

Statements

Doctoral Education: Another Tragedy of the Commons?

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The Commission on the Future of Graduate Education in the Pharmaceutical Sciences report published in the journal provided an overview of the state of graduate education in the biomedical and pharmaceutical sciences through 1998. The report's authors have continued to closely follow graduate education in these areas and express concern that the recent dramatic increases in the federal support of biomedical research, specifically the doubling of the NIH budget, is producing an excess of PhD graduates in the biomedical sciences. They suggest that these continual increases in program enrollment are primarily driven by personnel needs of the academic research enterprise itself (*The Tragedy of the Commons*), not by employment demands or most importantly, the educational needs of graduate students. The result is that too many biomedical science PhD graduates end up in increasingly prolonged postdoctoral positions. The PhD oversupply problem is driven to a great extent by the unlimited supply of talented foreign students, which negates the role of market factors in moderating demand for graduate education, and obfuscates the decrease in academic preparation and interest of U.S. students in graduate study in the sciences. The authors provide recommendations for addressing the problems raised in this report.

Change, even for the better, is not without inconvenience.
- Samuel Johnson

INTRODUCTION

President Bush's proposed 2003 Fiscal Year budget contains a recommendation for a \$3.7 billion increase in the National Institutes of Health (NIH) budget, which if passed, will accomplish

the goal of doubling of the NIH's budget over the past five years. In addition to increased support for biomedical research, NIH grants fund, directly and indirectly, a large cadre of graduate students and postdoctoral fellows who provide the "manpower" that drives the biomedical research effort. Direct

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support of graduate education in the form of institutional and individual training grants provides only a small fraction of the support for graduate education, with the vast majority of students and fellows supported by individual grants, program project research grants or university assistantships. While the increase in graduate student and postdoctoral support driven by these dramatic increases in biomedical research has its upside, the downside is an ever growing number of new biomedical sciences PhD graduates who, along with an increasing number of foreign-educated PhD and MD graduates, continue to fill an already bloated postdoctoral pool.

The numbers of PhD students and graduates in the pharmaceutical sciences from AACP member colleges and schools of pharmacy have remained relatively constant for the past seven years. The demand for PhD graduates in most of the pharmaceutical science disciplines has remained strong, because of the continued growth in pharmacy programs and the pharmaceutical industry. Additionally, postdoctoral fellowships are uncommon in pharmaceuticals and pharmacy administration because of the demand by academic and industry employers to hire these PhD graduates upon completion of their degrees. To meet the demand for PhD-level pharmaceutical scientists, it has been suggested that biomedical science graduate programs promote careers in the pharmaceutical industry in addition to their traditional focus on careers in academia(1).

Why then, with such a favorable future for PhD programs in the pharmaceutical sciences, do potential problems exist that may be caused by the overproduction of PhD graduates in other disciplines? We posit that the state of graduate education in the life and biomedical sciences, as well as in non-science disciplines, may influence, positively or negatively, all the graduate programs on that campus, including the pharmaceutical sciences. This may be reflected in graduate program requirements, financial support of graduate students, concurrent support of programs with similar outcomes, and state legislature support for numbers and types of programs on individual campuses in a multi-institutional system. In what follows, it is our objective to review the overall state of graduate education in the U.S., and provide pharmacy faculty and administrators a background and perspective for evaluating their own graduate programs(2).

THE TRAGEDY OF THE COMMONS

Garrett Harding, in his influential paper of 1968, drew powerful attention to what he described as "The Tragedy of the Commons," whereby a common resource that is available for use in the public domain by all is overexploited because there is an individual benefit, albeit to the ultimate detriment of both the common pool resource and its users(3-5). The classic example is cattle grazing on the common land, where there is an individual benefit to expand use of this resource, but one where the cost of overgrazing, overpopulation, or overexploitation is imposed on all. Conversely, an altruistic decision made by one individual to reduce their use of the common resource is a major cost to that individual, but only a minor benefit to other individuals. Hence, expansion of individual use of this resource is ultimately non-sustainable and a tragedy for the commons.

There is a parallel between Hardin's thesis and doctoral education. Research funding, graduate student enrollments, and the numbers of postdoctoral fellows increasingly drive faculty and institutional reputation. Unlike the traditional commons analogy, the size of programs is not primarily driven by

natural growth of domestic students but by the importation of foreign students, eliminating the potential impact of market forces on the size of program. This profligate expansion (overgrazing) of doctoral program enrollment over the past decade has given rise to a substantial set of frustrations for the graduate who is unable to satisfy his or her career expectations. Doctoral programs also place a considerable strain on the financial resources of higher education, and have been accused of turning baccalaureate students into "second class citizens" at research universities.

There are various solutions that can, in principle, be imposed to remedy the exploitation of the commons. Hardin argued that the solution lay in management and generalized his conclusion as follows: "A managed commons describes either socialism or the privatism of free enterprise. Either one may work; either one may fail." Hardin describes the two extremes of management — "socialism" with a centrally managed economy, or "privatism" with a market-determined economy. Others, notably Ostrom *et al.*(5), have been less stark in their conclusions and have argued that, "tragedies of the commons are real, but not inevitable," and that there are scenarios alternative to the "either or" choice of socialism or privatization. The growing problems associated with the uncontrolled growth of graduate education in the U.S. have been universally recognized as "inevitable."

The Present State of Graduate Doctoral Education

Many discussions of the fundamental issues around graduate education in the sciences, social sciences, and humanities, specifically the purpose and characteristics of doctoral education, its support, and the career prospects of the graduates have occurred in the past decade, resulting in numerous books, symposium proceedings, and Web pages(6-19). The 1992 volume by Bowen and Rudenstine identified two major problem areas: (i) funding, and (ii) the internal characteristics of programs(6). These areas, together with those of doctoral enrollment and career prospects, have formed the basis for continuing discussion and recommendations for improving PhD education during the past ten years.

Bowen and Rudenstine observed:

"...only about half of all entering students in many PhD programs eventually obtain doctorates (frequently after pursuing degrees anywhere from six to twelve years). In sharp contrast, it is common for completion rates in leading professional schools of business, law and medicine to exceed 90 percent. And it is not just the plight of the ABDs... that has caused completion rates in PhD programs to be low: attrition has been high at all stages of graduate study."

There is little evidence that this situation has improved, since time-to-degree continues to increase despite the many proposals that it be shortened. The registered time-to-degree is now 7.3 years and the average age for degree conferment is now 33.8 years(8). Other published reports have discussed graduate education with particular reference to the overall record numbers of PhD graduates, their employment prospects and career opportunities, the impact of the changing faculty employment patterns in universities, financial support, and graduate student expectations(9-17,19). The report commissioned by the Pew Foundation discusses a survey of doctoral students in eleven programs in twenty-seven universities(11). The report concluded:

- "The data from this study show that in today's doctoral programs, there is a three way mismatch between student goals, training and actual careers."
- "The training that doctoral students receive is not what they want, nor does it prepare them for the jobs they take."
- "Many students do not clearly understand what doctoral study entails, how the process works and how to navigate it effectively."

These conclusions are similar to those drawn by the prestigious American Association of Universities (AAU) in a general description of graduate education issues across the sciences, engineering, social sciences, and the humanities(15). Although the AAU represents only a small fraction of the PhD-granting institutions in the U.S., the organization membership does include the majority of the major research universities, and the most highly reputed graduate programs. Moreover, AAU member institutions graduate over 50 percent of the total PhDs granted in the U.S. Their report, "Graduate Education: Report and Recommendations" states that:

"The overriding purpose of graduate education is and always must be the education of graduate students. In designing graduate programs and advising graduate students, university administrators and faculty members must hold the interests of students paramount."

The AAU recommended the reform of doctoral education derived from a fundamental observation made in the body of the report:

"The view emerging from... national and institutional examinations of graduate education is that the balance between institutional and departmental benefits from and responsibilities for graduate education has in many cases shifted too far in the direction of institutional and departmental benefits, to the detriment of graduate students and programs."

The recommendations from the AAU report include efforts to recruit more domestic and minority students, improve financial assistance, provide better career planning, and more effective faculty mentoring. These AAU recommendations are similar to those made in reports in 1998 and 2000 from the National Research Council (NRC) focusing on the broad areas of biological, biomedical, and behavioral research(8,16). The most recent NRC report was notable for two specific statements concerning doctoral production(8):

- "...well above that needed to keep pace with growth in the U.S. economy and to replace those leaving the workforce as a result of retirement and death."
- "...research training and overall PhD production in these fields should not be increased."

Both NRC reports argue for a reduction in graduate enrollment, an increased emphasis on program quality, and a call to halt new programs at institutions eager to climb the research ladder or to satisfy the research-oriented career aspirations of their faculty, many of whom are recruited from research-intensive institutions. However, a call for decreased doctoral enrollment is not one to which the majority of faculty and faculties are readily attracted(19).

The Carnegie Foundation has announced, "The Carnegie Initiative on the Doctorate," intended to advocate a "broader conceptualization of doctoral education than the present graduate experience typically includes." Selected experimental initiatives are planned to provide for these broader experiences(20). Whether this latest venture will actually result in real change remains to be determined.

Manpower Needs: An Excess of Doctoral Education?

The number of PhD graduates from all disciplines decreased in 1999 for the first time in 14 years, reflecting the decrease in graduate program enrollment starting in 1996(7,21 -23). This decrease in PhD degrees awarded was not uniform, with the largest decreases occurring in engineering and the physical sciences, and the smallest decreases occurring in the humanities and social sciences. This decrease may have been merely transitory, because an increase was again observed between 1999 and 2000(24). The 2000 graduation data also demonstrate non-uniform trends across the broad disciplines. For example, the life sciences had the largest increase from 1999 to 2000, while the physical sciences had the largest decreases. PhD degrees awarded in physical sciences, which includes chemistry, physics, and mathematics have dropped 9.1 percent since 1997, while the humanities had an increase in 11 percent.

In response to the 1999 decrease in PhD graduates, Robert Weisbuch, President of the Woodrow Wilson National Fellowship Foundation, commented(23):

- "I... was shocked and dismayed to discover that those very fields that have been decimated by the academic job shortage were not the fields where the declines occurred. This is Marie Antoinette country."
- "We have what's tantamount to an economic depression in these, and one hopes that departments would pay attention to that fact."

The Marie Antoinette country Weisbuch refers to includes the discipline of English. Entry-level job opportunities in higher education for PhDs in English increased by 5.3 percent to 671 in 2001, but unfortunately, the number of PhD degree awarded also rose by more than seven percent to 1,070 (25). Perhaps those without employment in higher education were fortunate enough to find employment in the "private" sector.

The qualitative conclusions and expressed concerns that "we are overproducing PhDs" also derive support from calculated projections of workforce need. These projections are difficult to make for the PhD workforce, but the recent NRC report on biomedical education suggests that the "average" growth rate of 3.3 percent in the supply of biomedical workers will yield an expansion in the workforce from 91,440 in 1995 to 128,511 in 2005(8). However, if the growth rate is less than this, and the Bureau of Labor statistics forecasts a rate of 2.1 percent, then there will need to be a correspondingly larger decrease in the numbers of graduates. A fixed workforce projection would require a dramatic decrease from the current PhD production of some 5500 a year to less than half this number by 2005.

In *The PhD Factory: Training and Employment of Science and Engineering Doctorates in the United States* by Charles Goldman and William Massy (9), several important conclusions are reached on the basis of modeling exercises. Specifically, the authors argue that the recruitment of PhDs is driven by university and departmental needs and that these are

largely unrelated to the external labor market. They further argue that "quality" is not the rate-determining step that controls graduate admissions. The calculations by Goldman and Massy suggest, with well-acknowledged limitations, that for virtually every science and engineering field, there is a significant gap between PhD production and employment. There are exceptions—psychology, computer science and chemistry—but for all other fields studied (engineering, mathematics, biological sciences, geology, economics and physics), there are significant overproduction rates for which it is unlikely that external non-academic employment rates will provide compensating uptake.

The following quotes from Goldman and Massy are illustrative of some of the factors that drive graduate program expansion:

- "The factor that comes into the admission of graduate students is basically the number of faculty."
- "... it comes back to this TA problem. Some departments have these huge classes that need a lot of TAs..."
- "You can't admit more than you can identify funding for."
- "...the problem with our graduate program is not enough good applicants, pure and simple. I think that's a general problem that's not limited to University X. There are many universities that are not happy with their graduate applications..."

The "head count" or FTE enrollment of both undergraduate and graduate students in public institutions that use enrollment-driven budget models, is a critical determinant of the institutional budget and one often associated with significant penalties for under-enrollment, thus providing an impetus for expansion at any price.

Drs. Juliano and Oxford, professors of pharmacology and physiology respectively, at the University of North Carolina at Chapel Hill School of Medicine, suggest that there has been a decline in the overall quality of the graduate student pool and that some institutions sustain these enrollments by admitting questionably qualified candidates(26). They also state the occasionally whispered but rarely stated view that "...there also seems to be a significant number of individuals receiving PhDs who arguably neither belong in nor will appreciably benefit science."

The Demographics of Doctoral Education

The rise in graduate school enrollment observed over the past decade has been driven by foreign students(22,27). The reported decline in science and engineering PhD degrees granted to foreign students between 1996 and 1999 reflects the temporary decline in foreign student enrollment between 1992 and 1996(28,29). From 1996 to 2000, foreign student enrollment in science and engineering graduate programs increased by over 20 percent(27). U.S. student enrollment in sciences and engineering programs declined over this same time period. The decrease in U.S. student interest may be driven by a number of factors, including: (i) a generally favorable labor market for non-PhD graduates; (ii) a realization by U.S. students that the PhD career track is long and not well paid, and frequently followed by a lengthy, unstable, and poorly paid postdoctoral period with uncertain academic career prospects; and (iii) a K-12 educational system that does a poor job in preparing U.S. students in mathematics and the sciences. The dissatisfaction in a PhD career track was expressed in a survey of the American Society of Cell Biology members, where some 25 percent of

those surveyed indicated that they would not again pursue a PhD degree. Furthermore, graduates of second- and third-tier institutions appeared to be the least satisfied with their career choice(30). The rise of postdoctoral fellow organizations at a number of institutions is also probable evidence of a lack of satisfaction with the current situation (inter alia, 31).

The economist, Paul Romer has addressed the issue of U.S. student involvement in science and engineering careers and has argued that critical bottlenecks exist in the training of scientists and engineers at the undergraduate and graduate levels (32,33). At the undergraduate level, most institutions do not shift resources or recruiting priorities to favor the more expensive science and engineering education programs. Romer argues that there should be significant federal resources available to academic institutions that commit to increasing the number of science and engineering graduates at the undergraduate level. At the graduate level, institutions continue to favor graduate training that prepares individuals for the already saturated academic market(1). Non-U.S. students are both capable and willing to fill any demand gap, real or apparent.

Quite apart from the intellectual considerations of doctoral study, it is clear that there are powerful financial incentives for non-U.S. students to enter U.S. graduate programs, since the dollar differential in salary between the BA/BS level pay in the student's home country and PhD student stipend in the United States makes U.S. graduate education attractive. This, in turn, reduces the incentive for change in the Academy, if it involves the awarding of higher graduate student stipends and benefits to U.S. graduates. The willingness of foreign scientists and engineers admitted on the H-1B visa program to accept lower wages, and for their employers to offer lower wages than U.S. citizens for similar job responsibilities has resulted in increased criticism of that program(34). The substitution of foreign for domestic graduate students and scientists/engineers are simply further examples of the "Race to the Bottom" with other components of the U.S. economy(35).

An increasingly expressed social dilemma is that of decreased minority graduate student enrollment, particularly in the sciences and engineering(36). Many of the same reasons for lack of U.S. student interest in graduate education are true for minority students, despite the many federal programs directed at increasing their participation in the sciences and engineering. Minority student graduate education will continue to suffer unless universities pay increased attention to this issue. Some have argued that the existence of large pools of talented non-U.S. students available for graduate programs in the sciences and applied sciences, minimizes the need to nurture and recruit U.S. minority graduate students(37,38). B.L. Lowell, Director of Research at Georgetown University's Institute for the Study of International Migration observed that the U.S. reliance on foreign scientific talent may not be all beneficial and that, "In the medium to long term, the outlook is questionable"(38). If only partially true, this reflects poorly on U.S. graduate education, and in any event the problem is certainly exacerbated by the increasing number of non-U.S. post doctoral fellows. This postdoctoral pool, with many participants "parked in orbit" waiting for permanent positions, doubt less impacts on the attitudes of U.S. graduate students, potential graduate students and employers. MIT Professor Eric Weinstein has argued that government, universities, and industry have collectively contributed to the lack of enthusiasm for science and engineering education for U.S. students by ensuring that, "deteriorating terms of employment and depressed wages has a steady cumulative effect on the attractiveness

of advanced technical training for the best U.S. students”(39).

Impact of Doctoral Education on the Undergraduate Teaching Mission of the University

The expansion of higher education post-WWII and the reward system for research has led to both individual and institutional drives toward research that may actually be in overall terms detrimental to both higher education and the role of the professoriate. Doctoral graduate programs are very much a part of this problem. In the 1980s, Clark Kerr, then Chancellor of the University of California at Berkeley, spoke of the prestige and the rewards to "the non-teacher;" there is little doubt that this trend continues unabated today. Additionally, there is a parallel institutional race to become a "Research University" and to move up one or two places in the Carnegie classification and be recognized primarily for more research support, more graduate students, more postdoctoral fellows, and "More respect and influence" - THE OLIVER TWIST SYNDROME.

"The Research University is the model that all other institutions try to emulate. The widespread acceptance of this hierarchy has made research "the central professional endeavor and the focus of academic life:" it is accepted as the route to national status "(40).

Both increased doctoral enrollment and the drive of universities to achieve "research status" over the past thirty years have had major consequences for undergraduate education in Research Universities(41). First, an increase in the amount of undergraduate teaching performed by teaching assistants and adjunct faculty as senior faculty exchange or abandon teaching commitments for research time and as newly appointed junior faculty are provided with reduced teaching loads so they may build their research careers. A report from the Coalition on the Academic Workforce provides quantitative support for this now well-recognized phenomenon(42). Full-time faculty taught less than 60 percent and teaching assistants taught approximately 20 percent of the introductory courses in the majority of the disciplines in the humanities and social sciences. The same situation is true for the sciences, especially the large introductory biology, chemistry, and mathematics courses. As the percentage of non-U.S. graduate students has increased, the question of their fluency in the English language and their teaching competence looms large(43). The likely impact of these issues on graduate education further discourages U.S. students from pursuing careers in science and engineering, where our K-12 standards are already too low. In her opening address to the American Association for the Advancement of Science annual meeting 2001 in San Francisco on February 15, 2001, President Mary L. Good argued that the United States must attract more undergraduate students into science and engineering, a sentiment in accord with that advanced by Paul Romer(32,33).

"We have a decreasing cadre of professionals in the sciences and engineering... and since 1986, BS degrees in engineering, mathematics and computer science have dropped by about 20 percent". "The goal should be to increase the pool of students capable of science, math and engineering careers rather than concentrating totally on the very few of the brightest and best prepared students."

Postdoctoral Fellows: The Problem Deferred

Many of the problems facing graduate education are evident in the postdoctoral fellowship, a significant and almost compulsory contemporary component of higher education in the science and engineering disciplines. Reports from the Association of American Universities(44) and the National Academy of Sciences(45) both document the rapidly increasing pool of postdoctoral fellows (PDFs) derived from internal PhD production and from direct non-U.S. entry. The number of PDFs has approximately doubled in the last fifteen years and it is estimated that there are now over 50,000 such individuals in the United States of whom approximately 50 percent are non-U.S. citizens. Both reports acknowledge that for many individuals, the postdoctoral experience is satisfying, career enhancing, and indeed necessary, but it is also clear that for many individuals it is a dead-end prospect. The net result of the postdoctoral population increase has been simply to add a "PDF problem" to an already existing "PhD problem." In fact, this large PDF pool is the "dirty little secret" of the Academy. Maintenance of this pool permits the depression of salary levels in many areas of post-PhD employment by providing labor excess and serves to actively discourage U.S. students from entering graduate programs in these same areas. In turn, the lack of entry of U.S. students into PhD programs permits industry (with willing cooperation from the academy) to request and receive increasing allocations of H-1B visas to recruit non-U.S. workers and thus complete the cycle of decreasing U.S. student interest and enrollment(34).

At a recent convocation on the postdoctoral experience sponsored by the Committee on Science, Engineering and Public Policy, there was general agreement on the need for change, but no agreement on how to make change occur(46). In response to proposals for defined institutional standards for postdoctoral fellows, Maxine Singer, President of the Carnegie Institution of Washington, stated:

"...the greater the amount of freedom we give to principal investigators, the better the science."

Reminiscent of that old English nursery rhyme, "They hang the man and flog the woman who steals the goose from the common, but let the greater criminal go who steals the common from the goose." Old English Rhyme (Anonymous)

The Solutions

Inasmuch as research, research support, and higher education are not monolithic structures, change must occur at several levels - the faculty member, program, department, school or university, funding agency, principal investigator, and employer. None of these alone is likely to advocate change, since each individually profits from maximum exploitation of the existing system. Indeed, graduate students are regarded by many funding agencies, including the Federal Government, as enthusiastic employees accomplishing substantial work at low cost. In an opinion in November 2000, the National Labor Relations Board commented:

"The graduate assistant's relationship with the employer is thus indistinguishable from a master-servant relationship"(47).

The tentative nature of the conclusions that have been reached and the recommendations that have been made in all the reports on graduate education is due in part to the multi-component

nature of the problem. However, it is clear that institutions should undertake a broad-based examination of their graduate programs with regard to the quality and size of the enterprise, and that this examination should include both internal and external criteria and the imposition of higher standards. Such criteria and standards should include the following:

1. The size of the PhD program should reflect the quality and size of the applicant pool, placement of students, student support, faculty size, activity and breadth, physical facilities, and program and faculty productivity and reputation. A graduate program should only be started after a "critical mass" of faculty have demonstrated a history of scholarship and continued ability to attract sufficient financial support for their research and graduate student support. A graduate program should not exist to provide an inexpensive source of research assistants for faculty research activities or to routinely supply teaching assistants for undergraduate or professional classes. Expanding external financial resources should not dictate an automatic and corresponding increase in graduate student numbers.
2. Programs should maintain and make publicly available a database containing program characteristics, composition and size of the graduate student body, stipends, teaching activities and programs for students, graduation rates, time to degree data, placement, and career records.
3. Teaching assistants in a graduate program should have well-defined responsibilities and be engaged in a systematic sequence of teaching activities that provide a defined learning and programmatic experience. Their teaching should be systematically evaluated and be made a formal part of their academic record with course credit and grade given. Teaching assistants should not be used solely to repetitively teach large sections of courses where faculty have lost interest in teaching.
4. Full-time faculty should fulfill an appropriate and comprehensive role in the teaching activities of the department relative to graduate students and part-time faculty, and this role must be recognized as a major university responsibility. Furthermore, senior faculty should be regularly involved in the teaching of the most junior students; this task should not be relegated exclusively to teaching assistants or junior faculty.
5. Universities should examine closely graduate programs in departments that share similar disciplinary boundaries to ensure that they are not duplicative with respect to expensive graduate program resources, including courses and seminars. Universities should consider consolidating or linking these closely related programs in "umbrella structures" and/or closing such programs and diverting resources to "focus areas" where excellence can be obtained. The advantages to broader graduate areas are they permit more interchange among disciplines that are now separated by artificial departmental boundaries, they are more attractive to students who increasingly seek broader opportunities in both education and research, and they are increasingly likely to attract research funding. Consolidation can also reduce the administrative costs associated with supporting multiple small programs.
6. Fellowships should be provided to full-time students with four to five years of full support, tuition remission, and health benefits to ensure a more coherent graduate education. These fellowships should be adequately supported

with a minimum stipend guaranteed at such a level that will enhance the graduate student experience and permit degree completion within this time. With tuition remission additional, this sum should provide sufficiently for a time-to-completion within the stipend period. Provision of such fellowships directly to the student will provide more control to the student over his or her education. If students additionally serve as teaching assistants during the fellowship period, they should be compensated further to provide for self-support during the additional time necessary for PhD completion. The provision of sensible stipends, attainable time-to-degrees and relief from the present situation of teaching assistantships may alleviate the present malaise in U.S. graduate education and may be the first steps in correcting an aberrant labor market in doctoral graduate students.

7. Universities must recognize that the present system of graduate education is a system of underpaid employment. It is hypocritical for universities to resist attempts to form graduate student unions or to provide benefits if they are not prepared to enact the necessary conditions and expectations, including livable stipends for graduate students as "apprentice scholars, privileged to work closely with the greatest minds of their universities"(48-51).

The recommendation that graduate programs should not be initiated if significant faculty research and financial support for graduate students are unavailable may be wrongly interpreted as detrimental to hiring faculty and faculty scholarship at institutions without graduate programs. We maintain that graduate programs should be built upon a base of existing faculty scholarship and student financial support, not the reverse. Additionally, we reject the belief that significant faculty scholarship can only occur within the milieu of graduate education(52).

None of the suggestions above will improve the enrollment of U.S. students into science and engineering graduate programs without improvement in the enrollment and graduation of undergraduate science majors. This will require a new and vigorous commitment to enhance science and mathematics education at both the high school and undergraduate levels. Universities will have to take a leadership role in this effort. The magnitude and time-course of this task should not be underestimated; a decade may pass before major change will occur.

CONCLUSIONS

For at least a decade, the following question has been posed both to and within higher education, "Are we producing and excess of PhD-trained individuals in the sciences and engineering, the social sciences, and the humanities?" The question posed is one that higher education is equipped to study, but not well equipped to answer. Investment in higher education overall, and research-based doctoral education in particular, are important contributors to the present and future health, welfare, and prosperity of the United States. It is difficult to argue that a well-educated citizenry is not, overall, a valid and indeed laudable political and societal ambition. The public investment made in higher education is a "public good," providing an incentive to the private economy to contribute to research that benefits both the private and public economies through the subsidized production of PhD-trained scientists, engineers, social scientists, writers, and artists. However, like heroic medical procedures, there are "costs" involved in providing this

public good, and the issue of graduate education must be examined in view of both its benefits and costs.

We have attempted to demonstrate through an analogy to Garrett Harding's *Tragedy of the Commons* that the rapid and unfettered growth of the graduate education enterprise has given rise to some of the same problems that arise when any common resource is overexploited. The U.S. higher education system and particularly the faculty will not allow for external management or Harding's socialism. However, the enterprise has negated the effects of free market privatism as evidenced by countering decreased U.S. student interest through admission of unlimited numbers of non-U.S. students to fill the ranks of the available teaching and research assistantships funded internally or externally (53). There are hidden costs of a brain gain and the maintenance of the science and engineering research enterprise in the U.S. by increasing the flow of foreign-educated students and workers is likely to be to our nation's ultimate detriment(29,39,54). By this statement, we in no way are suggesting and are not implying that non-U.S. graduate students, postdoctoral fellows and PhD recipients have not or will not continue to significantly and positively contribute to the vitality and strength of this country. However, they should not be used to cover the failings of the enterprise, which has become progressively unattractive to U.S. students.

There are signs that some institutions are recognizing the problems with the graduate education experience that has made it so unattractive to U.S. students: (i) graduate student stipends are receiving more attentions at many institutions, although a living wage is still the exception(49-51); (ii) the NIH's NRSA predoctoral fellowship will have a stipend of \$18,156 commencing in 2002 and is designed to grow each year; (iii) the new PhD program at the Watson School of Biological Sciences at Cold Spring Harbor, NY has laudable aims, including the intention to produce PhD graduates in 4-4.5 years. It also provides a dual mentor system and a mentored teaching experience for its students; and in our own colleges and schools of pharmacy, faculties are experimenting with curricular models that will permit selected students the opportunity to pursue a professional and graduate degree simultaneously, resulting in a shortened pathway to both the PharmD and PhD degrees.

"Our higher degrees were instituted for the laudable purpose of stimulating scholarship, especially in the form of "original research." Experience has proved that great as the love of truth amongst men, it can be made still greater by adventitious rewards. The winning of a diploma certifying mastery and marking a barrier successfully passed, acts as a challenge to the ambitious; and if the diploma will help gain bread-winning positions also, its power as a stimulus to work is tremendously increased. So far, we are on innocent ground; it is well for a country to have research in abundance, and our graduate schools do but apply a normal psychological spur. But the institutionizing on a large scale of any natural combination of need and motive always tends to run into technicality and to develop a tyrannical Machine with unforeseen powers of exclusion and corruption"(55).

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