

Table 3. REGRESSION PREDICTING PRESTIGE OF POSTDOCTORAL INSTITUTION (N=200)

Independent Variables	Standardized Coefficient	Metric Coefficient
Ph.D. in ag. school	-.17*	-.334*
Married at Ph.D.	-.06	-.129
Ph.D. prestige	.16*	.129*
Age at Ph.D.	-.04	-.010
Undergrad. selectivity	.08	.040
Mentor's citations	.08	.048
Publications	-.06	-.068
Citations	.09	.075
R^2	.098	

*Coefficient significant at .05 level.

IMPACT OF POSTDOCTORAL TRAINING ON THE FIRST JOB

As previously noted, there is evidence that postdoctoral training is not a sound financial investment for the individual scientist, that the opportunity cost is not cancelled out by greater subsequent earnings than those of non-trainees. Is it possible that there is some form of non-monetary payoff from postdoctoral training, beyond the opportunity to improve one's research skills? One hypothesis is that a postdoctoral position increases the chances of getting a desirable job, where desirable refers to non-monetary rewards. According to the National Science Foundation, "Postdoctoral appointments have been relied on traditionally by Ph.D. holders as stepping stones to permanent research appointments in academic institutions." Table 4 provides some evidence for this claim. For all 557 biochemists, we estimated a linear regression in which the dependent variable was a dummy variable coded 1 if the first "real" job (immediately after the doctorate or after postdoctoral training) was in academia and 0 if it was not (63 percent of the jobs were academic).[6] Results are shown in the left-hand panel of Table 4. The linear regression was also corroborated with a maximum likelihood logit analysis (t-statistics from both analyses are shown for comparison).

Only two variables had statistically significant effects on the probability of an academic job, and both these effects were quite strong. Those with agricultural degrees were much less likely to enter academia while those with postdoctoral training were much more likely to do so, a result consistent with previous studies (Folger et al.; Reskin). In another regression (not shown) there was no difference between those with postdoctoral

Table 4. ESTIMATES FOR LINEAR AND LOGIT MODELS PREDICTING FIRST JOB IN ACADEMIA

	All Biochemists (N=557)				Postdoctoral Trainees (N=200)			
Independent Variables	Stand. Coeff.	Metric Coeff.	t	Logit t	Stand. Coeff.	Metric Coeff.	t	Logit t
Ph.D. in ag. school	-.21	-.209	-4.68	-4.50	-.16	-.160	-2.08	-2.08
Married at Ph.D.	-.03	-.036	-.63	-.63	-.05	-.054	-.71	-.73
Ph.D. prestige	.06	.027	1.33	1.33	.00	.0018	.05	.09
Mentor's citations	-.08	-.027	-1.82	-1.79	.07	-.023	-.87	-.90
Publications	.05	.029	.92	.96	.04	.024	.47	.56
Citations	.03	.012	.49	.48	.09	.041	.99	1.04
Postdoctoral training	.30	.193	4.67	4.55	--	--	--	--
Postdoctoral prestige	--	--	--	--	.03	.013	.34	.34
R^2		.104				.045		

titles of fellow or trainee and those with titles of research associate or assistant; both were equally likely to enter academia.

The interpretation of these effects remains ambiguous. On the one hand, it could be that academic departments give preference in their hiring to individuals with postdoctoral training or to those with non-agricultural degrees. An alternative explanation is simply that those with agricultural degrees are less interested in academic positions and do not bother to apply. Similarly, one would expect that Ph.D.s who are not interested in an academic career would not seek out postdoctoral training—the opportunity cost would simply be too great. Once again we face the quandary whether the observed associations reflect candidates' preferences or employers' preferences.

For the 200 biochemists who did take postdoctoral training, we estimated a second regression to see if the *prestige* of the postdoctoral institution had any impact on whether the first subsequent job was in academia. The results in the right-hand panel of Table 4 show that this was not the case. Among postdoctorals, the only factor affecting the academic-nonacademic dichotomy was a degree from an agricultural school.

Of course, simply getting an academic job is not enough. Presumably the biochemists who got academic jobs were also interested in getting a job at a prestigious institution. Was postdoctoral training any advantage in getting a more prestigious job? The results in the left-hand panel of Table 5 provide an answer to that question. For the 348 biochemists whose first real job was in academia, we regressed the Roose-Andersen rating for that institution on several of the variables examined previously. Although those with postdoctoral training did slightly better than those without (a difference of *.211* on the *5*-point scale), the difference was not significant at

Table 5. REGRESSIONS PREDICTING PRESTIGE OF FIRST JOB

	All Those at Rated Institutions (N=348)		Former Postdoctorals at Rated Institutions (N=150)	
Independent Variables	Stand. Coeff.	Metric Coeff.	Stand. Coeff.	Metric Coeff.
Ph.D. at ag. school	-.15**	-.440**	-.16*	-.497*
Married at Ph.D.	-.04	-.147	-.12	-.359
Ph.D. prestige	.25**	.314**	.12	.151
Mentor's citations	.09	.082	.12	.114
Publications	.01	.015	-.11	-.185
Citations	.08	.106	.10	.125
Postdoctoral training	.08	.211	--	--
Postdoctoral prestige	--	--	.26**	.313**
R^2	.14		.17	

*Coefficient significant at .05 level.
**Coefficient significant at .01 level.

the *.05* level. The two variables which did have significant effects were prestige of the doctoral department and the dummy variable indicating a degree from an agricultural school. The two predoctoral productivity measures had little effect, corroborating results of Long et al. for a subset of this sample.

Despite this null result, it cannot be said that postdoctoral training was inconsequential in getting a good job. *Where* that training took place had a major impact. For the 150 postdoctorals whose first position was in a rated academic institution, we regressed institutional prestige on the usual variables *plus* the prestige of the postdoctoral institution. The results in the right-hand panel of Table 5 show that postdoctoral prestige is by far the most important determinant of the prestige of the first job. In fact, the magnitude of the effect (either standardized or unstandardized) is almost identical to that of *doctoral* prestige in the regression for the full sample. For postdoctorals, the effect of doctoral prestige declines to the point where it is no longer statistically significant. The only other variable which affects prestige of first job is, as before, the dummy variable indicating a degree from an agricultural school. It thus appears that when a biochemist takes a postdoctoral position, the prestige of his new institutional affiliation replaces the prestige of his doctoral department. The choice of a postdoctoral institution then becomes critically important in determining one's future career chances.

It is not yet clear just how postdoctoral prestige facilitates a biochemist's entry into the academic labor market, although it seems plausible that the same processes operate as with doctoral prestige. Elsewhere (Long et al.) we have argued that neither the prestige of the mentor nor predoctoral productivity explain away the effect of doctoral prestige, and the same may be true for postdoctoral prestige. This cannot be tested for mentor prestige since we do not know the name of the postdoctoral supervisor. However, we do have counts of publications and citations for the postdoctoral years. When those are substituted for the measures of predoctoral productivity in the regression for the 150 postdoctorals, the results hardly change at all (regression not shown). It cannot be maintained, then, that postdoctorals at prestigious institutions got better jobs because they published more or better papers during the postdoctoral training period. Rather, it appears that hiring departments pay more attention to where one got postdoctoral as opposed to doctoral training.

EFFECTS ON LATER PRODUCTIVITY

From the perspective of science policy, the key issue is not whether postdoctoral training leads to desirable careers but whether it actually improves the research capabilities and contributions of trainees in measurable and lasting ways. A committee of the National Research Council (c) has characterized the postdoctoral appointment as "a combination of intensive research activity and an opportunity to enhance the research technique of the trainee under the guidance of an experienced investigator." Thus, a reasonable expectation is that returns from the national investment in postdoctoral training would take the form of greater research productivity —papers published and citations received—by those with postdoctoral training than by otherwise comparable doctoral scientists.

Several studies have found sizeable differences in counts of publications and citations between those with and those without postdoctoral training (Folger et al.; National Research Council, a; Reskin) and this study is no exception. Our dependent variables were the number of papers published by each biochemist in the interval from eight to ten years following receipt of the doctorate and the number of citations made to those papers. While strongly correlated ($r = .62$), citations were far from being a simple multiple of publications.

On the average, former postdoctorals published 26 percent more papers than non-postdoctorals (means were 4.77 and 3.78 respectively) and received 75 percent more citations (means were 24.07 and 13.78 respectively). While these differences raise the possibility that postdoctoral training made for later productivity, they hardly demonstrate that fact. An alternative explanation is that postdoctoral training positions were given to the most able doctorates who would have published more than their fellow cohorts even without postdoctoral training. Without a randomized experiment, that explanation can never be entirely ruled out. Nevertheless, by statistically controlling for other characteristics of biochemists—especially predoctoral productivity—we can get some better indication of the plausibility of these competing hypotheses.

Table 6, Panel A, presents the results of a linear regression in which the dependent variable was the natural logarithm of the number of publications,[7] and the independent variables were those seen in the previous analyses, including a dummy variable indicating postdoctoral training. The strongest effects are clearly those of doctoral prestige, age at Ph.D., and number of predoctoral publications, all in the expected direction. The effect of having held a postdoctoral position is marginally significant at the *.05* level with a one-tailed test. Because of the logarithmic transformation of the dependent variable, the unstandardized coefficient for the dummy variable can be transformed into a percentage increase by the expression $100[exp(b) - 1]$ where b is the coefficient. Thus, the coefficient of *.161* for the postdoctoral dummy corresponds to former postdoctorals publishing 17 percent more than non-postdoctorals, net of other variables. We see, then, that while the effect of postdoctoral training on later publication rates is reduced by the introduction of other variables, it is not entirely eliminated.

It is possible, however, that the effect of postdoctoral training on

Table 6. REGRESSIONS PREDICTING LATER PUBLICATION COUNTS

	All Biochemists (N=557)				Postdoctorals (N=200)	
Independent Variables	A. Stand. Coeff.	Metric Coeff.	B. Stand. Coeff.	Metric Coeff.	C. Stand. Coeff.	Metric Coeff.
Ph.D. in ag. school	-.08*	-.170*	-.03	-.056	-.05	-.122
Married at Ph.D.	-.03	-.090	.01	.032	.03	.086
Ph.D. prestige	.12**	.116**	.08*	.074*	.10	.095
Age at Ph.D.	-.13**	-.034**	-.16**	-.042**	-.13*	-.040*
Mentor's citations	.07	.049	.07	.047	.05	.036
Publications	.14**	.178**	.10*	.124*	.01	.019
Citations	.10*	.099*	.11*	.109*	.12	.129
Postdoctoral training	.08*	.161*	.05	.099	--	--
Postdoctoral prestige	--	--	--	--	.08	.100
High prest. academia	--	--		.389**	--	--
Research center	--	--		.344**	--	--
Business or industry	--	--		-.354**		
R^2	.139		.199		.075	

*Coefficient significant at .05 level.
**Coefficient significant at .01 level.

publication rates is not a result of extended training and research experience but rather a consequence of the fact that former postdoctorals are more likely to be employed in settings where research is expected and supported. As seen in Table 4, for example, postdoctorals were much more likely than others to have their first subsequent job in an academic setting. To test this possibility, a set of dummy variables representing employment sector was added to the regression equation. The three variables were chosen to represent four sectors: high prestige academia, low prestige academia, non-academic research center, and business or industry.[8] The results in Panel B of Table 6 support this alternative explanation. Employent sector has a substantial effect on later productivity (the R-square increases from .139 to .199) while the effect of postdoctoral training declines substantially.[9] According to the new equation, postdoctorals publish only 10 percent more papers than others, a figure that is not significantly different from zero.

It appears, then, that the effect of postdoctoral training on later publication rates is explained by the fact that postdoctorals got jobs in research-intensive settings (Long and McGinnis). It could still be the case, however, that *where* one got postdoctoral training made a difference in later productivity. Panel C of Table 6 gives evidence against that hypothesis. For the 200 postdoctorals in rated universities, the logarithm of publication counts was regressed on the measures of predoctoral status plus the prestige of the postdoctoral institution. Although in the expected direction, the effect of postdoctoral prestige is far from statistically significant.

The final step was to replicate the preceding analysis with citations as the criterion variable. Panel A of Table 7 shows that several variables had sizable impact on the number of citations, all in the expected direction. As usual, the best predictor was the number of citations to predoctoral publications. The effect of postdoctoral training, however, was highly significant and represented a 37 percent edge over non-postdoctorals. While this is a substantial decline from the 75 percent advantage that appears in a simple comparison of means, it is still a large effect. We then added the three dummy variables for employment sector to see if the effect of postdoctoral training could be explained by its impact on the sector of the first job. Again employment sector makes a sizeable difference in citation rates and does explain a small part of the postdoctoral effect. That effect is still highly significant, however, and represents a 32 percent advantage on the part of postdoctorals. When postdoctorals were divided into fellows and research associates, there was no difference between the two groups in later citation rates (regression not shown). Last, we attempted to see if the prestige of the postdoctoral institution had any impact on later citation rates. The regression results in Panel C of Table 6 offer no support for that hypothesis.

Table 7. REGRESSIONS PREDICTING LATER CITATION COUNTS

	All Biochemists (N=557)				Postdoctorals (N=200)	
Independent Variables	A. Stand. Coeff.	Metric Coeff.	B. Stand. Coeff.	Metric Coeff.	C. Stand. Coeff.	Metric Coeff.
Ph.D. in ag. school	-.09*	-.221*	-.06	-.152	-.12*	-.316*
Married at Ph.D.	-.02	-.054	.01	.037	-.01	-.027
Ph.D. prestige	.15**	.162**	.12**	.124**	.12	.126
Age at Ph.D.	-.14**	-.042**	-.16**	-.048**	-.15*	-.050*
Mentor's citations	.08*	.058*	.07	.051	.07	.061
Publications	.02	.028	.00	.000	-.04	-.063
Citations	.24**	.273**	.24**	.271**	.20*	.222*
Postdoctoral training	.14**	.317**	.12**	.277**	--	--
Postdoctoral prestige	--	--	--	--	.02	.024
High prest. academia	--	--		.430**	--	--
Research center	--	--		.334**	--	--
Business or Industry	--	--		-.073	--	--
R^2	.210		.224		.113	

*Coefficient significant at .05 level.
**Coefficient significant at .01 level.

Summary and Discussion

Here are the major conclusions we have drawn from the preceding analysis:

1. Predoctoral productivity had no effect on the likelihood of getting postdoctoral training. For those who got such training, predoctoral productivity had no effect on the prestige of the postdoctoral institution. Yet measures of predoctoral productivity were among the best predictors of productivity several years later.
2. Older doctorates and those with degrees from agricultural colleges were much less likely to get postdoctoral training, net of other variables. Prestige of doctoral department and prestige of the mentor also had moderate positive effects on the likelihood of getting postdoctoral training.
3. The prestige of the postdoctoral institution was modestly affected by the prestige of the doctoral department and the college in which the doctorate was earned.
4. Postdoctoral trainees were much more likely than others to move into academic jobs, net of other variables.
5. Of those who entered academia, former postdoctorals were no more likely than others to get jobs in prestigious departments. Among postdoc-

torals, however, the prestige of the postdoctoral institution replaced doctoral prestige as the best predictor of the prestige of the first academic job.
6. Postdoctoral training appears to have some positive effect on later publication rates, although this is largely a consequence of the fact that postdoctorals tend to get jobs in research-intensive sectors.
37. Net of other variables, postdoctorals get over thirty percent more citations to their later publications than non-postdoctorals. This difference is *not* attributable to the different employment patterns of former postdoctorals.
8. Prestige of postdoctoral institution appears to have no effect on later productivity.
9. Age at Ph.D. had a strong impact on both publication and citation rates, net of other variables.

These findings suggest some tentative answers to the three questions which guided this study:

Are postdoctoral training positions awarded according to universalistic criteria? The impact of doctoral prestige and mentor prestige is consistent with other studies and is ambiguous with respect to universalism. These variables could be interpreted either as indicators of scientific ability or as indicators of position in a social network that relies on ascriptive processes. The strong negative effect of age at Ph.D. on the probability of getting postdoctoral training is also ambiguous in its interpretation. A natural explanation is that older Ph.D.s would not want to further extend their educational careers in the absence of large payoffs. Yet others have used age at Ph.D. (or closely related measures) as an indicator of ability, and the strong negative effects of age on later productivity lends support to this view. Hence, the negative effect of age could also be seen as evidence for universalism.

These ambiguous results are overshadowed, however, by the fact that established records of research productivity have no impact whatever on whether one gets a postdoctoral training position. These are the least ambiguous indicators of scientific ability and, as we have seen, early productivity is a good predictor of productivity ten years into the career. It appears that those who make decisions about postdoctoral positions are either unconcerned with scientific ability or else they believe that predoctoral publication does not indicate a candidate's potential.[10]

Does postdoctoral training enhance one's position in the job market? Certainly postdoctorals are much more likely to get academic jobs, but it could be argued that this is simply because those who choose a nonacademic career see no point in postdoctoral training. It must be remembered that when these doctorates were seeking jobs, academic positions were relatively plentiful. Thus, the lack of postdoctoral training was not a barrier to getting a job in academia. In fact, of those entering academic jobs, 42 percent had *not* had postdoctoral training.

The real question is whether, having entered the academic labor market, one could get a better job with postdoctoral training than without. If better means more prestigious, the answer is no. On the other hand, if a biochemist did get postdoctoral training, it made a big difference where that training took place. Postdoctorals at better schools got jobs at better schools.

If postdoctoral training per se did not enhance one's job opportunities, why then did new doctorates choose to participate in such training? Possible explanations include erroneous beliefs, tradition, and inability to find an acceptable academic job. Again, the last explanation seems implausible in view of the booming academic job market of the early 60s. It may be that new doctorates anticipated the answer to our third question: Does postdoctoral training enhance one's research productivity? Our results suggest that it has little if any effect on the volume of productivity, but may have important effects on the visibility or utilization of one's work. To the extent that new doctorates desire their work to have maximal impact on other scientists, choosing to get postdoctoral training would appear to be a rational decision. These results also suggest that the allocation of public monies to support postdoctoral training has at least some measurable impact on the quality of scientific work. Whether that investment is cost-efficient is a question well beyond our capabilities to answer.

Assuming that postdoctoral training really does increase the visibility or use of biochemists' work, it is natural to ask how that effect is produced. The conventional wisdom is that postdoctoral training enables one to gain additional specialized skills and knowledge under the direction of an experienced investigator. In short, it is essentially an extension of graduate training with a greater emphasis on research skills. If that were the case, then the quality of training should vary greatly across departments and mentors, and this variation should be reflected in later citation rates. Yet prestige of the postdoctoral institution (which is known to be a fairly good proxy for resources and faculty quality) has virtually no impact on later citation rates. Thus productivity outcomes show a pattern exactly opposite to that of job outcomes: getting postdoctoral training makes a difference but where one gets it makes no difference.

To explain this apparently anomalous result, we suggest that the key resource involved in postdoctoral training is something that does not vary much across institutions—time to do research without teaching responsibilities. We suspect that time is so important because it enables the postdoctoral person to put aside his dissertation topic and begin investigations of greater potential importance (Curtis). In contrast, the new doctorate who immediately begins his career with a tenure-track position must cope with his new responsibilities as a teaching faculty member. While that may not reduce the quantity of research, it may greatly inhibit one's ability to venture into new areas. In short, we believe that one of the chief functions of postdoctoral training is the facilitation of intellectual mobility.

Can these conclusions be generalized to other scientific fields? We see no reason to suspect that other fields would differ. Although biochemistry has long been a field with one of the highest rates of postdoctoral training, it has only been at the vanguard of a long-term trend. In our sample, 49 percent of the biochemists pursued postdoctoral training. Several years later, between 1971 and 1975, 78 percent of biochemists and 57 percent of all biomedical doctorates took postdoctoral training (National Research Council, b). Similar trends have been documented in chemistry and physics (Coggeshall et al.). In short, many other fields are now investng in postdoctoral training at levels comparable to those in biochemistry in the late fifties and early sixties.

But are the processes the same in different fields? Obviously more data from a variety of disciplines are necessary for answering this question. Yet biochemistry itself provides some suggestive evidence for the invariance of causes and consequences of postdoctoral training. One of the unique features of biochemistry is the split between agricultural and medical orientations to the field. In every one of the tables presented above, those who obtained their degrees from agricultural schools differed significantly from other biochemists: They were much less likely to get postdoctoral training, and those who did take postdoctoral training did so in less prestigious institutions. Similarly, they were much less likely to start their careers in academia, and those who did take academic jobs were in less prestigious institutions. Finally, their rates of publication and citation were significantly lower than those of other biochemists. In many respects, then, these two subdivisions of biochemistry behave almost as though they were two quite different fields.

Despite these differences, the processes operating *within* each of these two groups of biochemists were remarkably similar. For all of the linear and logit regression models presented above, we tested for interactions between a degree from an agricultural school and all of the other variables. This is equivalent to testing whether the regression models were the same for the two groups. In only one case was there a significant difference: the effect of marital status on getting postdoctoral training was stronger among those with an agricultural degree. In short, major differences in commitment to postdoctoral training, academic career lines, and publishable research do not add up to much difference in the causes and consequences of postdoctoral training.

Notes

1. These sources included *National Faculty Directory* (Gale Research Company), *Directory of Graduate Research* (American Chemical Society), *American Doctoral Dissertations* (Xerox) and *Dissertation Abstracts* (Xerox).
2. We estimate that this number represents nearly 90 percent of all males who received biochemistry doctorates in those years and who remained in the U.S.

3. About 15 percent of the trainees held multiple postdoctoral appointments. For these, the rating of the last postdoctoral institution was used.
4. These weights are roughly proportional to the number of biochemists holding jobs in the different bioscience departments. The complete three-digit ratings of all rated institutions were kindly supplied to us by Charles J. Andersen.
5. In another regression (not shown) we added a dummy variable indicating whether the postdoctoral position was a fellowship or a research associateship. There was not a significant difference between the two types of position.
6. A job was defined as academic if the employer was an institution of higher education. No distinction was made between tenure-track or non-tenure-track positions, or between four-year and graduate institutions.
7. For a justification of the logarithmic transformation of productivity measures, see Allison. Before taking the logarithm, 0.5 was added to each individual's publication or citation count. Note also that the logarithmic transformation is very similar in form to the square-root transformation used in some other analyses of these data (Long; Long et al.). It is unlikely that different results would have been obtained if the square root transformation had been used here.
8. The median Roose–Andersen bioscience rating was taken as the dividing line between high and low prestige academia. Unrated institutions were classified as having low prestige. Most of those in non-academic research centers were employed by NIH or USDA. The numbers of biochemists in each employment sector were: 166 in high prestige academia, 185 in low prestige academia, 113 in non-academic research centers, and 93 in business or industry.
9. We also examined the possibility of interaction between the effects of postdoctoral training and employment sector. None was statistically significant.
10. It is often claimed that predoctoral publications are not good indicators of scientific potential because most predoctoral publications are co-authored with faculty mentors. The results in Tables 6 and 7 do not support this claim.

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