

THE POSTDOCTORAL RESEARCH ASSOCIATE-INSTRUCTOR

Do we use the new PhD wisely as only a research fellow? Added teaching responsibilities could be beneficial to him, the students and his department.

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OVER TWO YEARS AGO Richard Martin described some problems that have developed around the "superscholar" or postdoctorate on the US campus. He noted¹ that the usefulness of the postdoctorate to society is being questioned, and many suspect that the appointment simply serves as a haven for professional students who contribute relatively little to society, or who in one way or another are delaying a useful and permanent adjustment to society.

Because of the increasing difficulties with science funding, we question more acutely whether the productivity of postdoctorates is commensurate with their cost. Here I will present some thoughts on the question and concentrate on a new concept: the postdoctoral research associate-instructor or researcher-teacher. This concept might help couple the declining growth rate in science to the expanding growth rate in college instruction and, at the same time, help alleviate other problems on US campuses.

Sociophysics of productivity

A number of attempts have been made to formulate laws of productivity by measuring scientific publications. These attempts have grown from the desire to stimulate productivity and from concern for the "scientific explosion." Leroy H. Mantell² has recently made an analysis that yields a rather

conservative estimate of the meaningful expansion of scientific literature, suggesting that, thanks to the large population of nonproducers, the information explosion is not as serious as has been thought. Mantell calls attention to the law proposed by Alfred J. Lotka,³ which in its integral form states that the number of persons N writing at least p papers in a lifetime is given by

$$N = \frac{N_1}{p} \quad (1)$$

where N_1 is the number of scientists who have written at least one paper. Line 1 in the figure shows the form of this function for $N_1 = 100$, compared with some experimental data taken from Derek J. de Solla Price.⁴ Lotka's law unfortunately overestimates the noncontributors,⁵ (it is singular at $p = 0$), as well as the population for larger values of p .

Three more versatile distribution functions are also shown in the figure; they can be used to overcome both defects. A generalized and regularized form

$$N = N_0 \frac{a b}{(p + a)(p + b)} \quad (2)$$

where N_0 is the total population, goes over to Lotka's law when a approaches zero and b approaches infinity. It also contains Price's⁴ modification of Lotka's law by letting a approach zero.

Line 2 in the figure shows this function for $N_0 = 938$, $a = 0.1$ and $b = 14.5$.

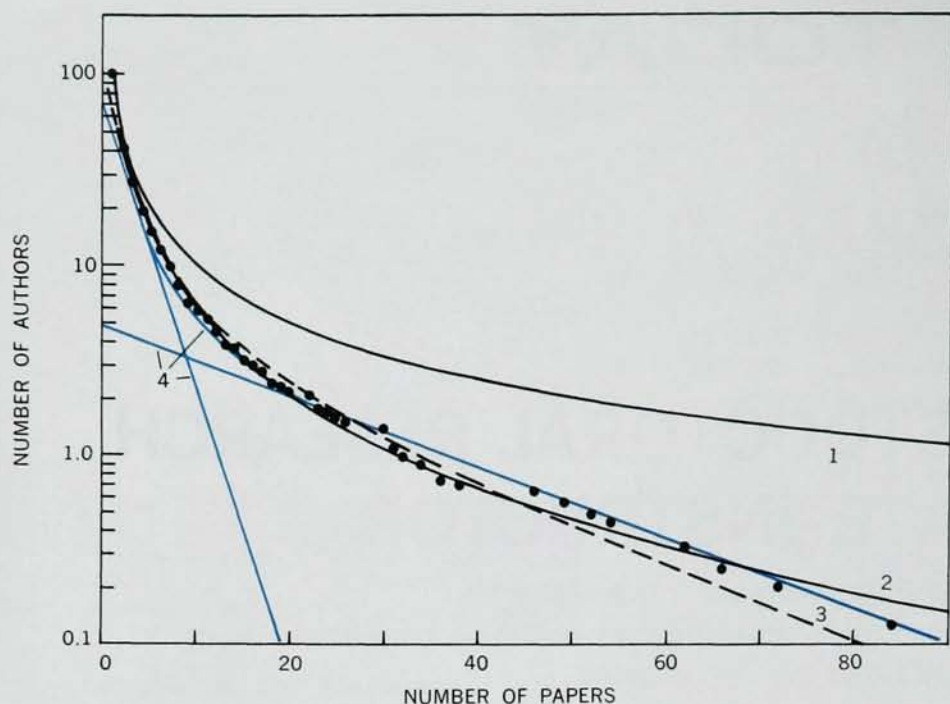
The form

$$N = N_1 \frac{(e^{1/b} + \alpha)}{(e^{p/b} + \alpha)} \quad (3)$$

used in atmospheric physics, contains as special cases the Fermi-Dirac ($\alpha > 0$), Maxwell-Boltzman ($\alpha = 0$) and Einstein-Bose ($\alpha = -1$) distributions. Where α is positive, the equation is equivalent to the Woods-Saxon distribution function used in the inde-



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PRODUCTIVITY DISTRIBUTION. Curve 1 represents the integral form of Lotka's law (equation 1). Curves 2, 3 and 4 show the form of equations 2, 3 and 4 respectively. The two straight lines associated with line 4 (color) are the two exponential components; the curve, their sum. The dots represent experimental data from early volumes of the *Proceedings of the Royal Society*, as compiled by Derek J. de Solla Price.¹

pendent-particle model of the nucleus.⁷

Computer optimizations to the data gave $\alpha \approx -1$, therefore suggesting, as a law of sociophysics, that productivity closely follows Einstein-Bose statistics. Line 3 in the figure shows equation 3 for $N_1 = 74.5$, $\alpha = -1$, $b = 23.2$.

A previous study⁸ suggested that reward for scientific effort follows Fermi-Dirac statistics, where the zero-point level is about \$10 000. Should the temperature of science be lowered and Einstein-Bose condensation occur, scientific output could approach zero as cost approaches infinity!

The distribution

$$N = N_0 [(1 - \alpha)e^{-p/a} + \alpha e^{-p/b}] \quad (4)$$

shown as line 4 in the figure for $N_0 = 75$, $\alpha = 0.06$, $a = 2.9$, $b = 23.3$, suggests that we have basically two populations—a small high-yield population and a large low-yield population. The two straight lines in the figure are the exponential components and the curve is their sum. All three are shown in color. These analyses are based upon data taken from early *Proceedings of the Royal Society* that have been roughly validated by 20th-century data from *Chemical Ab-*

stracts.⁴ There are, however, many open questions, such as time dependence,^{2,5} correlations between quantity and quality, the nature of the discipline, creativity of contribution and multiplicity of authorship.

We will be concerned here, however, with the large low-yield population, for this low productivity constitutes a serious basis for questioning our PhD programs. Far too many nonproductive men are being honored with this symbol of high scholarship, and this lack of productivity has become a major problem on the postdoctoral scene.

Postdoctorate: a dirty word?

A major difficulty in postdoctorate development stems from habits and attitudes that many PhD's acquire during their graduate training. These attitudes result partly from the stereotyped image of the scientist that developed immediately after World War II: "Give a scientist complete freedom and everything he wants, and not only will he produce pearls of publishable wisdom, but also useful contributions to the lot of mankind will spin off his work at regular intervals."

Unfortunately this picture is distorted, for most PhD's are unproductive, and their publication yield is very

low. When this yield is weighted against the scientific value of the published works, it usually becomes yet more meager. Many investigations, although competently executed, are comparable to stamp collecting, and their absence would not be missed. Indeed, professional postdoctorates, or permanent researchers engaged in the stamp-collecting type of research, may actually be detrimental, because they grind away too rapidly and at too great an expense at problems that might best be reserved as PhD "licensing" tests.

We can only conjecture how the yield in publications, corrected by their true worth, relates to the long- or short-term needs of society. This is a relevant question when research cost reaches the magnitude of other programs that are clearly of public importance. Therefore, one must avoid postdoctorates who might damage a research program, such as:

- Men who are nonfinishers or marginal finishers, who often raise smoke screens to mask their lack of dedication and inability to do good or complete work.

- Men who do not maintain an equitable balance between their demands and diversions from the research professor's energies and funds on the one hand, and their contributions to his program and to the broader educational purposes of a university on the other.

- Men who are not honest and forthright in agreements and who are destructively critical. Often such "criticists" or "glibicists" are disguising their lack of originality by arrogance, which makes collaboration difficult.

- Men who take a problem at the "cutting edge" and go off on a tangent of little value either to general knowledge or to the continuing research pro-



"Many investigations . . . comparable to stamp collecting would not be missed."

gram they are specifically working on.

• Loners who cause the professor to fall off the pace of his own field. The problem of the competent loner who is past the usual postdoctoral level in scientific maturity and competence is more complex. Basically, a postdoctoral fellowship under a grant or contract to a senior investigator is not a proper vehicle for such people.

These are the men who have made "postdoc" a dirty word, and a research professor and his university must learn to avoid them. Let us now consider the positive side.

Collaboration

Scientific research at the forefront of knowledge in a quantitative discipline is one of the most demanding types of human endeavor. To finish a meaningful study requires hard work in comparing theory and experimental data, careful study of related literature, and also creativity, imagination and judgment. Universities attempting to improve their scholarly position must encourage the development of strong research programs. In addition to scholarly glory, research programs provide indirect benefits in the form of student employment opportunities and training.

The graduate student is usually viewed as the primary collaborator for a research professor. Unfortunately in many institutions graduate students devote a major portion of their energies to course work and exams to fulfill the requirements for a PhD and are thus unable to concentrate heavily on a research problem. This handicap, together with their inexperience in research, greatly limits the usefulness of graduate students as collaborators on difficult topics. Consequently the natural role of the postdoctoral research associate is as a collaborator with research professors on mathematically or physically complex topics. The number of good graduate students receiving degrees at such prestigious schools as Harvard, Princeton and MIT exceeds the number of postdoctoral opportunities at these institutions. The postdoctorate provides a natural mechanism for distributing this good talent more uniformly across the country.

Unfortunately many "collaborators" play the game as if it were a zero-sum game, that is $T_a - G_a + T_b - G_b = 0$, in which T_a is "take" of a in the form of recognition, money, security; and G_a is the "give" in the form of effort

(past, present and future), resources, past achievements and administrative time. With this erroneous assumption some parasites often exert their efforts towards $T_b = G_a + G_b$, in which case $T_a = 0$. A fairer relationship is $T_a = G_a$ and $T_b = G_b$, but this is still not a meaningful collaboration. A model more in the spirit of scholarly collaboration would be a set of coupled equations with nonlinear mixed terms. Here the yield depends greatly on the mixed terms and the collaboration is undoubtedly successful if $T_a \gg G_a$ and $T_b \gg G_b$.

If effective collaboration develops between a postdoctorate and a professor, both parties benefit greatly. The professor can continue to expand his understanding of his subject despite the serious drain by unproductive demands. This ability is vital if he is to pose good research problems to students of later generations. The postdoctorate benefits by starting right at the frontier of knowledge reached by the professor. As he works, he can usually ground himself in the new subject areas by probing in all directions from the initial point of attack. Here is the major educational function of the postdoctorate, because he acquires further research experience, broadens his background, probes more deeply into a specific topic and sees its relationship to fundamentals. He should learn to overcome professional insecurities, in particular the "scientist block" (not completing a study), and thereby improve his publication record. Also he should learn something about the difficult but necessary balance between independence and compromise that characterizes successful collaborations. All of this experience prepares him for a future role as a professor. Indeed, the postdoctoral years are becoming a fine filter for the selection of faculty members in institutions that have, or aspire to have, strong research programs. Most good universities insist on about two years of productive postdoctoral experience before awarding regular faculty posts, to obtain a clear indication whether the man is a high research-yield or low research-yield type.

I have indicated that the postdoctorate can serve a good function to a man and a campus. Can this function be broadened and strengthened?

A remedy for Berkeleyitis

Recently a member of the Florida Board of Regents remarked, "God

forbid that the University of Florida become another Berkeley or Columbia." His concern, of course, is related to the great student unrest at these two universities rather than to their very distinguished positions in many fields. Consider, therefore, the relationship among the problems of Berkeley, the postdoctorate, the graduate student and the undergraduate student.

A great complaint among undergraduates is that professors are busy with consulting, government panels and wheeling and dealing, and are neglecting the students. As a solution, many propose that we replace the "great scholars" with "great teachers." They do not explain how a man can be a great teacher without a deep and fundamental understanding of current knowledge.

It should be clear that finding a balanced solution between the depersonalization, which is viewed as the cause of Berkeleyitis, and the time-consuming personalization, which is visualized as the ideal, will be difficult. A research professor's time is consumed by the continuing demands of research and the accompanying administrative tasks, and therefore it would be difficult for him to have a large number of personal contacts with undergraduates.

But one possible remedy is to encourage postdoctoral research associates to play a useful role in undergraduate education. The valuable teaching resource they represent is utilized in the concept of the postdoctoral research associate-instructor or researcher-teacher.

The possible benefits are manifold. For the university this concept provides an opportunity to upgrade not only its research program but also its teaching program. For the postdoc it provides teaching experience that broadens his future academic opportunities and that should provide better financial remuneration. The postdoctorate is usually a keener, more enthusiastic and alert individual than the typical graduate student or the full-time teacher with little research competence, and he should improve the quality of the department's instruction.

Furthermore the institution has an opportunity to look the postdoctorate over carefully as a prospective permanent faculty member. The portion of support borne by the teaching department should, in principle, re-



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lieve the supervisory professor's budget and make some of these resources available for other purposes. To the granting agency this departmental support represents a contribution to the supported research program. In this way all parties can benefit.

On the other hand, there are hazards associated with this approach. The postdoctorate might, by virtue of his teaching commitment, tend to neglect his primary research responsibilities or disassociate himself from the senior investigator's program; the professor may not make appropriate allowance, in his expectation of research performance, for the postdoctorate's teaching role.

Assuming that the postdoctoral researcher-teacher concept is initiated in good faith and is hence beneficial to the university, the postdoctorate, the department, the research professor and to the granting agency, the question of quantitative arrangements arises. It is my opinion that the teaching load should be as small as possible, preferably 8-12 hours per week, including preparation time. The typical department gives the full-time faculty member a teaching load usually of 15-25 hours a week (including preparation), so that he can devote substantial time to research. Half of this load is not an unreasonable diversion of effort for the postdoctoral researcher-teacher. It implies that the department sponsors some of the postdoctorate's research effort. Also, the compensation should be approximately half that of a faculty post plus half that of a regular postdoctoral stipend for the academic year, plus the full postdoctoral stipend for the summer.

As a concrete illustration, let us suppose that an instructorship of \$9000 per academic year and a grant postdoctorate of \$8400 per annum are available. Thus, an additional fund of \$2600 only is needed to create two \$10 000-per-annum postdoctoral research associate-instructorships. If arranged properly, both appointments would usually benefit by \$3600 tax deduction. The grant would thus bear \$11 000 and the university \$9000 in direct salary costs, plus whatever overhead rate is allowed. The total cost of maintaining two researcher-teachers is about the same (a little lower if the university provides summer employment for the teacher). Roughly speaking, the two organizations share equally, which is reasonable, because both should be interested in encouraging teaching and research.

Present and future advantages

We come to the final question: Would two postdoctoral research associate-instructorships hold a significant advantage over an ordinary instructorship plus an ordinary postdoctorate? In my opinion the answer is "Yes."

A major advantage at this time is that it would turn staff positions at research-oriented schools into positions for new PhD's. Such openings are vitally needed to give young postdoctorates time to find their professional bearings. Statistics show that a PhD does not assure productivity in research. Thus a primary function of the postdoctorate period is to help the man and society make a finer judgment of his research potential and in most cases to help establish his proper position in higher education. If the man has very good research potential, he should at the end of his postdoctorate be helped towards a permanent post at a PhD-granting institution, or a national research laboratory. If he has modest capability, then an MS-granting institution would be his natural and proper environment. If he has little research capability, a junior college or BS-granting institution would be most suitable for him. His success at these institutions, particularly in the last two that represent a major outlet for PhD scientists, would be greatly aided by his teaching experience.

The teaching role should not seriously retard the postdoc's research program, since it is clear that productive people remain productive despite

8 or 12 hours of diversionary effort. Indeed, a diversion is frequently helpful to a man as an alternative outlet for his mind. In this case, the postdoctoral researcher-teacher, who is serving needs of the undergraduate, may also be relieved that his entire contribution to society is not based only on his creative research abilities.

It would appear that the postdoctoral research associate-instructor could, if correctly implemented, alleviate many national problems. With it we could preserve the postdoctorate for the positive functions it can serve, help to couple the lagging growth of science to the vigorous growth of college education and relieve some of the problems related to the generation gap. Most importantly, if properly developed, it could serve as a means for strengthening both the educational and the research functions of the US campus.

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