Commission on the Future of Graduate Education in the Pharmaceutical Sciences

Final Report

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Executive Summary

An Overview of Graduate Education in the United States

Nationally, graduate education has received relatively little attention compared to undergraduate and professional education over the past several decades. The primary responsibility for graduate education lies within the academic department and with the individual faculty member, whereas the entire university and the professional colleges and schools are responsible for undergraduate and professional education. Undergraduate and professional education programs undergo mandated external regional and specialized accreditation to maintain participation in federal loan programs or to qualify for professional licensure. Conversely, graduate education programs are not accredited and only undergo internal or external evaluation for National Institutes of Health (NIH) training grant applications, or if mandated by the university or state-level higher education boards. Additionally, the cost of graduate education at most state institutions is hidden in the larger instructional budget, as state legislatures generally do not allocate dollars for faculty research or graduate education. A national evaluation of graduate programs has been conducted twice in the past two decades by the National Research Council (NRC), but these evaluations are not inclusive of all academic disciplines, and they have been criticized as little more than opinion surveys similar to those published annually in popular national magazines.

Increasing criticism of the national graduate education enterprise arose in the early 1990s, primarily from new Ph.D. graduates in the physical sciences, who had difficulties finding desirable employment opportunities. Concerns about this "oversupply" of Ph.D.s, or an "undersupply" of employment opportunities in the graduate's areas of research interest began to focus national attention on graduate education. The Committee on Science, Engineering, and Public Policy (COSEPUP) of the NRC in 1995 attempted to examine the career paths of Ph.D. graduates in the sciences and engineering, and define the most appropriate structures and functions for graduate education. COSEPUP members "…were sufficiently troubled by the lack of generally available information to conclude that students', professors', and mentors' lack of accurate, timely, and accessible data on employment trends, careers, and sources of student support is a serious flaw in our educational system." The COSEPUP final report, "Reshaping the Graduate Education of Scientists and Engineers" concluded that "…the job opportunities of the future will favor students with greater breadth of academic and career skills…."

Additional reports and recommendations on graduate education have been produced by the American Chemical Society (ACS), the Federation of American Societies for Experimental Biology (FASEB), the American Association of Medical Colleges (AAMC), the American Association of Universities (AAU), and another committee of the NRC. Related reports have been issued by the American Association for the Advancement of Science (AAAS) on the declining graduate enrollment of minority students, the Commission on Professionals in Science and Technology (CPST) on the status of postdoctoral fellows in the U.S., and the Carnegie Foundation on the state of undergraduate education in research universities.

These studies and reports of the graduate education enterprise have several common conclusions and recommendations:

- The Ph.D. degree should remain a research-intensive degree, but provide more curricular or experiential options to increase the breadth of skills of graduates.

- Potential graduate students should be provided with accurate and timely information about career prospects so students can make informed choices about their careers.

- Non-U.S. students have primarily been responsible for the rapid growth in the number of Ph.D. degrees awarded in the last decade.

- The growth in Ph.D. degrees, particularly in the biomedical sciences, has contributed to a significant increase in the number of postdoctoral fellows and time spent in postdoctoral positions.

There is disagreement among the various reports as to what should be done or even whether anything should be done about the present "oversupply" situation. Increasing the breadth of graduate programs for the purpose of preparing Ph.D.s for alternative (non-academic) careers was recommended by some and rejected by others. Most reports suggested that no attempt should be made to limit enrollment in graduate programs, including foreign students, but a recent NRC study suggested that graduate programs in life sciences should constrain their rate of growth and that no new programs should be developed except under rare and exceptional circumstances. Concurrent with the recent recommendation to limit enrollment in graduate programs in the life sciences, Cold Spring Harbor Laboratory and the NIH have announced plans to initiate Ph.D. programs that are independent of any university affiliation.

Graduate Education in the Pharmaceutical Sciences in Colleges and Schools of Pharmacy

Graduate education in the pharmaceutical sciences is and has been a major concern of the Pharmacy Academy and the American Association of Colleges of Pharmacy (AACP). An AACP standing Committee on Graduate Education was initially appointed in 1946 to address the acute shortage of qualified pharmacy faculty following World War II. In 1978, Past-President Jere Goyan appointed a Special Committee on Research and Graduate Education that became the present standing AACP Research and Graduate Affairs Committee (RGAC). The RGAC addressed the issue of graduate program quality in colleges and schools of pharmacy from 1978-1979 to 1985-1986. AACP Past-President Jean Paul Gagnon appointed a study commission in 1986 to perform a comprehensive study of graduate education in the pharmaceutical sciences. The study commission, chaired by Dean August P. Lemberger published, "Graduate Education in the Pharmaceutical Sciences: The Quest for Quality" in 1989. This report reviewed the state of graduate education in colleges and schools of pharmacy and recommended that all graduate programs undergo regular, voluntary external evaluations for the purpose of improving program quality.

The Commission on the Future of Graduate Education in the Pharmaceutical Sciences (the Commission) was appointed in 1996 by AACP Past-President Charles O. Rutledge. Dr. Rutledge charged the committee to examine the following issues:

- What are the numbers and abilities of Ph.D. graduates needed in the pharmaceutical sciences now and in the future? In particular, what faculty should be used to monitor the supply and demand of pharmaceutical scientists and how can programs adjust the supply to meet the current and projected demand for scientists?

- What should be the nature of the education and training of Ph.D. students in the pharmaceutical sciences? Additionally, what is the appropriate range of skills needed by Ph.D. students in order to maintain productivity in a rapidly changing scientific environment practiced on a global scale?

The Commission examined past and present demographic data on graduate programs in the pharmaceutical sciences, career pathways of past graduates, and the recommendations and suggestions from pharmacy faculty at the Commission's conference on graduate education held prior to the 1998 AACP Annual Meeting to derive the following conclusions and recommendations.

One finding of the Commission is that the current outlook for pharmaceutical science graduates from colleges and schools of pharmacy appears to be good to excellent, with no apparent need to constrain future enrollment, unlike the biomedical sciences. This is in large part due to the bright future of the pharmaceutical and related biotechnology (life sciences) industries that employ significant numbers of pharmaceutical scientists. Unlike other life science disciplines, pharmaceutical science Ph.D. graduates have generally viewed an industrial career to be equivalent to an academic career, not as a less desirable "alternative" career.

The bright future envisioned for the new integrated life sciences industry is being built around the emerging discoveries in genomics and an increasing understanding of the molecular basis of many diseases. This future scenario poses both opportunities and challenges for graduate programs in the pharmaceutical sciences in colleges and schools of pharmacy. The challenges primarily come from within the university as many biomedical science, chemistry, biomedical engineering departments, and schools of public health refocus their research in areas of drug discovery, drug design, drug action, drug delivery, drug marketing, pharmacoeconomics, and the drug-related areas of health care policy to avail themselves to the increasing financial resources available to conduct research in these areas. To maintain and enhance a successful research and graduate program within the university environment, pharmaceutical science graduate programs and faculty in colleges and schools of pharmacy will have to simultaneously become both more competitive and collaborative with other academic disciplines within the university.

The Commission offers the following recommendations to assist colleges and schools of pharmacy with strengthening their graduate programs in the pharmaceutical sciences and planning for the future:

Recommendation 1: To maintain both the viability and visibility of graduate programs in the pharmaceutical sciences, colleges and schools of pharmacy must offer students research environments where competitive, funded, cutting edge research is performed under the supervision of highly qualified faculty mentors.

Recommendation 2: Institutions contemplating starting graduate programs (Ph.D. or M.S.) should only do so after an objective examination of the need for graduates with the particular expertise that the program is designed to provide. An inventory of faculty research experience, extramural financial support, and the research infrastructure (i.e., instrumentation, animal facilities, etc.) available to perform cutting-edge research in the proposed program area should be conducted, and deficiencies corrected *before* initiating a graduate program. Colleges and schools of pharmacy at less-research intensive universities should identify non-pharmacy departments (i.e., chemistry, mathematics, statistics, etc.) on their campus or on an adjacent campus that can provide research support and didactic courses at a level advanced enough to provide sufficient breadth to the proposed programs of graduate study.

Recommendation 3: Pharmaceutical sciences faculty are encouraged to engage in multi- or interdisciplinary research and graduate training programs within their own institution and with other faculty within the university. Pharmaceutical sciences faculty need to be more proactive in proposing and organizing interdisciplinary institution-based and campus-wide research programs, centers, or institutes, despite the possibility that the majority of faculty participants may not be from the college or school of pharmacy.

Recommendation 4: Graduate programs in the pharmaceutical sciences should establish, compile, and assess longitudinal databases of performance indicators to internally and externally assess faculty, student, and program quality. Sufficient data should be made public to assist potential graduate students to determine if the program is consistent with their research career aspirations. A common set of performance indicator measures should be submitted annually to AACP for the purpose of constructing comparison college and school cohorts (benchmarks) for chairs and deans to evaluate and improve the performance of their graduate programs.

Recommendation 5: All colleges and schools of pharmacy with graduate programs should provide "survival skills" training to their graduate students through a combination of didactic presentations and supervised experiences. These survival skills include, but are not limited to: research ethics, written and oral communication skills development, teaching skills development, computer skills enhancement, career counseling, and research team building opportunities.

Recommendation 6: Colleges and schools of pharmacy need to increase their recruitment efforts for U.S. students from disciplines other than pharmacy. The availability of large numbers of qualified foreign pharmacy graduates should not be used as a continual justification for the lack of recruitment of U.S. educated students. Colleges and schools of pharmacy also need to explore innovative approaches to increase the numbers of U.S. pharmacy students in graduate programs, through joint Pharm.D./Ph.D. programs that offer a significant decrease in time to complete both degrees.

Recommendation 7: Colleges and schools of pharmacy are encouraged to examine a Ph.D. program in the clinical sciences as an appropriate addition to their graduate program offerings.

Recommendation 8: Colleges and schools of pharmacy are encouraged to reexamine the M.S. degree as an applied pharmaceutical science graduate degree with a prescribed set of didactic and research requirements for completion.

Recommendation 9: The topic of graduate education should become an area for programming at AACP Annual Meetings.

Introduction

Background

Graduate education in the pharmaceutical sciences has been a major concern of the American Association of Colleges of Pharmacy (AACP) since the 1940s when there was a large projected shortfall of qualified faculty members to staff the nation's colleges and schools of pharmacy. In 1946, a standing Committee on Graduate Education was appointed, followed by the establishment of a Teacher's Conference on Graduate Education. These structures were abolished with the reorganization of AACP in 1973.[1] However in 1978, AACP Past-President Jere Goyan appointed a Special Committee on Research and Graduate Education that became the present standing AACP Research and Graduate Affairs Committee (RGAC), which meets annually and submits a report on their deliberations of the charges given to them by the AACP President.[2]

The 1985-1986 RGAC proposed a comprehensive study of graduate education in the pharmaceutical sciences.[3] As a result, a Study Commission was appointed by AACP Past-President Jean Paul Gagnon, and was chaired by Dean August P. Lemberger of the University of Wisconsin. The Study Commission published an excellent report, "Graduate Education in the Pharmaceutical Sciences: The Quest for Quality" in 1989 to assist AACP member colleges and schools in evaluating and strengthening their individual graduate programs.[4] The future of graduate education in the pharmaceutical sciences was again addressed by the 1995-1996 RGAC.[5] At this time, AACP Past-President Mary Anne Koda-Kimble gave the RGAC the following charges:

- What is or what will be the effect of workforce downsizing in the pharmaceutical industry on postprofessional and graduate education programs in pharmacy?
- Are our traditional areas of graduate study likely to create graduates with the necessary skills to fulfill emerging needs of the industry and Academy?
- Is the structure of our graduate education and postgraduate education training programs appropriate to accommodate rapidly changing and newly evolving disciplines?
- What is the appropriate range of skills needed by graduate students in order to maintain their productivity in a changing, multidisciplinary environment?

Since AACP standing committees have a limited time to investigate issues and develop their recommendations, the 1995-1996 RGAC recommended that a "Commission on the Future of Graduate Education in Schools of Pharmacy" be appointed to more thoroughly investigate some of the charges given to the committee by Dr. Koda-Kimble. The 1995-1996 RGAC also made a number of recommendations that addressed these issues and are consistent with the recommendations in this report.

The Commission on the Future of Graduate Education in the Pharmaceutical Sciences (the Commission) was appointed and charged in 1996 by AACP Past-President Charles O. Rutledge to examine the following issues:[6]

- What are the numbers and abilities of Ph.D. graduates needed in the pharmaceutical sciences now and in the future? In particular, what factors should be used to monitor the supply and demand of pharmaceutical scientists and how can programs adjust the supply to meet the current and projected demands for scientists?

- What should be the nature of the education and training of Ph.D. students in the pharmaceutical sciences? Additionally, what is the appropriate range of skills needed by Ph.D. students in order to maintain productivity in a rapidly changing scientific environment practiced on a global scale?

The Commission Members

The Commission members appointed by Past-President Rutledge are listed in Appendix 1. The Commission Chair is Dr. David J. Triggle, presently Vice Provost for Graduate Education and Dean of the Graduate School of the State University of New York at Buffalo. Dr. Triggle previously served as Dean of the School of Pharmacy at that institution. Drs. Cassady and Knapp are deans of pharmacy at institutions with vigorous graduate programs. Drs. Ernest Mario, Joseph Mollica, and Alice Till all received their undergraduate and graduate education degrees from colleges and schools of pharmacy, prior to careers in the pharmaceutical industry. Dr. Mario presently serves as Chairman of the American Foundation for Pharmaceutical Education (AFPE) and Dr. Till presently serves as President of the Generic Pharmaceutical Industry Association (GPIA). Dr. Jere Goyan served as Dean of the University of California-San Francisco School of Pharmacy for over twenty years and served as FDA Commissioner in addition to his present industrial position. Dr. Paul Anderson, a distinguished research chemist, has been active in the American Chemical Society (ACS) Section of Medicinal Chemistry. Dr. John P. Perkins, in addition to serving as Dean of the Graduate School at the University of Texas-Southwestern Medical Center, is a distinguished pharmacologist. Dr. Perkins is also a member of the American Association of Medical Colleges Group on Graduate Research, Education, and Training (GREAT Group) which has a primary interest in graduate education in the biomedical sciences. Dr. Renee Williard received her undergraduate and graduate degrees from schools of pharmacy and prior to her present position, served on the staff for the Pew Commission and as a postdoctoral representative on the AAMC GREAT Group.

In addition to the official members, meetings of the Commission were attended by Mr. Robert M. Bachman, President of AFPE and Dr. Jules LaPidus, President of the Council of Graduate Schools (CGS). Dr. Kenneth W. Miller serves as the AACP staff liaison to the Commission.

Commission Activities

The Commission had two meetings in 1997. At the first meeting, the Commission discussed many of the issues presented in this report. The following points were raised by members of the Commission with regard to the needs of the pharmaceutical industry, the major employer of Ph.D. graduates in the pharmaceutical sciences:

- There is an increasing need for graduates in health outcomes research, formulation, and product development.
- In the past, employment in one pharmaceutical company was generally life-long. However, this has dramatically changed, and it is now imperative that employees demonstrate their value to the company every day in order to learn and change with the science.
- Communication skills are critical to employees who need to convince others of the value of their work.
- Graduates must be aware of the possibility of not having the same job from year to year.
- Graduates must realize that science is competitive, global, and very exciting with a great potential for success.
- Research is more specialized in small companies, and there is a need for scientists with specific skills.
- Since industrial research is conducted under time constraints, a researcher must know when to terminate a project.
- Researchers in industry must realize the difference between “need to know” and “nice to know” problems.
- Communications in the industry are generally oral or short written reports.

The Commission members also raised a number of issues with regard to the nature of graduate programs:

- It is important for graduate students to learn the "fundamentals." The nature of content of the "fundamentals" in the different disciplines will vary, but the ability to solve problems was identified as central to the graduate education experience. The determination of when or whether a student really "understands" their area of study must be made by the advisor, mentor, or preferably, by the faculty committee.
- Graduate students must take more responsibility for their research projects, not primarily as sources of labor for an externally-funded research project. This is extremely difficult in situations where the research project is providing financial support for the student. An American Association of Universities (AAU) report on graduate education has pointed out that the federal policy (OMB Circular A-21) stipulates that "a bone fide employer-employee relationship" exists between a graduate student and faculty investigator funded by a federally funded research grant, is contrary to sound educational policy and should be changed.[7]
- Graduate students must learn "how to learn" since their future research activities will be vastly different than their Ph.D. research project.
- It is important to become an "expert" in a certain area, which requires the student to focus on what makes him/her unique. There was some disagreement as to whether this should occur during the graduate degree program or during a postdoctoral experience.
- Many U.S. students entering graduate school have not established the ability to integrate knowledge from different disciplines. This may be a result of the segmented nature of undergraduate education, but it is a deficiency that must be corrected in the graduate program.
- Graduate programs must provide a well-rounded and solid education, not just a set of research techniques.

The Commission held a conference preceding the July 1998 AACP Annual Meeting in Snowmass Village/Aspen, Colorado in order to solicit the input of the pharmacy academy. The conference program consisted of a keynote speaker from outside of pharmacy, invited pharmacy graduate faculty from the pharmaceutical sciences who were asked to address the future of their respective discipline, plus workshops to provide an opportunity for graduate faculty and deans to engage in a discussion of how the issues raised by the Commission can be addressed in their institutions. The recommendations presented by the symposium speakers and developed in the workshops are summarized in Appendix 2.

The Commission also conducted the following surveys to broaden its perspective on the future of graduate education in the pharmaceutical sciences: 1) a survey of selected pharmaceutical industry scientists to obtain additional opinions on the desirable outcomes of graduate education, and 2) opinion surveys of faculty members, graduate students, and postdoctoral fellows at colleges and schools of pharmacy.

A number of other reports and publications on graduate education in general, graduate education in the biomedical sciences, and graduate education in the pharmaceutical sciences served as background material for the Commission's deliberations. These reports, Commission surveys, pharmaceutical science graduate program demographic data, and the contributions of participants at the 1998 AACP Conference, all contributed to the final recommendations made by the Commission at the end of this report.

The Future of Graduate Education

Global Issues Affecting Academia

The report of this Commission is set in a period of remarkable and fast-paced change occurring at local, national, and international societal levels, affecting virtually all institutions, including universities. During a three-year period (1996-1998), the United States moved from record budget deficits to a balanced or surplus budget, with a three-year, double-digit rise in the stock market followed by significant market fluctuations. Projections of huge reductions in the federal support of non-defense R&D in 1996 have been reversed by several years of significant increases in the National Institutes of Health (NIH) and National Science Foundation (NSF) budgets. Influential members of Congress are now calling for a "doubling of the NIH budget over ten years." Moreover, American shares of international scientific prizes continue at their extremely high level with corresponding leadership in both scientific publication and citation.

These trends might suggest that there is little need for change in our educational policies, and that continuation of our present "system" will serve us well into the next century. Yet, despite this apparent basis for American optimism, there is a high level of concern about the future in graduate education. This concern arises from: the long-term structural issues of medical and social support of an aging population; the profound demographic and cultural changes that are impacting American society; the widening disparities of the rich and poor; the decline of social and family structures; and the increasing realization that the existing educational systems, particularly K-12, are inadequate or defective. These issues are becoming detrimental in the long-term to the United States in an inevitably and increasingly globalized economy of both conventional commerce and the new commerce of information. A recent National Science Board working paper points out the need to make decisions of priority not only within a scientific field as is currently accomplished through peer review, but in a new paradigm *across* scientific fields.[8] This, it is argued, will better place the United States in an increasingly competitive scientific and technological global market. These and related observations suggest that there are important problems facing us and that major structural changes are both needed and inevitable.

The Changing "Research University"

Universities are the predominant producers of our science and engineering graduates, and have been the principal creators of much of our basic research since World War II. Universities will be particularly susceptible to the impact of the changes as previously noted, because they are not well suited to adjust to rapid change. Almost one thousand years old, universities are one of the world's most durable institutions. In the Western world, universities are, paradoxically enough, victims of their own success. The virtues of the "American Research University" have been widely described and increasingly emulated nationally and in other countries. An article in *The Economist* referred to the university as "the knowledge factory," and observed that universities are now widely recognized, and indeed expected to be producers of "useful knowledge."[9] Furthermore, the sciences, rather than the humanities are now seen as having effectively supplanted the "liberal education" of the previous centuries. Both of these factors have led to an increasing demand for education at the college level. Additionally, economic globalization and the "siliconizing" of many industries have led to an increasing demand for "life-long education," whereby new learning and skills are continually obtained and refreshed. Simultaneously, with these changing expectations of the university have come technologies that permit the widespread dissemination of information and learning. The university will increasingly no longer be the place where scholars and students gather "within-the-walls," rather the global distribution of, and access to, information will make "place" and "time" far less determinant components of college-level education. This transformation of higher education will be further spurred by the cost of the modern research university that is simply far too expensive in its existing configuration to accommodate all of the potential students who demand access to this education. In response, universities will become increasingly diverse and specialized in their functions. At one extreme, "The University of Phoenix," a for-profit virtual university, and "The Western Governor's Virtual University" are both designed to make optimum use of the new information technologies to deliver learning to their students at multiple sites and multiple times. These will be "user-friendly institutions that stress convenience and value for students of a variety of ages; students who increasingly mix work and learning while pursuing their baccalaureate degrees one or two courses at a time." At the other extreme will be those institutions where "traditional-aged students matriculate at largely residential campuses and seek the kind of professional credentials that historically have guaranteed middle-class status and economic security." Institutions, including many state universities, whose colleges and schools do not define either of these alternatives, will increasingly have to plan their missions with great care and selectivity to be competitive in either arena.

There are powerful changes taking place in the nature of the disciplines of the sciences themselves within the macro-environment of the approximate 3,600 institutions of higher education. Universities are typically composed of powerful departments created to maintain the scientific discipline and its associated faculty, research, and educational missions. Increasingly, however, the disciplines have spread beyond departmental boundaries and new disciplines have emerged at the boundaries of existing ones. The influence of genomics and computer techniques have transformed existing biological and chemical disciplines and have created entirely new fields (i.e.,bioinformatics). The competition between the old and the new, particularly at the research level, creates new tensions that are exacerbated in times of declining resources. Increasingly, universities have to make decisions of academic priority for the allocation of resources. However, in the academic environment where process and participation are equally important, decisions are often not structured to ensure maximum effectiveness.

These changes are particularly stressful for the research university and its faculty to either contemplate or implement. However they are inevitable, given the demographic and economic factors that are impacting higher education. Additionally, the research university will be further transformed as increasing amounts of R&D are supported by industry and the role of the Federal Government continues to decline, despite the recent increases in the NIH and NSF budgets. The Federal Government supplied in excess of 50 percent of research funding in 1980. That figure will be less than 30 percent in 1998, with prospects shrinking even further. Finally, the impact of changes in health care provision on Academic Health Centers has not yet been fully realized.

It cannot be assumed that all of these possible changes will equally impact all programs in the research university. Nonetheless, the triple impact of changes in the public and political expectations of higher education, the altered climate of research funding patterns, and the changes in the financing of academic health centers will affect graduate programs in the health and biomedical sciences areas. It is important to recognize that the graduate programs of colleges and schools of pharmacy are typically a small component of the total graduate enterprise of the university, are a small component of the national pool of Ph.D. graduates in the life sciences and chemistry, and that the pharmaceutical sciences disciplines are no longer seen as unique to pharmacy. These features create both vulnerability and opportunities for strength and support of the pharmaceutical sciences in the changing research university of the 21st century.

Overview of Graduate Education in the United States

Issues in graduate education centered on the pharmaceutical sciences in colleges and schools of pharmacy must be seen not only in the perspective of their small and comparatively specialized focus, but also in the broader perspective of graduate education, in general.

Science and Engineering

The question of the market need for Ph.D.s in science and engineering is an ongoing concern to students, employers, and universities. Predicting supply and demand in any labor market is not simple, and the science and engineering market, where the time for Ph.D. degree completion exceeds that for change in employment demands, is no exception. The academic market for full-time Ph.D.-level faculty has stabilized or decreased in recent years for several reasons: 1) the abandonment of a mandatory retirement age for faculty, 2) the financial stress in many universities leading to nonreplacement of departing faculty, 3) the increasing use of part-time and adjunct faculty, and 4) the difficulties in obtaining continuous research funding in certain disciplines. The number of full-time faculty in colleges and schools of pharmacy, approximately doubled from 1986-1997, but the increase is primarily due to the increase in pharmacy practice faculty (Figure 1). The number of full-time faculty in pharmaceutics, medicinal chemistry/natural products chemistry, and pharmacology/bioscience has increased approximately 10 percent from 1986-1997, and most of this increase can be ascribed to the addition of new pharmacy colleges and schools.

Employment in the industrial sector presents a more heterogeneous picture, with considerable variation by sector. The biotechnology and pharmaceutical industry sectors continue to show significant overall growth and opportunity, but not necessarily for Ph.D.-level scientists. The growth in the biotechnology and pharmaceutical industry is accompanied by major changes in organization, including consolidation of large pharmaceutical companies with biotechnology firms, and continued proliferation of smaller research specialty companies. At the same time these changes have been occurring in academic and industrial marketplace, there has been continued major growth in the number of Ph.D. degrees conferred in science and engineering, primarily because of a large, and until very recently, continuing increase in the number of non-U.S. students.

Although the issues of graduate education in science and engineering have been discussed at length, a consensus has not been developed concerning any national policy for change in access to programs, enrollment of non-U.S. students or postdoctoral fellows, program restrictions, or funding of graduate education.[10,11,12,13] The unemployment rate for Ph.D. degree holders in the biomedical and pharmaceutical sciences remains very low, although many, particularly in the biomedical sciences are in extended post-doctoral fellowships, leading to what a recent NRC report termed "a crisis of expectation."[13] Many graduates may not be working in areas that they desire, particularly research careers in academic settings, which will not be a realizable option for the overwhelming majority of graduate students. This factor alone will demand that graduate programs and graduate students both be more aware of, and responsive to, the realities of the employment market.

Congressman George Brown (ranking Democrat on the House Science Committee) has commented, consistent with the recent NRC publication, of the need to reexamine national priorities and goals for research and development, including those in academic settings.[14]

> *"For nearly twenty years, we have linked academic R&D grants and graduate education, assuming that some portion of our R&D funding will go to support graduate students. But we never clearly spelled out our higher education goals separate from the performance of R&D. This unthinking linkage of R&D to graduate education means that the number of Ph.D.s produced reflects the availability of academic R&D funding*

rather than having a relationship to a set of national goals for S&E graduate education. The predictable result of this haphazard system is a series of surprises such as the current overproduction of S&E Ph.D.s."

"This revelation also prompts an examination of academic institutions in contributing to our current graduate education problems, for if there is an "overproduction" of Ph.D.s one is led naturally to an examination of the "overcapacity" within the academic system."

Indeed many universities, frequently with prodding from their state legislatures, are critically examining the roles and sizes of their graduate programs that are typically one of the more expensive features of the total budget.

Partly in response to growing concerns about science policy and graduate education, the Committee on Science, Engineering, and Public Policy (COSEPUP) of the NRC published a report, *"Reshaping the Graduate Education of Scientists and Engineers"* in 1995.[10] This widely discussed report made a number of general recommendations as follows:

1. **Offer a Broader Range of Academic Options.**
   - To produce more versatile scientists and engineers, graduate programs should provide options that allow students to gain a wider range of skills.
   - To foster versatility, government and other agents of financial assistance for graduate students should adjust their support mechanisms to include new education/training grants to institutions and departments.
   - To promote versatility, care must be taken not to compromise other important objectives when implementing changes.
2. **Provide More Clear and Timely Information and Guidance.**
   - Graduate scientists and engineers and their advisers should receive more up-to-date and accurate information to help them make informed decisions about professional careers; broad electronic access to such information should be provided through a concerted nationwide effort.
   - Academic departments should provide the information referred to above to prospective and current students in a timely manner and should also provide career advice to graduate students. Students should have access to information on the full range of employment possibilities.
3. **Devise a National Human Resource Policy for Advanced Scientists and Engineers.**
   - A national discussion group—including representatives of governments, universities, industries, and professional organizations—should carefully examine the goals, policies, conditions, and unresolved issues of graduate-level human resources.

These broad recommendations are aimed at improving *all* graduate programs in science and engineering. Although it is likely that all graduate programs and their students would benefit from these recommendations, some issues, notably those involving national funding policies, lie outside the scope of universities and individual programs. It is also clear that the challenges of career choice greatly differ for graduates. For example, those facing the recent graduate in high-energy particle physics are both quantitatively and qualitatively different from those facing the graduate in bio-informatics or pharmaceutics. More specific analyses of graduate programs are available from the Federatgion of American Societies for Experimental Biology (FASEB), the NRC's Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists, AAMC, and AACP, focusing on the life (biomedical) sciences and the pharmaceutical sciences respectively.[12,13,15,4]

Biomedical Sciences

A FASEB conference on graduate education held in 1997 focused on four major questions concerning graduate education in the broad area of biomedical sciences.[12] A starting point for the conference was the discussion of the dramatic increase in the number of Ph.D. graduates in science and engineering observed in the past decade. There was a 50 percent or greater increase, with nearly 70 percent of this increase being accounted for by non-U.S. students for the biomedical sciences. The conference addressed four principal concerns:

1. **What are the employment trends for biomedical Ph.D.s?** Historical trends may be useful and these data should be published. However, it must be recognized and the students must be aware that career trends may change, and quite significantly, during the predoctoral/postdoctoral period.

2. **How should admission into biomedical Ph.D. programs be regulated?** It was deemed inappropriate to regulate Ph.D. production at the national level and to limit future production on the basis of projections concerning the future job market. Admission of non-U.S. students should not be capped arbitrarily, however predoctoral students should not be admitted primarily to fulfill institutional needs for teaching or research assistants.

3. **Length and type of training: Are they appropriate to the spectrum of opportunity?** Although the focus of Ph.D. training should continue to be original research as embodied by the Ph.D. thesis with in-depth training in one area, there should also be opportunities for broader exposure to the biological and physical disciplines and with degree completion in no more than five to six years. Students should be aware of, and faculty should be supportive of, the range of career options available to students, and programs should exhibit flexibility to encompass students' career goals.

4. **How should the quality of biomedical graduate programs be measured?** Both self-study and periodic review by outside scientists are important components of quality assessment. Although national accreditation standards are not recommended, the NIH and NSF training programs are advanced as models of excellence.

These considerations are remarkably similar in broad outline to those advanced in the COSEPUP report on graduate education. In particular, both studies noted the difficulty of predicting employment trends over the approximate ten-year span of a predoctoral and postdoctoral training period. Moreover, both studies recommend the continued in-depth focus of Ph.D. training, but with opportunities for additional breadth of education within a five- to six-year period. However, both studies did not recommend limiting graduate enrollment.

The NRC Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Sciences (the Committee) examined the same data on Ph.D. recipients as the FASEB committee, but arrived at different conclusions.[13] The Committee noted that the dramatic increase (42 percent) in Ph.D. degrees awarded between 1987-1996 in the life sciences was almost exclusively in the biomedical sciences, and was primarily due to degrees awarded to non-U.S. citizens (permanent and temporary residents). The Committee noted that in 1995, as many as 38 percent of life-science Ph.D.s—five to six years after receipt of their doctorates—still held postdoctoral positions or other nonfaculty university positions, were employed part-time, or were unemployed (1-2 percent); compared to 11 percent in 1973. The increase in the time-to-degree, plus a long postdoctoral period may account for the decline in young investigator (less than 37 years of age) applications for NIH awards. The Committee also noted that the opportunity to obtain a tenured academic position after receiving a life-science Ph.D. degrees had dropped from 61 percent for those graduating in 1963-1964 to 38 percent for those graduating in 1985-1986. The Committee viewed that conditions would not change enough in the near future to provide employment for the large number of life science Ph.D.s now waiting in the postdoctorate holding pattern.

The Committee issued a series of recommendations, some of which are consistent with those of the COSEPUP and FASEB reports, but several others urging a more proactive approach to solving the perceived problem of having too many Ph.D. graduates.

1. **Constraining the Rate of Growth of the Number of Graduate Students in the Life Sciences**. The Committee recommends that the rate of growth in the number of graduate students in existing graduate education programs be voluntarily constrained, except in programs serving an emerging field or encouraging the education of members of underrepresented minority groups. The Committee understands that control over graduate training occurs at the department level, "…some might argue that this solution is expecting unreasonably altruistic behavior on the part of established investigators and training program directors." Additionally, the Committee suggested that while institutions should not arbitrarily place limitations on the numbers of visas issued for foreign students, graduate programs should not continue to enroll unlimited numbers of foreign nationals to compensate for the shortfall in U.S. student applications.

2. **Education for Alternative Careers as part of the Graduate School Experience**. In contrast to the COSEPUP recommendations, the Committee concluded that opportunities for Ph.D. graduates in alternative careers were limited. The Ph.D. degree should remain a research-intensive degree, with the current primary purpose of training future independent scientists. However, the Committee did recommend that universities identify specific areas in the biological and biomedical sciences for which master's degree level training is more appropriate to meet the manpower needs of industry.

3. **Funding of Postdoctoral Fellows**. The Committee recommended that federal and private agencies make more "career-transition" grants available for postdoctoral fellows, who are presently unable to apply for their own NIH grants. The number of transition grants recommended amounts to approximately one percent of the postdoctoral pool and appears to be merely a symbolic gesture.

4. **Informing Potential Graduate Students of Career Opportunities**. In agreement with the COSEPUP and FASEB reports, the Committee recommended that accurate and up-to-date information on career prospects be made available to prospective graduate students by the graduate department, enabling students to make informed decisions about their careers.

5. **Changing the Mechanism for Funding Graduate Students**. The Committee, like COSEPUP, recommended that federal agencies expand training grants and individual graduate fellowships instead of research grants to support graduate education in the life sciences. A contrary perspective of one of the Committee members to this recommendation is published in the report, stating that expanding training grants while not having a mechanism for controlling graduate student support on research grants, conflicts with the Committee's desire to stabilize graduate enrollments. Furthermore, foreign students are not eligible for training grant support, and in the event that research grant support of graduate training were diminished with an increase in training grants, this recommendation would result in placing limitations on foreign graduate students.

The Committee's most controversial recommendation, constraining the growth of graduate programs in the life sciences, particularly in the biomedical sciences, is in stark contrast to the COSEPUP and FASEB reports, which opposed any regulation of biomedical Ph.D. production at the national level. Interestingly, committees containing nationally recognized biomedical scientists wrote these reports using the same Ph.D. enrollment and graduation data. All the reports identified that the large rate of growth of biomedical science Ph.D.s over the past decade has occurred while available faculty positions have remained relatively stable. Is there an "excess of expectation" or "crisis of expectation" with biomedical science Ph.D. graduates? It depends on your point-of-view.

The Role of Medical Schools in Graduate Education

In recognition of the importance of biomedical Ph.D. training to medical schools and the lack of both adequate data and classification into national databases, the AAMC formed the GREAT Group.[16] The GREAT Group's focus is to "promote quality Ph.D. and postdoctoral education in the biomedical sciences." The profiling of the graduate student population in U.S. medical schools is now available from 1994-1995.[15] The report estimates the size of the graduate student population to be approximately 18,600 in the 122 medical schools that offer graduate degrees, with approximately 2,500 Ph.D. or M.D./Ph.D. degrees granted annually. In relative terms, the graduate education enterprise (Ph.D.s) in the nation's medical schools is approximately eight times larger than that in pharmacy colleges and schools. Based on NSF data, medical schools graduate approximately one-half of the biomedical scientist Ph.D.s annually, and approximately one-third of the life (includes biomedical) scientists annually.

Dr. John Perkins, Dean of the Graduate School of the Southwestern Medical Center, and a member of the GREAT Group and of the Commission, analyzed the issues around Ph.D. production in the biological/biomedical sciences (Bio-Sciences).[17] Using the data provided by NSF in the publications, "Selected Data on Science and Engineering Doctorate Awards," and "Survey of Graduate Students and Postdoctorates in Science and Engineering," and from the NRC "Survey of Earned Doctorates," Dr. Perkins also concluded that there has been a steady increase of approximately three to four percent per year for the past decade in the production of Ph.D. graduates, with a significant increase in the number of female and non-citizen students. Approximately 50 percent of the U.S. bioscience postdoctoral population is now made up of non-U.S. citizens, with the total pool expanding at an annual rate of three to four percent. The percentage of Ph.D. graduates achieving tenure-track appointments has been steadily declining for the past fifteen years and is now approximately 37 percent of the population. Simultaneously, the percentage employed in the broad biologically-based industry has increased, and self-reported unemployment for Ph.D. bioscientists has remained essentially constant for the past two decades at approximately 1.5 percent. Dr. Perkins' analysis suggests that an excess of Ph.D. or postdoctoral bioscientists does not exist, but rather an excess of expectation of career fulfillment. He further observes that graduates of 15 prestigious universities produce 25 percent of the total annual production of bioscience Ph.D.s and that this production alone might provide a four to six fold excess for faculty replacement at these same universities.

Overview of Graduate Education in the Pharmaceutical Sciences

The Lemberger Commission

This AACP report (AACP Commission chaired by August Lemberger) on graduate education in the pharmaceutical sciences provided an analysis of graduate program statistics over a twenty year period (1965-1985).[4] Student numbers, origins and academic characteristics, program numbers and sizes, faculty involved in graduate education and their research and publication records, as well as research support were provided in the report. The graduate programs that were analyzed included: medicinal chemistry, pharmacology, pharmaceutics, pharmacy practice, and pharmacy administration.

The Commission observed a consistent increase in graduate enrollment in the pharmaceutical sciences, an increase in federal and other research support, and evidence for strong quality of academic programs in all of the disciplines. The Commission observed, however, marked disparities between programs and cited evidence to suggest that a significant number of programs were weak to average in quality. This evidence included absence of extramural funding and publications by significant percentages of faculty, and absence of true quality in graduate student selection. The Commission made the following recommendations:

- Pharmacy faculty undertaking to prepare pharmaceutical scientists must meet and maintain contemporary criteria of quality in the conduct of their graduate programs.
- Pharmacy faculty involved in graduate education must continually evaluate their programs using an external review component.
- A national discipline-specific database for guidance of graduate program personnel undertaking self-evaluation be generated and updated periodically.
- AACP should serve as a coordinator of periodic data collection and dissemination regarding the status of graduate programs in the pharmaceutical sciences.

The Commission concluded that a number of graduate programs in the pharmaceutical sciences had achieved excellence, although a significant number of weak programs also existed jeopardizing the entire graduate program enterprise.

The impetus for the formation of the Commission had originated from the 1985-1986 AACP RGAC, who proposed to comprehensively study graduate education in the pharmaceutical sciences with the following objectives:[3]

- Development of standards of quality and criteria for evaluation of graduate programs in the pharmaceutical sciences,
- Development of guidelines for self-evaluation by colleges and schools of pharmacy, and
- Establishment of voluntary programs for self-evaluation by colleges and schools of pharmacy.

The proposal to form the Commission to study graduate education in the pharmaceutical sciences was based on a perceived crisis that was due to a critical shortage of qualified pharmaceutical scientists in both academic and industrial positions. There appeared to be a movement of qualified pharmaceutical scientists from academia to industry, and a concern arose that mature graduate programs had reached a limit in physical and human resources. The demographics of professional program enrollment had dramatically changed during the previous decade, with women constituting approximately 60 percent of pharmacy students. Professional degree pharmacy graduates had traditionally been the major source of graduate students in the pharmaceutical sciences, however a perception existed that many potential graduate students were choosing the doctor of pharmacy degree tract instead. Those who did choose graduate school were not as well prepared for graduate study, due to recent changes in the pharmacy curriculum. Rather than addressing the perceived problems with faculty and students, which were insoluble by any committee action, the Commission addressed the issue of program quality. Several previous RGACs had proposed the concern for quality control measures for graduate programs, specifically self-evaluation of graduate programs, but little action resulted. The Commission was successful in fulfilling its first two objectives. The third objective, the establishment of a voluntary program for self-evaluation of graduate programs has not been universally accepted. However, there is increased interest by university administrations in program evaluation, and the standards and guidelines developed by the Commission may be increasingly used.

The Current Commission

The current Commission on the Future of Graduate Education in the Pharmaceutical Sciences arose from a recommendation of the 1995-1996 AACP RGAC.[5] The idea for the present Commission was stimulated by: another perceived manpower crisis, an oversupply of Ph.D. scientists, a downsizing of the workforce in the pharmaceutical industry, a rapid rise in outsourcing of research and development activities, an increasing globalization of the pharmaceutical industry, and a rapidly changing focus of disciplinary research to interdisciplinary or team research. A major concern of the 1995-1996 RGAC, that was also indicated in the 1995 COSEPUP report, "Reshaping the Graduate Education of Scientists and Engineers," was the necessity of increasing the breadth of the graduate educational experience without diluting the intensity of the research component. The 1995-1996 RGAC also recommended that AACP survey Ph.D. degree holders, who graduated from 1975 to 1995 to assist member institutions in their strategic planning efforts.

Measures of Graduate Program Status and Quality

There have been several attempts to evaluate the quality or "reputation" of various science and engineering disciplines. The most comprehensive studies have been conducted by the NRC on the status of research-doctorate programs in the sciences in 1982 and 1993.[18,19] The 1993 NRC study collected considerable demographic and "faculty productivity" data on a variety of programs in the arts, humanities, and sciences. These "objective" measures of program quality were not used to determine and rate program quality. Program quality, or more accurately, program reputation, was determined by panels of discipline peers, who rated 50 randomly selected programs in their field, only being provided with faculty rosters from each program being rated. All programs were rated by at least 100 peers. Retrospectively, average peer ratings were correlated with the "objective" measures of program quality. Objective program characteristics showing the "strongest" correlation with reputational standing included the number of faculty and students in a program and the "level of faculty research and scholarship." Three measures of faculty research and scholarship were used in the 1993 NRC study.

1. The pattern of federal grant support for the period 1988-1992,
2. The publication and citation patterns for the period 1988-1992, and
3. Selected "awards and honors" among faculty in the Arts and Humanities.

The 1993 NRC's study reputational ratings correlated very well to those published by the popular press (i.e., *U.S. News and World Report*) in their annual higher education ratings issues, because both types of surveys were based on subjective peer perception of reputation.[20] The NRC study did not evaluate the outcomes of graduate education; specifically the performance of the graduates. Several institutions have proposed investigating certain measures of graduate performance, but none have been published.

Individual pharmaceutical science graduate programs, with the exception of pharmacology, were not evaluated in the 1993 NRC study, because they were judged as not meeting the size criteria for inclusion; 500 Ph.D. degrees in 50 programs conferred for the years 1986-1990. The pharmacology programs of some U.S. colleges and schools of pharmacy were included in the NRC study. Pharmaceutics programs do appear to meet the criteria and should be included in future NRC analyses. Medicinal chemistry/pharmacognosy programs in colleges and schools of pharmacy have recently dropped below the size requirement but could be included under a university's chemistry program evaluation. Social and administrative pharmacy is too small to be included in the foreseeable future.

The following discussion and analysis of pharmaceutical science program enrollment and program size, degrees granted, graduate employment, research funding, publication rates, and citation impact provides the present Commission's view of the past and present status of graduate education in colleges and schools of pharmacy. These data provided a framework for examining the status of graduate education in the pharmaceutical sciences, particularly as the programs compare to other scientific disciplines.

Pharmacy Graduate Program Enrollment

AACP has gathered and reported enrollment and graduation data on graduate students in pharmacy consistently since 1955, and sporadically since 1933. Changes in the specific data gathered, such as full- and part-time enrollment, and in the pharmaceutical science disciplines over the past 30 years creates some difficulties in analyzing specific longitudinal trends. Demographic information on the graduate education enterprise in the pharmaceutical sciences is available in the *American Journal of Pharmaceutical Education* (*AJPE*) since 1933, in the *AACP Profile of Pharmacy Students* since 1990.

The Lemberger Commission provided extensive analysis of total graduate program enrollment and student demographics from 1965-1985, and reported:

- Graduate program enrollment increased steadily through the 1970s and leveled off from 1980-1985.
- The drop in the percentage of graduate students with a previous degree in pharmacy, which occurred from 1965-1975 had appeared to level off at 60 percent during the 1980s.
- The percentage of females enrolled in graduate programs steadily increased from 11 percent in 1965 to 35 percent in 1985.
- Enrollment of foreign students had steadily increased throughout the 1980s, reaching 32.4 percent in 1986.

The Lemberger Commission analyzed total graduate program enrollment (M.S. plus Ph.D., full- and part-time). In retrospect, combining M.S. and Ph.D. enrollment numbers led to a biased picture of the status of graduate education in the pharmaceutical sciences, because:

- it was and is not possible to distinguish between enrollment in a "terminal" master's degree program or enrollment in a master's degree program as a prerequisite for admission to a Ph.D. degree program, and
- it was and is not possible to ascertain the full-time equivalence of part-time students, and part-time students are approximately half the enrollment in a master's degree program.

Separating M.S. and Ph.D. degree program enrollment demonstrates that the unchanging level of graduate program enrollment from 1980-1985 noted by the Lemberger Commission, resulted from the enrollment patterns in M.S. and Ph.D. programs going in opposite directions (Figure 2). Total (full- and part-time) Ph.D. program enrollment has, in fact, increased steadily from 1974-1994, primarily due to increasing full-time Ph.D. enrollment (Figure 3). Full-time Ph.D. program enrollment has plateaued from 1994-1997. Total M.S. program enrollment peaked in 1980 and then declined steadily until 1992. Total M.S. program enrollment increased from 1993-1995 and then has remained relatively stable through 1997 (Figure 4). The percentage of full- and part-time enrollment in M.S. degree programs remained relatively equal from 1974-1997.

The Lemberger Commission provided an analysis of total M.S. and Ph.D. enrollments by pharmaceutical science disciplines in five-year intervals from 1965-1985. All disciplines exhibited a general increase in total enrollment (M.S. and Ph.D.) during this period with the exception of pharmacognosy, which decreased. AACP combined pharmacognosy enrollment data with medicinal chemistry in 1986.

Full-time Ph.D. program enrollment in all the pharmaceutical science disciplines (pharmaceutics, pharmacology, medicinal chemistry/pharmacognosy, pharmacy administration) has increased from 1980-1997 (Figure 5). Since 1980, pharmaceutics enrollment has more than doubled, and in 1986, displaced medicinal chemistry/pharmacognosy as the largest Ph.D. program in the pharmaceutical sciences. Pharmacy administration (social and administrative sciences) has had the greatest percentage increase in enrollment since 1980. However, the absolute enrollment numbers remains relatively small, even when combined with pharmacy practice, the largest component of the "other" category.

Female enrollment in full-time Ph.D. programs in all the pharmaceutical sciences has continued to increase faster than male enrollment, increasing from 32 percent in 1986 to 45 percent of the total enrollment in 1997. Enrollment of foreign students in full-time Ph.D. programs has also continued to increase faster than U.S. student enrollment, reaching 47.8 percent in all the pharmaceutical sciences in 1997. Full-time Ph.D. enrollment of foreign students in pharmaceutics was 58.1 percent of the total. While a major source of graduate students in the past, students holding a professional degree from a U.S. college or school of pharmacy comprise a decreasing percentage of the total graduate student enrollment in the pharmaceutical sciences. U.S. pharmacy students made up 30-35 percent of the total enrollment in full- and part-time Ph.D. programs from 1980-1987. This percentage has steadily dropped since 1988, reaching a level of 16.3 percent in 1996 and rising slightly to 17.2 percent in 1997. However, the absolute number of U.S. pharmacy students enrolled in graduate programs has not changed that dramatically since 1975 (Figure 6), and more pharmacy graduates are enrolled in graduate programs at the present time than during the peak B.S.-degree enrollment 1970s.

Program Size

The issue of "critical mass" of faculty, graduate students, and postdoctoral fellows is often raised in discussions of graduate degree program quality, including the Lemberger report. As previously noted, the 1993 NRC study found that there was a positive correlation between the numbers of faculty and students and the "reputation" of the graduate program. For example, the average enrollment in graduate programs from the top to the bottom quartile in pharmacology was 35.3, 23.1, 15.0, and 11.9 students, respectively. A 1995 ACS survey of chemistry doctorate programs also found that external federal funding (primarily NSF) per Ph.D. graduate student is greater for institutions that produce higher numbers of Ph.D.s.[11]

The enrollment in graduate programs in the pharmaceutical sciences is small compared to other scientific disciplines. Of 56 colleges and schools of pharmacy reporting enrollment in a Ph.D. program in 1997, 34 had fewer than 40 full-time students in all their Ph.D. programs.[21] Only one institution enrolled more than 100 full-time Ph.D. students. Furthermore, the enrollment in individual disciplinary programs was relatively small with medicinal chemistry/pharmacognosy (30/42), pharmacology (33/38), pharmaceutics (32/49), and pharmacy administration (24/24) having fewer than 20 full-time Ph.D. students enrolled. Only 19/63 pharmacology in the 1993 NRC study programs rated in the top two quartiles had fewer than 20 Ph.D. students enrolled. There were no programs in the top three quartiles with fewer than 20 Ph.D. students enrolled in chemistry.

As pointed out in the Lemberger report, students on a large university campus in small graduate programs can obtain the assistance of graduate students and faculty from other disciplines and attend campus-wide symposia. The problems associated with small programs might occur on campuses where graduate programs in the pharmaceutical science disciplines exist in isolation. Having increased availability of the student's advisor and other faculty mentors may alleviate this isolation issue. Moreover, Ph.D. graduates often do not enter the employment market directly, but spend two or more years in a postdoctoral position, almost always at another institution in a highly research-intensive environment where new Ph.D. graduates can dramatically increase their research skills. For example, the ACS survey, which examined employment patterns of chemistry doctorates from 1988-1994, found that the same percentage of chemistry Ph.D.s receiving degrees from larger and smaller degree-granting programs, obtained four-year academic positions. That assumes these positions are most competitive to chemistry Ph.D.s. Approximately 65 percent of chemistry Ph.D.s obtain industrial positions. These many confounding variables associated with the immediate research environment and the postdoctoral experience make the specification of a minimum for "critical mass" almost impossible. (However, potential graduate students should know the size of the graduate student body and "active" graduate faculty, before enrolling in a graduate program.)

Ph.D. Degrees Awarded

Student enrollment is important for the future of a program, but the success of a program depends on the quantity and quality of its students and graduates. The number and gender of Ph.D. graduates in pharmacy from 1960 to the present is available in tabular and graphical format in the *AACP Profile of Pharmacy Students*. The numbers of Ph.D. graduates prior to 1960 are available in the Executive Committee reports found in the annual issues of the *AJPE*. Dr. Robert Mrtek, in his classic article on the history of pharmacy education, extracted and published the number of M.S. and Ph.D. degrees reported in *AJPE* from 1900-1975.[22]

The number of Ph.D. degrees granted in the pharmaceutical sciences has increased and leveled off several times from 1950 to the present (Figure 7). An increase in the degrees awarded was evident in the '60s and '80s, with plateaus or even small decreases in the '70s and '90s. Since 1970, the increase in the number of degrees awarded has primarily been due to the increased number of degrees awarded to females and foreign students.

The number of Ph.D. degrees awarded in the individual pharmaceutical science disciplines has fluctuated from year to year, but the trend has been slightly positive, with the exception of medicinal chemistry/pharmacognosy, which has been relatively constant (Figure 8). A perspective on the relative size of the total number of Ph.D. degrees awarded in the pharmaceutical sciences from 1994-1997 (300-358) is provided by comparison with the number of Ph.D. degrees granted in the biomedically-related biological sciences and selected engineering and chemistry disciplines. In 1995, 5,878 Ph.D. degrees were granted in the biomedically-related biological sciences, and 189 Ph.D. degrees in biomedical engineering.[23] The rate of increase in the number of Ph.D. degrees in these disciplines has been rapidly increasing. Additionally, approximately 800 Ph.D. degrees were awarded each year in analytical and organic chemistry in 1994-1995.[24] Like pharmaceutical chemistry/pharmacognosy, Ph.D. degrees awarded in organic and analytical chemistry have been relatively constant from 1986-1995. Ph.D. graduates in all these biomedical and chemistry disciplines are hired in large numbers by the pharmaceutical industry, which is also the major employer of Ph.D. graduates in the pharmaceutical sciences.

Research Funding

External federal funding is considered to be an important measure of faculty quality. The Lemberger Commission conducted a survey of external funding of graduate faculty in 1986. While total external funding appeared to be considerable ($40,000,000 federal, $60,000,000 total), the major finding of the survey was a substantial discrepancy with the level of funding among institutions, and specifically across pharmaceutical science disciplines. The Lemberger Commission found that more than one-third of all graduate faculty had no external (federal and non-federal) funding, which is probably still true at the present time. Similar large discrepancies in research funding among selected pharmacy colleges and schools was noted by the 1980 Argus Commission.[25]

For the past several years, AACP has obtained NIH funding data on faculty from colleges and schools of pharmacy. The total amount of federal money (grants, contracts, training grants) received by faculty in colleges and schools of pharmacy has significantly increased from Fiscal Years 1986-1997, approaching $100,000,000. The amount of NIH funding received by the colleges and schools differs by orders of magnitude, even when corrected for the number of full-time, Ph.D.-level faculty members (Table 1). Although NIH is not the only source of external research funds, it constitutes slightly more than half of the external research funding reported by member institutions in the *AACP Survey of Financial Data*.

Faculty Publication and Citation

The quality and quantity of faculty publications are the most visible indicators of faculty research productivity. The Lemberger Commission found that 25 percent of all graduate faculty did not have any publications in 1986. The 1980 Argus Commission also found a great discrepancy among the numbers of publications by all pharmacy faculty from 1977-1979, with ten percent of faculty publishing more than five papers per year, and 48.6 percent of faculty not publishing any papers. Drs. Dennis Thompson and Larry Segars, in an investigation of U.S. colleges and schools of pharmacy publication rates from 1976-1992 using the Science Citation Index Corporate Index, found that numbers of publications/faculty/year has increased steadily during the period studied, but noted that only 13 (18 percent) of colleges and schools of pharmacy averaged one or more publications/faculty/year, and 38 (52 percent) averaged fewer than 0.5 publications/faculty/year.[26] The 1993 NRC study reported the number of publications per faculty over the five-year time period 1988-1992. In the discipline of pharmacology, 127 programs were evaluated. The average number of publications per faculty for the period 1988-1992 for those programs ranked in the top quartile was 14.51, while the average in the lowest ranked quartile was 5.39. Dividing these values by five (for the number of years), gives an average publication rate per year of approximately one to three per faculty member. Average publication rates per faculty per year in chemistry programs were similar to those in pharmacology, while average publication rates per faculty in sociology for example, ranged from 0.32-0.52, for programs in the lowest and highest quartiles, respectively.

The quality of a publication is difficult to ascertain. One measure of quality is the number of times a publication is cited by another publication. The number of citations can be obtained from the Science Citation Index. Determining publication quality by measuring the number of subsequent citations has been criticized, but national rankings of programs based on citation analysis are published.[27] Faculty who work in small research areas who publish significant research may not be cited frequently, but citation rate is not strictly a function of the number of publications.

AACP has not systematically collected publication or citation data on faculty from its member institutions. However, with the increased demand for program analysis by university administrations, and the need for more program information from potential graduate students, there may be a need for the Association to systematically collect and disseminate funding, publication data, and citation impact of faculty from graduate programs in the pharmaceutical sciences from publicly available sources.

Employment of Ph.D. Graduates

The NSF administers two graduate education surveys: the Survey of Earned Doctorates administered to all Ph.D. graduates, and the Survey of Doctoral Scientists and Engineers. The Survey of Earned Doctorates collects information on Ph.D. graduate demographics, research discipline, time-to-degree, financial support, and postgraduate plans. The Survey of Doctoral Scientists and Engineers is administered every two years to a cohort of Ph.D. graduates up to the age of 76. This survey collects information on the graduate's employment history, including postdoctoral experience, and employment activities. Upon the recommendation of the 1995-1996 RGAC, AACP staff developed a survey instrument based on these two NSF surveys in the Fall of 1996 to determine the employment pattern of Ph.D. graduates from colleges and schools of pharmacy from 1975-1996 (Appendix 3). The survey (AACP Survey of Earned Doctorates) was distributed to member institutions with Ph.D. programs, which then mailed the survey to their Ph.D. alumni. The individual institutions collected the surveys and returned them to AACP for analysis.

Thirty-eight out of the 54 institutions contacted, administered, and returned completed surveys. Responses were obtained from 1,542 Ph.D. graduates, which during the period from 1975-96, are approximately 28.5 percent of all Ph.D. graduates from colleges and schools of pharmacy. The percentage of returned surveys from the participating institutions, averaged approximately 45 percent, with some institutions receiving over a 90 percent response rate. The demographics of the survey respondents were similar to the published demographics of the entire Ph.D. population, indicating that the survey results obtained are representative of the population.

The complete survey results are found in Appendix 4, but selected excerpts follow:

- 85 percent of respondents reported full-time employment, excluding postdoctoral positions. 90 percent of pharmaceutics and pharmacy administration, and 80 percent of medicinal chemistry and pharmacology respondents reported full-time employment.
- Approximately 15 percent of medicinal chemistry and pharmacology respondents reported employment in a full-time postdoctoral position, as compared to 5 and 2 percent for pharmaceutics and pharmacy administration respondents, respectively.
- Only 1 percent of respondents reported that they were unemployed and seeking employment as of September 1996.
- Approximately 52 percent of all respondents indicated business/industry as their employer, almost exclusively in the pharmaceutical industry.
- A considerable difference existed in industrial employment among the pharmaceutical science disciplines. Approximately 70 percent of pharmaceutics, 47 percent of medicinal chemistry, 37 percent of pharmacology, and 22 percent of pharmacy administration respondents indicated industry as their employer.
- 23 percent of respondents reported holding a full-time faculty position, again with considerable variation among disciplines. 17 percent of pharmaceutics and 60 percent of pharmacy administration respondents held a full-time faculty position.
- Applied research was the employment activity most often reported as being of primary or secondary importance by respondents in pharmaceutics and medicinal chemistry, basic research by pharmacology, and teaching by social and administrative pharmacy. Pharmaceutics respondents chose research and development management as the second most common primary or secondary employment activity.
- The time required to obtain the Ph.D. degree has increased steadily from 1975-79 until 1994-96, from approximately five to six years. This increase occurred in all disciplines.

- The average time spent in a postdoctoral position also increased from 1975-79 through 1990-94 in medicinal chemistry and pharmacology from approximately 1.5 to 2 years.

The survey indicated that Ph.D. graduates in the pharmaceutical sciences appear to have little difficulty in obtaining meaningful employment. It is possible that the small number of those who did not respond contain a higher percentage of the unemployed, but there is no information to support that conclusion. The pharmaceutical industry, particularly the large integrated companies, is the major employer of Ph.D. graduates in the pharmaceutical sciences, particularly those in pharmaceutics. The concern regarding a lack of academic positions for Ph.D. graduates which is common among the other science disciplines, does not appear to be a major issue for pharmaceutical science Ph.D.s. To the contrary, academic pharmacy has increasingly hired new faculty from science disciplines other than the pharmaceutical sciences, due in part, to a shortage of available candidates from the pharmaceutical sciences.

Survey of Industrial Scientists

The 34 survey participants were attendees at a scientific symposium, "Discovery and Development of Novel Therapeutic Agents for the 21st Century" held in Durango, Colorado in 1997. The survey instrument and responses are found in Appendix 5. Selected findings are as follow:

1. The most important quality sought when hiring for a scientific position is to have specific scientific or technical expertise. The second most important quality is the ability to focus on required research outcomes.
2. The ability to work as a team member, and to have interpersonal and communication skills were of intermediate importance.
3. Possessing a broad range of scientific interest and expertise and management skills were considered less important.
4. A majority of respondents thought the average length of the doctoral program in the life sciences (seven years) was too long, and contributed a number of possible solutions to this problem.
5. A majority of respondents thought a postdoctoral experience was required for success in the pharmaceutical industry.
6. A large majority of respondents agreed that a non-academic internship would be a valuable experience for Ph.D. students, but only half of the respondents would be willing to serve as internship advisors.

While this survey was not comprehensive or random, the responses provided useful insight into the perceived needs of the industry. The industrial survey respondents agreed with the Commission members on the importance of graduates or postdoctoral fellows possessing specific scientific or technical expertise for entry-level positions. The respondents were split on the view that today's recent Ph.D. graduates are too specialized in their research abilities and skills. Again, recommendations for increasing the breadth of the graduate experience, without increasing the length, were suggested. Although not specific for Ph.D. graduates in the pharmaceutical sciences, the respondents thought that recent Ph.D. graduates who were hired, did have the qualities they considered to be most important.

In addition to the suggestions provided by the Commission members and industrial scientist's responses, two editorials on graduate education appeared in *Pharmaceutical Research* in 1997.[28,29] Dr. Ronald Borchardt of the University of Kansas questioned whether current graduate programs in the pharmaceutical sciences are preparing students to work in a highly integrated and globalized industry, which includes more small companies working in specialized areas of research, often on contract for or with the larger integrated companies. Dr. Borchardt provided a number of recommendations to increase the breadth of the graduate education experience without sacrificing the most important part of graduate education, the development of expertise in a particular area of research. An important aspect of the increasing globalization pattern of the industry is the need for pharmaceutical scientists to be sensitive to social and cultural differences, which can only be obtained through life experiences.

In the second editorial, Dr. Alice Till, a Commission member and President of the Generic Pharmaceutical Industry Association, expressed concern that present graduate programs in the pharmaceutical sciences are increasingly focusing on drug discovery to the detriment of drug development, particularly pharmaceutical manufacturing and formulation science. Dr. Till also indicated that more emphasis was needed on the integration and practical application of the basic sciences and fundamental training currently provided in pharmaceutical science graduate programs. Both Drs. Borchardt and Till agreed on the need for learning to work in teams and possess excellent written and verbal communication skills.

The COSEPUP report recommended internships in industrial, government, or non-academic settings as a way to develop students' abilities and skills to work in non-academic positions. NIH training grant guidelines also suggest that industrial internships be incorporated into the Ph.D. program. Industrial internships appear to provide a rationale way of introducing students to applying their basic science education in order to solve industrial problems of practical importance. The Commission Survey of Industrial Scientists indicated that while a significant majority of respondents agreed with the value of a non-academic (industrial) internship, there was less but still considerable interest in serving as a internship advisor. An industrial internship, if designed properly and timed correctly, could address some of the concerns about graduate education raised by both Drs. Borchardt and Till.

The Impact of Emerging Technologies on the Pharmaceutical Sciences

The remarkable scientific and technological advances in genomics and bio-informatics, together with combinatorial chemistry and high-throughput screening, are expediting the identification of lead compounds in the discovery phase of drug development.[30] The application of genomics provides opportunities for gene therapy and genetic screening, as well as influencing chemistry and biology through such concepts as "self-reproducing molecules," "evolutionary chemistry," and "directed combinatorial biochemistry." Genomics' influence can also be found in the generation of new targets and the production of genetically-engineered cells designed for drug screening, and in the facilitation of drug targeting and activity. Additionally, genomics makes possible the inclusion of drug pharmacokinetics and metabolism as an integral phase of molecular discovery, potentially shortening and reducing the cost of the discovery process. This advent of functional genomics indicates that the treatment of disease is moving from a phenotypic base to a genotypic base. The use of technologies as "genes on chips" will allow the polymorphisms of genes concerned with a particular disease, for example hypertension, to be examined on an individual basis, thus rationalizing and making more efficient drug use through "pharmacogenomics." Lastly, the elucidation of an increasing number of bacterial genomes indicates that new leads for antibacterial drugs will become available. These increasing numbers of lead compounds is also putting pressure on drug delivery scientists to develop new, effective, and rapid methodologies for choosing those chemical leads that can be optimally developed into drug products.

Fundamental changes in the drug discovery process brought about by the advent of these new technologies are likely to impact graduate education in the pharmaceutical sciences in both the graduate curriculum and the research environment. The pervasive influence of the concepts and paradigms of molecular biology in all the pharmaceutical science disciplines will demand that functional genomics assume a significant role in the graduate curriculum. The emergence of small, focused biotechnology companies spawned by these new technologies, will impact the research environment of graduate education, as universities increasingly form strategic alliances with these companies, often formed by their own faculty members, and the larger pharmaceutical industry. The pharmaceutical industry is also being impacted by genomics. Mega-mergers of biotech, chemical, and agribusiness companies with pharmaceutical companies is creating a new life sciences industry with genomics as the common technology.[31] Strategic alliances between universities and the life sciences industry will demand more interdisciplinary approaches to the graduate research experience, particularly greater experience in group interactions and team work. These alliances will increase the likelihood that more graduate research will be carried out significantly, or even exclusively, in non-university settings.

Conclusions and Recommendations

The following set of conclusions and recommendations are based on the Commission's best judgment, after consideration of a number of recent reports on the state of graduate education, and on an analysis of the present state of graduate education in the pharmaceutical sciences. Considerable attention was given to the presentations and faculty discussion at the Commission's conference on graduate education held prior to the 1998 AACP Annual Meeting (Appendix 2).

A conclusion of the Commission is that the current outlook for pharmaceutical science graduates from colleges and schools of pharmacy appears to be good to excellent, and there is no need to constrain future enrollment as has been suggested for the life sciences. This is in large part due to the bright future of the pharmaceutical and related biotechnology (life sciences) industries that employ significant numbers of pharmaceutical scientists. Unlike other life science disciplines, pharmaceutical science Ph.D. graduates have generally viewed an industrial career to be equivalent to an academic career, not as a less desirable "alternative" career.

The bright future envisioned for the new integrated life sciences industry is being built around the emerging discoveries in genomics and an increasing understanding of the molecular basis of many diseases. These discoveries have been and will continue to be funded in large part by Federal Government support of academically-based research through NIH. The NIH has received large increases in its budget over the past several years. This future scenario poses both opportunities and challenges for graduate programs in the pharmaceutical sciences in colleges and schools of pharmacy. The challenges primarily come from within the university as many biomedical science, chemistry, biomedical engineering departments, and schools of public health refocus their research in areas of drug discovery, drug design, drug action, drug delivery, drug marketing, pharmacoeconomics, and the drug-related areas of health care policy to avail themselves to the increasing financial resources available to conduct research in these areas. To maintain and enhance a successful research and graduate program within the research university environment, pharmaceutical science graduate programs and faculty in colleges and schools of pharmacy will have to simultaneously become both more competitive and collaborative with other academic disciplines within the university.

The Commission offers the following recommendations to assist colleges and schools of pharmacy with strengthening their graduate programs in the pharmaceutical sciences and planning for the future.

Recommendation 1: To maintain both the viability and visibility of graduate programs in the pharmaceutical sciences, colleges and schools of pharmacy must offer students research environments where competitive, funded, cutting edge research is performed under the supervision of highly qualified faculty mentors.

The viability of graduate programs in the pharmaceutical sciences at colleges and schools of pharmacy will depend on the ability of deans and faculty to recognize areas of research that provide a unique identity to their programs and abilities in their students, and that contrast with or complement other areas of drug-related graduate programs on campus. Pharmacy colleges and schools need to take action to strengthen their research programs through a combination of new faculty positions, extramural faculty research support, internal program reorganization, and development of graduate student research internships with scientific colleagues in the pharmaceutical industry.

Recommendation 2: Institutions contemplating starting graduate programs (Ph.D. or M.S.) should only do so after an objective examination of the need for graduates with a particular expertise that the program can provide. An inventory of faculty research experience, extramural support, and the research infrastructure (i.e., instrumentation, animal facilities, etc.) available to perform cutting-edge research in the proposed program area should be conducted, and deficiencies corrected before initiating a graduate program. Colleges and schools of pharmacy at less-research intensive universities must identify non-pharmacy departments (e.g., chemistry, mathematics, statistics, etc.) on their campus or on an adjacent campus that can provide didactic courses at a level advanced enough to provide sufficient breadth to the proposed programs of graduate study.

The abilities or overall quality of the graduates is a more important issue to the future of graduate education in the pharmaceutical sciences in colleges and schools of pharmacy than the numbers of Ph.D. students. In this regard, the relatively small size of the graduate education enterprise in colleges and schools of pharmacy can either be an advantage or a disadvantage to their continued viability. Smaller programs can react more quickly to emerging research opportunities. The addition of one or two new faculty members, or a refocus of the research direction by several faculty can have a significant impact on the numbers of students and the research funding of the program. Some advantages will only occur if faculty are perceptive to new research opportunities and have or can obtain the research skills and supporting infrastructure to change their research focus. A major disadvantage of small-sized graduate programs is the lack of consistent and adequate financial resources that impacts the availability of the infrastructure necessary to carry out cutting-edge research. It is also very difficult for small programs to obtain an NIH training grant unless they can develop a program in cooperation with other disciplines. Small graduate programs can also suffer from a lack of university-wide and national visibility and ultimately, viability.

Universities are becoming increasingly skeptical about supporting new, expensive graduate programs in areas where there is not a critical mass of faculty members or sufficient numbers of graduate students. The large number of Ph.D.s serving in postdoctoral positions also argues against initiating new graduate programs or expanding existing programs, unless a need for those graduates can be demonstrated.

Recommendation 3: Pharmaceutical sciences faculty are encouraged to engage in multi- or interdisciplinary research and graduate training programs within their own institution and with other faculty within the university. Pharmaceutical sciences faculty need to be more proactive in proposing and organizing interdisciplinary institution-based and campus-wide research programs, centers, or institutes, despite the possibility that the majority of faculty participants may not be from the college or school of pharmacy.

The issue of multi- and interdisciplinary graduate programs generated considerable discussion at the Commission's symposium on graduate education in July 1998. The consensus among the participants was support of interdisciplinary programs where possible, both within pharmaceutical science departments and across related departments in the university. For small graduate programs, multi- or interdisciplinary graduate programs may be the only viable way to achieve a “critical mass” of students, faculty, and research resources. Initiation and involvement in university-wide interdisciplinary programs, centers, or institutes, provides pharmacy faculty with an opportunity to bring their unique and valued expertise to the endeavor, resulting in potential new sources of graduate students, extramural research funding, and enhanced visibility for the college or school of pharmacy. Pharmacy faculty who participate in university-wide programs should not lose their identity as pharmaceutical scientists, nor their involvement in the education of professional degree students in the college or school of pharmacy.

Recommendation 4: Graduate programs in the pharmaceutical sciences should establish, compile, and assess longitudinal databases of performance indicators to internally and externally assess faculty, student, and program quality. Sufficient data should be made public to assist potential graduate students to determine if the program is consistent with their research career aspirations. A common set of performance indicator measures should be submitted annually to AACP for the purpose of constructing comparison college and school cohorts (benchmarks) for chairs and deans to evaluate and improve the performance of their graduate programs.

Program evaluation and comparison is already a "fact of academic life." Rankings of universities, colleges, and programs is becoming an annual ritual for some newsmagazines because they are extremely popular with the public and useful for the highly ranked institutions. The popularity of these rankings also reflects the inability or unwillingness of the higher education community to provide agreed upon objective public information on the quality of their faculties, students, and programs.[32] The NRC's rankings of doctorate programs based on peer opinions are currently being used by university administrators to determine which programs will receive additional funding to maintain or build discipline excellence. Deans at colleges and schools of pharmacy are being requested to "rank" their graduate programs' quality against those of "peer" institutions. There are a few easily available measures of performance, such as the size of the faculty, the number of graduate students enrolled, Ph.D./M.S. degrees granted, and NIH funding data. There is no perfect set of performance indicators, but the larger the number of performance indicators, the better the comparative evaluation. AACP already collects considerable data from colleges and schools or pharmacy and has experience in providing confidential cohort comparisons of faculty salary data. This collection and comparison function could be extended to an agreed upon set of performance indicators of research and graduate programs.

Recommendation 5: All colleges and schools of pharmacy with graduate programs should provide "survival skills" training to their graduate students through a combination of didactic presentations and supervised experiences. These survival skills include, but are not limited to: research ethics, written and oral communication skills development, teaching skills development, computer skills enhancement, career counseling, and research team building opportunities.

The Commission agrees that the major focus and design of the Ph.D. degree program should be research-intensive to develop an independent pharmaceutical science researcher. Additional activities that add time to an already intensive academic program should be avoided. Many survival skills can be presented using existing graduate-level coursework and seminars, or through graduate student mentoring by faculty or program advisors. Students supported by university teaching assistantships who are particularly interested in an academic career should be given additional opportunities to interact with professional students in multiple classroom settings with increasing responsibilities, followed by faculty feedback and coaching. Team building can be incorporated into projects assigned to teams of students in graduate-level courses and through involvement of beginning students as assistants in the research projects of advanced graduate students and postdoctoral fellows or through participation in program-sponsored industrial internships.

Recommendation 6: Colleges and schools of pharmacy need to increase their recruitment efforts for U.S. students from disciplines other than pharmacy. The availability of large numbers of qualified foreign pharmacy graduates, should not be used as a continual justification for the lack of recruitment of U.S. educated students. Colleges and schools of pharmacy also need to explore innovative approaches to increase the numbers of U.S. pharmacy students in graduate school, through joint Pharm.D./Ph.D. programs that offer a significant decrease in time to complete both degrees.

There are many outstanding pharmaceutical science Ph.D. students and graduates who originally obtained their undergraduate or professional education in a foreign country, and the Commission does not recommend reducing the educational opportunities afforded to these students in the pharmaceutical sciences. However, foreign students, excluding those with a permanent visa, presently make-up approximately half of the Ph.D. students presently enrolled in colleges and schools of pharmacy, and some pharmaceutical science graduate programs enroll only foreign pharmacy students, as little or no recruitment effort is required. Some have suggested that the easy availability of qualified foreign students has contributed to the declining enrollment of underrepresented minority students in science and engineering graduate programs.[33]

It takes significant faculty effort and institutional financial resources to recruit U.S. biochemistry, biology, chemistry, engineering, and physics students to pharmaceutical science graduate programs, particularly those students who are not familiar with pharmacy and the pharmaceutical sciences. These non-pharmacy students can bring a different set of skills to the pharmaceutical sciences that will enrich the entire graduate program. Colleges and schools of pharmacy should allow non-pharmacy science majors the opportunity to enroll in selected pharmacy courses for credit to familiarize these students to the research and career opportunities in the pharmaceutical sciences. The development of B.S. degree programs in the pharmaceutical sciences has been viewed by some as a new source of graduate students, but presently there is not enough evidence to demonstrate that these programs fulfill this objective any better than a concerted recruitment effort of biochemistry, biology, chemistry, engineering and physics graduates into pharmaceutical science graduate programs.

Many colleges and schools of pharmacy are currently initiating joint Pharm.D./Ph.D. programs to attract some of their outstanding professional degree students into a pharmaceutical sciences research career. An increasing percentage of students entering Pharm.D. programs already hold a B.S. degree, so they could qualify as graduate students upon entry to the Pharm.D. program. It is too early to determine what joint degree program structure will be the most successful, but colleges and schools are encouraged to explore and offer joint degree programs to pharmacy students and report their successes and failures to the Academy.

Recommendation 7: Colleges and schools of pharmacy are encouraged to examine a Ph.D. program in the clinical sciences as an appropriate addition to their graduate program offerings.

Students are presently attracted to pharmacy, because they are interested in interacting with patients and other health professionals to optimize the outcomes of drug therapy. The Pharm.D. degree is designed to provide these students with the knowledge, skills, and aptitudes to enable them to perform that task. Pharm.D. graduates who wish to obtain the research skills required to develop and evaluate new drugs or drug therapy regimens, have to obtain those skills "on the job" through a residency or fellowship. Although this mechanism has been adequate for some graduates, it has not produced a sufficient number of clinical pharmaceutical scientists who are capable of obtaining competitive extramural funding and promotion and tenure at leading research universities. There is a need and demand for competent clinical scientists in both the pharmaceutical industry and academia, since M.D.s. and M.D./Ph.Ds. are not filling these positions.[34]

Recommendation 8: Colleges and schools of pharmacy are encouraged to reexamine the M.S. degree as an applied pharmaceutical science graduate degree with a prescribed set of didactic and research requirements for completion.

There is a large and growing need for pharmacists and biology/chemistry graduates with specialized management skills and technical science abilities by the health care, pharmaceutical, and biotechnology industries. Health professions graduates with significant management training are also in demand by hospitals, insurance companies, and government agencies. Several recent NRC committees have recommended that the M.S. degree be reinvigorated.[9,13] The 1996-97 RGAC addressed the topic of the M.S. degree and issued a number of useful recommendations regarding the potential of instituting an applied science M.S. degree as a viable graduate degree option for colleges and schools of pharmacy.[35]

Recommendation 9: The topic of graduate education should become an area for programming at AACP Annual Meetings.

The improvement of graduate education in the pharmaceutical sciences is part of AACP's mission. The conference on graduate education held prior to the 1998 AACP Annual Meeting demonstrated that there are many common issues facing those institutions with graduate programs or confronting those institutions considering adding graduate programs in the pharmaceutical sciences. An annual conference would provide an opportunity for pharmacy faculty to formally address graduate education and research issues.[36]

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Appendix 2:
Conference on the Future of Graduate Education in the Pharmaceutical Sciences
<u>Silvertree Hotel—Cabaret Room</u>

<u>Friday, July 17, 1998</u>

6:00-7:15 p.m. Welcoming Reception and Buffet Dinner

7:30-9:00 p.m. Welcome and Introduction of Keynote Speaker—Dr. David J. Triggle
Keynote Address by Dr. Karen A. Holbrook, University of Florida

Saturday, July 18, 1998

7:30-8:00 a.m. Continental Breakfast-***Fanny Hill/Silvertree Hotel***

8:00-8:30 a.m. Review of Commission's Interim Report—Dr. Kenneth W. Miller

8:30-10:40 a.m. The Future of Graduate Education in the Pharmaceutical Sciences

Pharmaceutics—Dr. Ronald T. Borchardt
Medicinal Chemistry—Dr. Robert W. Brueggemeier
Pharmacology—Dr. John P. Perkins
Social and Administrative Sciences—Dr. Bernard A. Sorofman
Clinical Sciences—Dr. Salomon A. Stavchansky

10:40-11:00 a.m. Break

11:00-11:50 a.m. Quality Control of Graduate Programs—Dr. David J. Triggle

12:00-1:00 p.m. Lunch-***Roof Garden/Conference Center***

1:00-2:00 p.m. **Breakout Sessions-I**

A. Skills and aptitudes needed by graduates planning careers in the pharmaceutical industry. How do you build them into the curriculum and how do you assess them? Dr. Alice Till, Moderator. ***Cabaret/Silvertree***

B. The future pharmaceutical sciences graduate program administrative structure: disciplinary or interdisciplinary, college- or university-wide? Dr. John MCassady, Moderator. ***Eldorado/Silvertree***

C. Maintaining or building graduate degree programs. What is the "critical mass" of funding, faculty, facilities, and students needed for a successful graduate program in the pharmaceutical sciences? Dr. David A. Knapp, Moderator. ***Elbert/Silvertree***

2:00-3:00 p.m. **Breakout Sessions-II**

A. What schools and colleges of pharmacy can do to insure graduate program quality Should graduate programs and faculty be examined as part of the professional program accreditation process? Dr. John P. Perkins, Moderator. ***Cabaret/Silvertree***

B. Recruiting graduate students for the pharmaceutical sciences. Dr. Renee Williard, Moderator. *Eldorado/Silvertree*

C. Is there a future for postgraduate graduate education, or how many degrees do you really need? Dr. Kenneth W. Miller, Moderator. *Elbert/Silvertree*

3:00-3:30 p.m. Conference Summary—Dr. David J. Triggle

Summary of Remarks and Discussion by Graduate Conference Speakers

Dr. Karen A. Holbrook—Keynote Address—Vice President for Research and Dean of the Graduate School, University of Florida

Dr. Holbrook covered a wide range of topics related to graduate education. Some of her observations were consistent with viewpoints already expressed in this report and will not be repeated. Those topics that were not addressed in the body of the Commission report, and issues considered to be controversial, will be the subject of this summary report.

The issue of overproduction ofPh.D.s was addressed by presenting the various options available to "solve" this problem, if in fact, a problem does exist. The importance of career planning for graduate students was emphasized, and the importance of assistance that faculty can provide students to expose them to the widest possible range of career opportunities. The term, "alternative careers" should not be used as it presumes that there are only one or several primary career pathways (i.e., academia or industry) for Ph.D. graduates. There are careers (plural), or there is a diversity of careers. She illustrated this view with examples of resources designed to assist Ph.D. graduates to find desirable careers.

The next century will be the age of biology. However, much of the progress in research in biology will not be defined by the traditional disciplines, but in research areas developing at the interface of traditional disciplines. "New technologies and new knowledge have recently revolutionized our abilities to understand normal biological functions and disease. A broad array of scientific disciplines made this revolution, and that consortium is now required more than ever if we are to follow new paths.[1]" The growing importance of interdisciplinary/interdepartment/intercampus programs as the future of graduate education in the biological and pharmaceutical sciences was supported by the speakers who followed.

Interdisciplinary/interdepartmental/intercampus programs:

- teach students to speak the languages of one or more disciplines;
- teach students to work comfortably in the intellectual domain of the multiple fields; and
- develop scientists who have both the in-depth knowledge of specialized methods required to be effective in research, together with an appreciation and understanding of the complementing methodologies essential for making significant advances on complex and challenging problems.

In addition to these new interdisciplinary degree programs, other approaches include providing core programs (e.g., biological sciences) where students enter the first year uncommitted to a particular discipline; consortia degrees; dual degree programs (M.D./Ph.D., Pharm.D/Ph.D., Ph.D./M.B.A., etc.); 3/2, 3/3, 3/4, degrees; and cyberdegrees.

Dr. Holbrook also addressed the qualifications for employment in the industrial sector. Although many of these skills are found in the Commission report, she provided several new and different perspectives, such as:

- leadership skills – students need to know about the "art of leadership" and the "science of management."
- skills in composition, writing, logic, clarity of thought.
- strength in influencing, negotiating, listening, and teaming.
- interpersonal skills.
- need "boundarylessness" – people who can survive amidst uncertainty and ambiguity.
- quantification skills.
- able to work in a diverse workforce here and abroad.

- capable of adapting to rapid change, dealing with today's leaner, flatter corporation with its preoccupation with quality and customer needs.

The need to be able to function in a global environment, a topic also addressed by DrBorchardt, was identified by Dr. Holbrook as a skill necessary for success in the 21st century.

Dr. Holbrook stressed the importance of teaching (mentoring) graduate students research ethics or research integrity. Examples of programs used at several different institutions were presented. She also presented an outline of a Preparing Future Faculty Program offered to graduate students at Arizona State University to assist graduate students in experiencing a full range of higher education settings, particularly those that focus on the undergraduate experience. Graduate students who participate in this program have an opportunity to practice being a faculty member at higher education institutions other than Arizona State University.

At too many higher education institutions, new faculty members receive little support in how to get off on the right foot in a faculty position. Many are overwhelmed with teaching responsibilities, faculty committees, and initiating their research programs. A new faculty position is a major investment for the university, college, and department and it is in their best interest of the department and university that this new faculty member succeeds. A related topic, mentoring was also stressed as being an important role for faculty with their graduate students, and even other faculty members. A Virginia Polytechnic University booklet "Facts of Life for Future Faculty: A Handbook for an Academic Career," designed to help new faculty members succeed in their academic positions, was used as an example of what departments might do to assist new faculty members succeed.

The topic of "After the Life/Biomedical Sciences Ph.D." was presented. Programs that prepare scientists for a career in the business world, such as the accelerated M.B.A. offered by Cornell University for Ph.D.s, and certificate degree programs (i.e., clinical trials management) offered by other institutions are examples. The individual with an undergraduate science degree, a graduate degree, and cross-trained, particularly in business or management, are being referred to as a "gold-collar worker."[2]

Dr. Holbrook concluded her presentation with an observation that criticism of the nature and value of a graduate education is not new. She illustrated this observation with quotes found in a presentation given twenty-five years ago by Dr. Bryce Crawford, Jr., a Professor of Physical Chemistry and former Vice-President for Academic Affairs at the University of Minnesota, are identical to those found in more recent reports on the state of graduate education. Recommendations for improvement in graduate education made in Dr. Crawford's 1974 presentation include:

- "graduate students should be required to spend time working outside the university" (Broadening Experiences Through Industrial Internships)
- "preferential treatment in recruitment, admission… should be given to groups hitherto discriminated against (Enhancing Diversity)
- "graduate schools should prepare a reorient themselves to fulfill a typical role in societal planning" (Benefiting To Society)
- "…cut back on these expensive Ph.D. programs…" (Rightsizing (Downsizing) Graduate Education)

Dr. Ronald Borchardt-Pharmaceutics-University of Kansas

Dr. Borchardt focused his comments on the future of pharmaceutical industry, because the majority of pharmaceutics Ph.D.s have careers in the industry.

The pharmaceutical industry is changing dramatically and continually in their research strategies, with the change occurring most rapidly during the past ten years. The previous separation of the drug discovery, drug development, and clinical testing has been significantly diminished. The overlap of these three areas will demand that future pharmaceutics scientists (graduate students) be able to talk to both counterparts in drug discovery and clinical testing (i.e., know their disciplinary vocabulary).

One reason why drug discovery and development have become more intertwined is that combinatorial chemistry produces thousands of new compounds in a matter of weeks, not years. Coupled with high throughput biological activity screening procedures, drug discovery synthesizes orders of magnitude of high affinity ligands in a relatively short time period. It is impossible to pursue development of each high affinity ligand, so only those with high potential to become drug products must be selected for continued development. Therefore, the identification of optimal pharmaceutical properties of these biologically-active ligands becomes more important, necessitating the integration of drug development (pharmaceutics) into the drug discovery process. Pharmaceutical properties include solubility, stability, hepatic and renal clearance, physical chemical properties (pKa, etc.), membrane permeability, metabolic pathways and metabolites, and protein binding, among others.

A complicating factor in this new era of drug discovery and development is that pharmaceutical properties must often be characterized with one milligram or less of available compound, instead of gram quantities of material as in the past. Graduate students must become familiar with analytical techniques that utilize such small amounts of material to accurately characterize pharmaceutical properties.

Dr. Borchardt addressed the training and education of students for the 21st century in his editorial in *Pharmaceutical Research.*[3] He reiterated some of the comments for the conference attendees.

> In the present graduate education model, students are given didactic experiences in a highly focused area, and perform their research project in a highly focused area. Some attempt is made to develop communication skills (i.e., seminars, poster sessions). The major professor attempts to determine when the student is able to: 1) ask the right questions, 2) design the right experiments, 3) design the right controls, and 4) interpret and write the results. In the graduate education model for the future, it is necessary to provide graduate students with:
>
> 1. more didactic breadth (the vocabulary of disciplines), so that they can effectively communicate with discovery, manufacturing, and clinical testing scientists.
> 2. an opportunity to participate in multidisciplinary research projects, so that they can learn to work in research teams.
> 3. more opportunities to refine their communication skills, including short communication techniques such as e-mail, and short memoranda.
> 4. more opportunities to use computers. Universities lag behind industry in this area.
> 5. exposure to ethical issues relating to research.
> 6. experience in industry through internships that are not simply summer work experiences, but through projects that can become an integral part of their graduate work.
> 7. exposure to an international research environment.

However, it is important that the graduate program does not:

1. sacrifice scientific depth.
2. sacrifice scientific excellence.
3. add time to the degree.

Dr. Borchardt provided an example of how these principles were applied to a new graduate program at the University of Kansas.

> Pharmaceutical chemistry (pharmaceutics) department faculty had identified the biotechnology industry as a growing area and realized that present graduates were not prepared to work with drug products (proteins, peptides, etc.) of this industry. Therefore, a separate specialty track in biotechnology was created within the department. Faculty members from other departments on campus were recruited to participate in the program, since there were not enough faculty members in the school of pharmacy with expertise in biotechnology. At present, approximately one-half of the biotechnology program faculty are from disciplines outside the school of pharmacy.
>
> All graduate students in the biotechnology track are required to take a course in molecular biology, primarily to learn the “vocabulary” of this area, not to become molecular biologists. They also take an advanced biotechnology course. Much of the advanced biotechnology course is taught by outside “adjunct” faculty with expertise in the area. All students are also required to take a course, “Issues in Scientific Integrity,” taught by 15 faculty members, who run discussion groups using case studies. An industrial internship is required of all students after they pass their preliminary exams. Considerable effort goes into arranging the research projects performed at the industrial sites, so that the work can be incorporated into the thesis. The industrial supervisor is made a member of the dissertation committee. One obvious bonus to the industrial experience is that students have access to biotechnology-derived molecules that would be prohibitively expensive for an academic institution to purchase. Students also have the opportunity to work with the modern analytical equipment that is also not available on most university campuses.
>
> The University of Kansas School of Pharmacy has also initiated a program to expose students to the international research environment. This has been called the Globalization of Pharmacy Education Network (GPEN). GPEN members include the University of Kansas, seven European (including Israel), three Japanese, and one Australian pharmacy graduate programs. The group is meeting once every two years, and provides a forum for graduate students to present their research work, attend faculty-presented short courses, and interact with colleagues from other universities.

Dr. Brueggemeier-Medicinal Chemistry-Ohio State University

Dr. Brueggemeier discussed the following areas in his presentation on the future of graduate education and research in medicinal chemistry/pharmacognosy (medicinal chemistry):

- Impact of trends in pharmacy
- Impact of trends in research universities
- Views from the pharmaceutical industry
- Views from Academia
- Training program for the Ph.D. degree
- Markers of quality-benchmarking
- Personal perspective—Interdisciplinary nature

Medicinal chemistry has not attracted a large percentage of its graduate students from U.S. pharmacy professional degree programs (B.S., Pharm.D.) for many years, as the pharmacy curriculum has become more biological science-based, rather than chemistry-based. However, most foreign student applicants have a B.S. degree in pharmacy. Most U.S. applicants have an undergraduate degree in chemistry or biochemistry.[4] These two different sources of students present some problem as the pharmacy graduates need additional mathematics, physical chemistry, and laboratory experience, while the chemists need basic medicinal chemistry and pharmacology coursework.

There has been an increased emphasis on research and development at the state-supported research universities, where many of our pharmacy programs are located. Universities are making selective investments to focus funds on the NRC top-ranked departments. This poses a problem for graduate programs in medicinal chemistry and other pharmaceutical sciences, because pharmacy programs are too small to be included in the NRC study, so it is more difficult to compete for additional university investment. University-based chemistry departments are also moving into medicinal chemistry with research programs such as "Chemistry of Life Processes" or "Chemistry at the Biology Interface."

The pharmaceutical industry's view of medicinal chemistry graduates from colleges and schools of pharmacy is provocative and startling.[5] A survey of medicinal chemistry research directors at major pharmaceutical companies in the U.S., Europe, and Japan indicated that they prefer to hire organic chemistry graduates from highly select universities, because "they can learn medicinal chemistry and pharmacology on the job." Approximately 28 percent of the medicinal chemistry graduates from U.S. pharmacy colleges and schools in the last ten years are employed in the pharmaceutical industry, while 56 percent are employed in academia.[4]

Medicinal chemistry is broadly defined in academia, although the focus is still on the synthesis of novel agents for therapeutic purposes. Increasingly, research in medicinal chemistry is directed towards biochemistry, enzymology, molecular biology, and other related topics. This diversity of research interests is reflected in the graduate programs in medicinal chemistry amongst colleges and schools of pharmacy. However, there does appear to be core curriculum for medicinal chemistry that includes drug design, drug discovery, structure activity relationships, molecular interactions, computational methods, and combinatorial chemistry. Medicinal chemistry graduate students also require a chemistry core, including organic reaction mechanisms, organic synthesis, and spectroscopy, and a biomedical sciences core including enzymes, receptors, molecular targets, metabolism, gene therapy, and bioinformatics. There were similarities with the topic areas recommended by Dr. Borchardt for pharmaceutics, primarily as a result of the increasing convergence of drug discovery and drug development in the pharmaceutical industry. Dr. Brueggemeier also agreed with Dr. Borchardt about the necessity of not losing sight of the fact that the Ph.D. is a research degree, therefore students must be involved in state-of-the-art research. He also agreed that research is becoming increasingly collaborative and performed in teams.

Dr. Brueggemeier discussed two topics in his presentation that stimulated considerable discussion among conference participants, markers of quality (benchmarking), and the increasing interdisciplinary nature of the research in the pharmaceutical sciences. Benchmarking is extremely important for graduate programs, not only for comparison to "peers," but also in identifying areas for improvement. He stated that there is a need for reliable databases for benchmarking and the willingness of department to share their results with each other or some "central" coordinating group. Faculty, students, postdoctoral fellows, and research facilities and infrastructure should all undergo some measure of quality for benchmarking purposes.

Departments have dominated university structure in order to maintain their academic disciplines and meet their educational missions, but increasingly, research and graduate education are transcending these departmental barriers. The demand for interdisciplinary activities will increase as faculty and their graduate students cluster around new problems and at the interfaces between current academic disciplines. Graduate education programs must be responsive to the development of these new interdisciplinary directors without the constraints of traditional structure. Medicinal chemistry is inherently an interdisciplinary field at the interface of chemistry, biochemistry, pharmacology, and molecular biology. To emphasize one aspect of medicinal chemistry training (i.e., synthetic organic chemistry) ignores the vital contributions of other areas such as biochemistry, pharmacology, and molecular biology in the training of graduate students. A singular emphasis would be a disservice to graduate students, future researchers, and future scholars and the interdisciplinary science of medicinal chemistry.

Dr. Perkins—Pharmacology—University of Texas Southwestern Medical Center

The origins of experimental biology research involved experiments on intact animals. Research evolved from animal and organ function to elucidation of biochemical pathways, and presently to a research focus on the structure and function of macromolecules (molecular level). Once the structure of the genome is known, scientists will have all the parts to solve the puzzle. We will know biology at the molecular level (the parts), and the next step will be to put all the parts back together to understand biology at the organismal level. Manipulation of organismal function has always been the goal of pharmacology, (i.e., pharmacologists want to control biological outcomes).

The future of pharmacology is very bright. The major difficulty facing pharmacology is that it is very difficult to make students aware of the discipline. The number of graduate students applying to the best pharmacology graduate programs is very small compared to number of students applying to mediocre biochemistry graduate programs. One of the difficulties facing pharmacology recruitment is that there is no undergraduate program in the discipline. (Editors Note: pharmacy students often pursued advanced degrees in pharmacology because it was the discipline that examined the mechanism of drug action. Contemporary pharmacy students are interested in how drugs work, but in patients, not animals).

Considering that attracting graduate students to pharmacology is difficult compared to other biological science disciplines, pharmacology programs must become involved in multidisciplinary graduate education programs that include other biological sciences. After one year of taking integrative biology courses and research experiences, pharmacology faculty can then attract students into their research programs. This will only occur if pharmacology faculty members are performing competitive (funded) research. Students are interested in "hot" topics, so to attract students into graduate programs, pharmacology faculty must be engaged in modern, up-to-date research, on interesting problems using the latest technology. It is up to the department, to hire competitive faculty and assist them in remaining competitive. Programs in pharmacology must be flexible and must interact with other faculty who bring new expertise into the area. One cannot sit back in disciplinary niches, but must seek out interdisciplinary opportunities. *The redefinition of physiology from the molecular basis is the future of pharmacology!*

Dr. Sorofman—Social and Administrative Sciences—University of Iowa

The Social and Administrative Sciences (SAdS) represents everything in the pharmacy curriculum that is not pharmaceutics, not medicinal chemistry, not pharmacology, and not clinical sciences. SAdS addresses the system of pharmacy in society, including pharmacy education, human behavior, social interactions, and the consumption of drugs. Like the other disciplines, SAdS has several important issues confronting its graduate programs and research. These can be separated into the focus and purpose of graduate programs; faculty issues of numbers and quality; research facilities and infrastructure; and numbers and quality of graduate students.

The broad diversity faculty backgrounds and research interests are both a strength and weakness of SAdS graduate programs. A small graduate program might have individuals with graduate degrees in anthropology, economics, marketing, and public health. The major problem created by this diversity of faculty background is often perceived as a lack of program focus and critical mass of faculty. Obtaining the required graduate-level courses for the program requires collaboration with other health science graduate programs, such as public health, biometry, preventative medicine, etc. A few programs with a selected focus such as pharmacoeconomics are beginning to be nationally recognized. The emergence of pharmaceutical care as the future of pharmacy practice has placed increased demand on SAdS faculty to focus more on pharmacy-related issues.

Faculty positions are difficult to fill in SadS, because there are too few graduates from SAdS or related graduate programs. A significant number of SAdS graduates are taking positions in the pharmaceutical industry rather than academia. Combined with the small size of most SAdS graduate programs, faculty recruitment will be a problem for the foreseeable future.

Recruitment of pharmacy students into SAdS graduate programs is difficult, for the same reasons as recruitment of students into other pharmaceutical science graduate programs. New pharmacy graduate salaries are often higher than entry-level academic salaries, and new practice opportunities are exciting. More graduate students in SAdS are coming from foreign countries and from non-pharmacy disciplines. The universal Pharm.D. degree for pharmacy should be looked at as an opportunity to recruit residents, fellows, and professional degree post-doctoral students.

Although SAdS faculty do not require the same laboratory space and expensive equipment as many of their faculty colleagues, they do have a need for office space and state of the art computers and database software. The small start-up packages for new faculty in SAdS does a disservice to those faculty members who are attempting to establish an independent research program. Another major need for funding is the support of graduate students. Most outside funding in SAdS is obtained from answering other people's questions, not the faculty member's. Too few dollars are available to construct the theories and instruments required to build of body of knowledge for the discipline.

In view of the difficulty of the small size of most SAdS graduate programs, why should colleges and schools of pharmacy maintain these programs? The primary reason is that this is the only area that focuses on the issues facing pharmacy practice and its place in the health care system in the future. Too few scholars examined the issues confronting pharmacy practice in the 1970s and 1980s. Pharmacy still does not even have solid workforce data. In the 1990s, SAdS faculty members have begun to create the tools and concepts needed to investigate social and behavioral phenomena in pharmacy, upon which the future of pharmacy practice will be based.

Dr. Stavchansky—Clinical Sciences—University of Texas at Austin

Dr. Stavchansky provided a historical view of the parallel development of the pharmaceutical sciences and pharmacy practice. When preparation of the drug product was the focus of the pharmacist, graduate programs in the pharmaceutical sciences evolved to create the knowledge base for this activity, particularly in pharmaceutics, biopharmaceutics, and pharmacokinetics. While the practice of pharmacy has evolved in recent years to become patient-oriented, no graduate program in the clinical sciences has evolved to develop a new knowledge base. A discipline, such as clinical pharmacy practice, cannot remain viable if it only dispenses knowledge and does not create new knowledge. The time has come to offer a Ph.D. degree in the clinical sciences to create a knowledge base for the continued evolution and growth of patient-oriented pharmacy practice. Additionally, clinical practice faculty in our colleges and schools need a Ph.D. degree to be competitive for research funding at the federal level, particularly those faculty in a research-intensive university environment.

(Editors Note: The House of Delegates unanimously accepted the following policy statement from the 1997/98 AACP Research and Graduate Affairs Committee, chaired by Dr. Stavchansky, on Wednesday, July 22, 1998.)

AACP supports the development of graduate degree programs for the purpose of educating and training pharmacist/clinical scientists at schools and colleges of pharmacy with adequate pharmaceutical science and clinical faculty and facility resources. The pharmacist/clinical scientist graduate programs should contain appropriate coursework and research requirements to award the appropriate graduate degrees (M.S./Ph.D.) to those individuals who successfully complete the program.

Panel Discussion Following Pharmaceutical Science Discipline Presentations (Borchardt, Brueggemeier, Perkins, Sorofman, Stavchansky)

Much of the discussion that was prompted by comments and questions for the audience revolved around interdisciplinary research and graduate programs. Concern was raised by several participants regarding difficulties with promotion and tenure for faculty who participate successfully in interdisciplinary programs, because it is at the department level that promotion and tenure are granted.

The necessity for pharmacy faculty members to have a commitment to the profession of pharmacy, even those hired from outside the pharmaceutical sciences, was stressed. It is the responsibility of the department chair to insure this commitment. Those pharmaceutical sciences faculty who become involved in interdisciplinary programs must maintain their identity with the pharmaceutical sciences while bringing some unique skill/knowledge to the interdisciplinary endeavor.

The concern of "where does the money go" for those faculty members who become involved in externally-funded interdisciplinary research was voiced. This becomes important not only for receiving recognition for a faculty members scientific contribution, but also plays a role as to what department or school receives the credit for the grant's indirect costs, as some of it may flow back to the department.

The importance of departmental chair support for faculty involved in interdisciplinary research and graduate education programs were emphasized. While the speakers were unanimously supportive of interdisciplinary endeavors, the faculty member must have the support of their department chair. Additionally, a faculty member must be aware of the university environment in setting the pathways for faculty activity and setting their personal priorities. There are large differences among universities in the emphasis they place on research and teaching and other related faculty activities.

Dr. Borchardt expressed his opinion that the B.S. degree in the pharmaceutical sciences (non-practice degree) was not an appropriate breeding ground for graduate school. Most colleges and schools of pharmacy do not have the resources to offer another degree in addition to the professional degree in pharmacy and graduate degree programs. He suggested attempting to make arrangements with chemistry and biology departments to set-up "emphasis" areas for their majors in the pharmaceutical sciences. These students could take selected pharmacy courses to become familiar with the pharmaceutical sciences. This topic was also raised in the afternoon discussion sessions.

<u>Dr. David J. Triggle—Dean of the Graduate School—University at Buffalo, State University of New York</u>

Graduate program evaluation would appear to be a reasonable, simple activity that addresses the following questions:

- What is the mission of the program?
- Is the program worth doing?
- If we were not already doing it, would we do it now?

Program evaluation becomes much more complex in a higher education academic setting, because it is difficult to separate evaluation from many of the other issues confronting higher education, such as the changing nature of the university, the national research enterprise, and (in the pharmaceutical sciences) the nature and organization of industrial pharmaceutical research.

Presently, the public recognizes the relationship between college and future employment opportunities and economic status, so there will be an increasing demand for a college degree, and even more on the need for lifelong learning opportunities to continue to maintain workplace skills. This increase in demand for education and training cannot be met by simply expanding the present physical plants of existing universities and colleges. There will be an increase in the role of new higher education entities (Phoenix U., Western Governors Virtual University, etc.) in providing distance and asynchronous learning to meet these increasing educational demands. Current institutions are also attempting to position themselves to take advantage of this increasing demand for higher education.[6] The "brand name" institutions (i.e., Ivy league, Stanford) research institutions are on one end of the spectrum and the "convenience" institutions such as Phoenix U. at the other end, while the majority of institutions (i.e., state university systems) are currently serving the majority of students. The reality that all institutions cannot be a major, brand name research university produces a tension in institutional mission, faculty and public expectations of the university's role, and political realities (funding).

Despite the public's recognition of the importance of a college degree (not necessarily education), there is unhappiness with student performance at all educational levels, K-12 and higher education. The poor performance (< 50% pass rate) of recent college graduates on a State of Massachusetts teacher's competency exam reflects poorly on all of higher education, not just schools of education graduates. Other poor measures of college graduate's competency, has lead to an increase in accountability demands, particularly for state-funded institutions. It is estimated that by the year 2001, all states will have performance indicators for all levels of education.

> "A performance indicator is a concrete piece of information about a condition or result of public action that is regularly produced, publicly reported, and systematically used for planning, monitoring, or resource allocation at the state or system level…" "Performance indicators include ratios, percentages, or other quantitative values that allow an institution to compare its position in key strategic areas to peers, past performance, or to previously set goals[7]…"

Performance Indicators have five primary uses:

1. **Monitoring**—the use of consistent and accurately obtained information as the basis of subsequent actions.
2. **Evaluation**—focusing on the attainment of goals.
3. **Dialog**—using performance indicators, two or more parties are able to communicate with a common language.
4. **Rationalization**—the accomplishment of a coherent policy-making process.
5. **Allocation**—of resources based on the accomplishment of steps 1-4.

There are presently a number of external performance indicators, or more specifically, rankings of programs. The most visible are the reputation-based surveys published by the weekly magazine, *US News and World Report*, and the NRC, although the latter has more academic cachet. Measures such as Web site hits, NIH funding levels, and numbers of faculty members of the National Academy of Sciences have been used as ranking measures. In any quantitative measure of performance, it is important that the effects of the size of the institution be considered. The impact of size on university ranking measures is dramatically illustrated in a recent publication on research performance of American Universities.[8]

Externally imposed performance indicators will lose their prominence if the academy assumes responsibility for providing measures of performance and provides the results to the public and policy makers. If the academy does not respond, the public will demand some measure of the desired results, even though the desired results are not agreed upon.

Desirable characteristics of performance indicators in an assessment of graduate programs:

- **Multidimensional**—recognizes multiple areas for comparison.
- **Diverse**—recognizes that all programs cannot be automatically compared.
- **Benchmarked**—comparisons should be made against recognized standards.
- **Clarity**—results should be clear and show trends and comparisons.
- **On-line**—encourages constant evaluation, faculty, and program participation.

Examples of performance indicators for assessing graduate degree programs:

Input Variables	Program Variables I	Program Variables II	Output Variables
Undergraduate GPA	Enrollment per FTE	Publications per FTE	Degrees awarded
Previous graduate GPA	Student attrition rate	Citations per FTE	Time-to-degree
GRE scores	Passing rate	Publication density	External exam pass rate
Advanced test scores	Time-to-degree	Citation density	Percent employed
Admissions selectivity	Honors and awards	Invited presentations	Placement
Admissions yield	Training programs	Research funding/FTE	Careers
Fellowships	National fellowships	Program ranking	External perceptions
Honors and awards	Program breadth	Cost	Student diversity

While there are a number of problems facing the academy with regards to graduate program evaluation, the solutions to those problems will only remain within the academy, if we:

- assume responsibility for our own future.
- clarify our mission, our objectives, and our priorities.
- make the consistent choices.
- reallocate resources.
- make the decisions stick.

Summary of Breakout Session Discussions

<u>What are the skills and aptitudes needed by graduates planning careers in the pharmaceutical industry? How do you build them into the curriculum and how do you assess them?</u>

This issue should not focus on meeting the needs of industry (or academia), but focus on meeting the needs of graduate students, providing them with the skills necessary to thrive in their chosen career.

- It is not necessary to reengineer educational programs to meet industry needs. Focus on research skills and fundamental knowledge of the discipline and do not: sacrifice depth for breadth, increase time to degree, and lose identity of the pharmaceutical sciences while stressing interdisciplinary efforts.
- Many skills needed by the industry are not obtained through coursework, but through interaction with mentors. Students cannot be treated as mere workers.
- There are several Internet sites (Biomednet) which address obtaining those skills not available in courses (i.e., "Adapt or Die" series).
- Graduate students need more familiarity with intellectual property issues and research ethics.
- Programs can bring in guest speakers from the industry to address issues facing scientists involved in the drug development process. Several graduate programs utilize this technique.

The ability to work as a team has been addressed in several national reports and also within the Commission report. Several questions and suggestions were made, including:

Can teamwork be taught through multidisciplinary projects with students and faculty from other programs?

- Attempt to achieve student collaboration within the department.
- Assign group or team projects in graduate courses much like M.B.A. program projects.
- Have team members evaluate each other as part of a team.
- Provide incentives to students and faculty to submit ideas for interdisciplinary, team projects.
- Send students to other laboratories (out-of-state) to learn new skills and have them return and teach skills to other students.
- Form collaborations with other faculty at programs in vicinity, including sharing of courses. For example, at Duquesne University and University of Pittsburgh, the focus of the two pharmaceutics departments differs: Duquesne is more focused on physical chemistry/pharmacy while Pittsburgh is more focused on pharmacokinetics and pharmacodynamics. Students can cross-enroll for courses in these two programs. This has also led to research collaborations between the two programs.

Explore greater use of the Internet for collaboration among graduate programs in pharmacy.

The assessment of graduate program outcomes is difficult, particularly those areas that are not related to didactic work. Tracking the career outcomes of graduates is a viable assessment technique.

<u>What is the future pharmaceutical sciences graduate program administrative structure: disciplinary or interdisciplinary, college- or university-wide?</u>

This issue was broken down into several small issues. The first was, " Should the traditional pharmaceutical sciences remain separated in departments or integrated into larger interdisciplinary departments?" The following comments were presented and discussed:

- Integrate pharmaceutical science departments, if possible. This can prove to be more difficult than it appears. In addition to reluctance on the part of faculty, alumni of the department are often upset about the disappearance of "their" department. However, in the long run, integration appears to offer more advantages than disadvantages.
- If two or more departments are willing to merge, but another department does not want to integrate into the program, move ahead with integration of those departments that are willing.
- Integration of pharmacy graduate programs can provide a stronger "pharmacy identity" if pharmacy program faculty become involved in interdisciplinary programs on campus.
- For smaller graduate programs, an integrated multi-disciplinary structure rather than separate departmental structure might be the only viable choice. (Editors Note: In both Dr. Holbrook's and Dr. Perkins' presentation, examples of integrated graduate programs were presented in which students take a common curriculum for the first year, and then chose a major field of research and a research advisor after completing the first year.)
- How do colleges and schools of pharmacy become involved in research/graduate education programs in emerging interdisciplinary areas, often at the university-wide level?
- In any interdisciplinary collaboration, pharmacy faculty must bring something unique and of value to the table, while maintaining their identity as pharmaceutical scientists. This same point was made several speakers in the morning session.
- In choosing new areas of research to develop, regional (state) needs should be considered an important factor, as it may assist in obtaining public funding of new faculty positions and research infrastructure.

<u>How does an institution maintain or initiate a graduate degree program? What is the "critical mass" of funding, faculty, facilities, and students needed for a successful graduate program in the pharmaceutical sciences?</u>

The critical mass of students, faculty, funding, and outcomes was considered separately.

- Student numbers depend on the number of faculty. Rather than examining absolute student numbers, the number of student/FTE faculty should be examined.
- Faculty numbers depend on the focus of the program, the narrower the focus of the program, the fewer the number offaculty needed. The absolute number of faculty cannot be the only consideration, the program environment is also important. Postdoctoral fellows, adjunct faculty, and other institution-wide faculty who significantly contribute to the program are important when considering faculty numbers.
- Funding is very important. All sources of funding need to be examined, not only university/college funding.
- Assessment of multiple program outcomes is important. The number of students completing the program, their subsequent employment, and their long-term careers all need to be considered. External review of graduate programs may be painful, but it is necessary and very beneficial (seeLemberger report).

What can colleges and schools of pharmacy do to insure graduate program quality? Should graduate programs and faculty be examined as part of the professional program accreditation process?

This very important contemporary issue will be the primary focus for our next graduate education conference prior to the AACP Annual Meeting in Boston, MA. See the summary of Dr. Triggle's talk for an introduction to this topic.

Recruiting graduate students for the pharmaceutical sciences.

This session broke down the issue into four topic areas:

- Recruitment of students from colleges and schools of pharmacy.
- Foreign pharmacy students—Are large numbers a concern for state supported institutions?
- Recruitment of non-pharmacy students.
- Non-professional degree programs in college and schools of pharmacy (i.e., B.S. in the pharmaceutical sciences)

Most students in a professional degree program in pharmacy have chosen that program because they want to be pharmacists. Institutions should not re-arrange graduate programs to simply attract pharmacy students, but should use research electives and summer research fellowships to plant the seed of a research career within the student. It is desirable to have pharmacy students in a graduate program in the pharmaceutical sciences, but it is also highly desirable to have a diverse graduate student body.

For those pharmacy students exhibiting an interest in a research career, it is important to get them involved in a research experience as early and as often as possible during their degree program. It would be desirable to have a genuine flexible Pharm.D./Ph.D. program or have pathways in the Pharm.D. program that facilitates obtaining a graduate degree. It was mentioned that colleges and schools of pharmacy with graduate programs do not always actively and effectively recruit their own students. Often students do not know what type of research, pharmacy faculty is undertaking.

The issue of what the desirable number of foreign students in a graduate program proves to be a difficult to assess and discuss. About 50 percent of graduate students enrolled in pharmaceutical sciences program are foreign students, and many of these foreign students have a pharmacy degree from their home country. Foreign students have been welcomed in pharmaceutical science graduate programs, but it is not in their best interest if a program does not contain any domestic graduate students, pharmacy or non-pharmacy. Programs who rely exclusively on foreign students may have problems using some of those students as teaching assistants. Additionally, foreign students cost more if the department or college has to assume the cost of out-of-state tuition waivers. Foreign students are "easier" to attract, and because they are often academically well qualified for graduate school, recruitment of domestic students does not become a program priority.

There is considerable ignorance among non-pharmacy undergraduates about some pharmaceutical science graduate programs. Medicinal chemistry has obtained the majority of its graduate students from undergraduate chemistry programs, and pharmacology has attracted a large percentage of its students from biology programs. It will be necessary to educate the faculty in their disciplines as to the opportunities awaiting Ph.D. graduates in the pharmaceutical industry, in order to attract non-pharmacy undergraduate majors to pharmaceutical science graduate programs. Summer research programs, brochures, seminars, attendance at graduate and professional degree fairs, and pharmacy electives for non-pharmacy students may be useful in attracting non-pharmacy students to the pharmaceutical sciences.

Finally, the B.S. in pharmaceutical sciences was discussed as an effective tool to attract students to graduate school. This is an area where colleges and schools have experienced very different results. SUNY-Buffalo has a successful program and is expanding to a B.S./M.S. degree program that can be completed in five years. Campbell University has a new program that is strongly supported by Glaxo Wellcome and other companies in the North Carolina Research Triangle. Students have been attracted to the program, but the number going on to a graduate degree is not yet known. However, other programs such as those at Michigan, Purdue, and the University of Pacific, have not been successful. Dr Borchardt challenged the concept of the B.S. in pharmaceutical sciences as "breeding" grounds for graduate students in the morning session, and suggested that they could use up already limited faculty resources. Alternatively, Dr. Perkins lamented that pharmacology suffers from a lack of student interest in the discipline, because there is no B.S. major in pharmacology. Comments during the session demonstrated the range of opinions regarding the purpose and use of degree track (i.e., "Never saw a B.S. program work as a tool to move to graduate programs," and "Shouldn't look at these programs strictly to recruit for graduate schools").

Is there a future for postgraduate graduate education, or how many degrees do you really need?

Dr. Holbrook briefly addressed this topic in with the mention of Cornell's M.B.A. program for Ph.D.s and the increase in certificate programs designed to improve specific skills of Ph.D. scientists.

The discussion initially focused on the potential of colleges and schools of pharmacy forming a "virtual college" to provide graduate degrees (M.S.) and graduate certificate programs to scientists and development personnel in the pharmaceutical industry, as Lehigh University is doing through its Educational Satellite Network. The difficulties of accreditation, certification, competency, and revenue generation appeared to be too complex to continue the discussion of a virtual college. The discussion then moved to the introduction of an on-line M.S. degree program in clinical research to be offered by Duke University and the NIH. The University of Pittsburgh is also involved in this effort. The increasing role of professional organizations (ASHP, ACCP, AAPS) in providing short course and certificate programs was raised. Pharmacy faculty members present many of these postgraduate degree programs. At this point Dr. Borchardt indicated that he participates in many of these short courses, but expressed concern that only industry scientists can afford to take the courses, not graduate students. The question was raised as to whether a virtual pharmacy college or pharmacy education network could provide a vehicle for delivering coursework (short courses and regular courses) to graduate students on campuses where faculty expertise in a particular area is lacking. If this were possible, it would redefine the concept of "critical mass" for offering a graduate program. There is also international demand for graduate level courses that could be provided by a virtual college.

Dr. Borchardt described an European/UK consortium of pharmacy graduate programs that convenes every summer for a week, where faculty offer short courses for graduate students. It was suggested that perhaps AACP could coordinate similar programs in the U.S. Short courses offered via a virtual college or through consortial meetings would be one method to increase the breadth of graduate education, without adding significant time to the degree. There was a growing consensus that AACP should take the lead in exploring the concept of a virtual college, and all the issues involved in such a venture, with the goal of providing expanded educational opportunities to graduate students in our own programs, persons in industry, and international programs.

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Appendix 3: Survey of Earned Doctorates
(1975-1996)

The data obtained from this national survey will be used by your school/college and the American Association of Colleges of Pharmacy for analysis of national status and trends.

Directions: Please print or type where indicated.

DEMOGRAPHICS AND EDUCATION HISTORY (Circle only one in questions 1-4.)

1. Sex: 01 Female
   02 Male

2. Marital Status: 01 Single, never married
   02 Married
   03 Separated, divorced, widowed

3. Citizenship: 01 United States, native

   02 United States, naturalized

   03 Non-U.S., permanent resident of U.S. (immigrant visa)

   Country of present citizenship

   04 Non-U.S., temporary resident of U.S. (non-immigrant visa)

   Country of present citizenship

   05 Non-U.S., with no U.S. residency or citizenship

   Country of present citizenship

4. Racial Background: 01 American Indian or Alaskan Native
   02 Asian or Pacific Islander
   03 Black
   04 Hispanic
   05 White

5. Number of Dependents (not including yourself)
   (Dependent=someone receiving at least one half of his or her support from you.)

6. List below, chronologically, all colleges (including two-year) and graduate institutions you have attended and each degree earned (if any). Be sure to give the years for ALL institutions attended. If space is insufficient, continue on back of page.

		Years Attended			Degree (if any)
Institution	State/Country	From	To	Field of Study	Title

7a. How many years did you spend as a **full-time** student and/or **part-time** student between receiving your first baccalaureate degree (or first professional degree or equivalent) and receiving your doctorate (include the period spent on your thesis and/or dissertation).

____ years as full-time ____ years as part-time

b. How many years, if any, did you spend in postdoctoral positions?____ years
(See question 12 for definition of postdoctoral position.)

8. Identify the field of your dissertation research (e.g.,drug absorption).

9. Name the department (or interdisciplinary committee, center, institute, etc.) and school or college which supervised your doctoral program.

Department/Institute/Committee/Program School/College

10. Indicate your sources of financial support during graduate school. Circle **all** sources from which support was received, if any.

Own/Family Resources
01 Own Earnings
02 Spouse's Earnings
03 Family Contributions

University-Related
04 Teaching Assistantship
05 Research Assistantship
06 University Fellowship
07 College Fellowship
08 Other

Specify

Major Professor's
Federal Research Grant
09 NIH
10 NSF
11 Other Federal

Specify

Other Federal Support
12 NIH Traineeship/Fellowship
13 Other HHS
14 NSF Fellowship
15 FIPSE Grant
16 Other

Specify

Non-Federal Fellowships
17 AFPE
18 Amer.Chemical Society(ACS)
19 Other Fellowship

Other Sources
20 Pharm.IndustryGrant/Contract
21 Foreign/non-U.S. Government
22 Employer
23 Other

Specify

EMPLOYMENT PROFILE

11. During SEPTEMBER 1996, what was your employment status? (Please circle the number of your response below. **Circle only one.**)

01 Employment full-time --	Skip to Question 16
02 Employment part-time --	Go to Question 12
03 Postdoctoral appointment* -- full-time ---	Skip to Question 16
04 Postdoctoral appointment* -- part-time ---	Go to Question 12
05 Unemployed, seeking full-time or part-time employment ------------------------	Skip to Question 14
06 Not employed and not seeking employment ---------------------------------------	Skip to Question 15
07 Retired and not employed --	Skip to End
08 Other --	Skip to End

*Postdoctoral appointment is defined as a temporary appointment in academia, industry, or government, the primary purpose of which is to provide for continued education and/or experience in research.

12. If you held a part-time position during September 1996:

a. Were you seeking a full-time position?
01 Yes
02 No

b. On average, how many hours per week did you work in September 1996?
____ hours

13. What was your MOST important reason for holding a part-time position during September 1996? (Circle only one.)

01 Part-time position preferred.
02 Full-time position preferred.
03 Family responsibilities.
04 Other, specify

NOW, PLEASE SKIP TO QUESTION 16

14. If you are unemployed but seeking employment during September 1996, which of the following factors MOST restricted your job search? (Circle only one.)

01 Geographic location
02 Family responsibilities
03 Need for part-time employment
04 Other, specify

NOW, PLEASE SKIP TO QUESTION 20

15. If you were not employed and not seeking work during September 1996, what was your MOST important reason for not seeking employment? (Circle only one.)

01 Temporarily absent for health or personal reasons
02 Family responsibilities
03 Suitable job not available
04 Other, specify

NOW, PLEASE SKIP TO QUESTION 20

16. Which category best describes the type of your principal employment OR postdoctoral employment during September 1996? (Circle only one.)

01 Self-employed
02 Business/industry
03 Pharmacy school/college
04 Medical school (including university-affiliated hospital or medical center)
05 College or University (e.g., non pharmacy/medicine)
06 Private foundation
07 Hospital or clinic
08 U.S. military service, active duty, or Commissioned Corps (e.g., USPHS)
09 U.S. government, civilian employee (e.g., FDA, HRSA, HCFA)
10 State government
11 Local or other government, specify
12 Other, specify

17. Please write the name of your principal employer (company, organization, postdoctoral institution, etc.) and actual place of employment during September 1996. If you were self-employed, write "self."

Name of Employer

City County

State or Foreign Country Zip Code

18. If you were employed by an institution of higher education:

a. What was your faculty rank? (Circle only one.)

01 Professor
02 Associate professor
03 Assistant professor
04 Instructor
05 Lecturer
06 Adjunct faculty
07 Other, specify ____
08 Does not apply

b. What was your tenure status? (Circle only one.)

01 Tenured, tenure received in 19
02 Not tenured, in tenure track
03 Not tenured, not in tenure track
04 Tenure not applicable

19. From the activities listed below, select your primary and secondary work activities for your principal job (as reported in question 17), in terms of time devoted during a typical week. Enter the appropriate code (01-17) for each in the space provided.

___ Primary activity ___ Secondary activity

01 Teaching
02 Basic research (e.g., study directed toward gaining scientific knowledge primarily for its own sake)
03 Applied research (e.g., study directed toward gaining scientific knowledge in an effort to meet a recognized need)
04 Development of equipment, products, systems
05 Design of equipment, processes, models
06 Management/administration of R&D
07 Management/administration of educational/other programs
08 Report and technical writing, editing
09 Professional service to individuals, clinical diagnosis, provision of pharmaceutical care
10 Consulting
11 Operations--production, maintenance, construction, installation
12 Quality control, testing, evaluation
13 Regulatory affairs
14 Sales, marketing, purchasing, customer and publicrelations
15 Statistical work--survey work, forecasting, statistical analysis
16 Computer applications
17 Other, specify

20. Since receiving your doctorate, how many full-time equivalent (FTE) years of professional work experience have you had (excluding postdoctoral study)?

____ year(s)

21. Since receiving your doctorate, how many different employers have you had, excluding any postdoctoral appointments?

____ employer(s)

22a. Was any of the work in which you were engaged during the past year supported or sponsored by U.S. Government funds? (Circle only one.)

01 Yes--Go to Question 22b
02 No--Skip to Question 23
03 Don't know--Skip to Question 23

b. If yes, which of these agencies or departments were supporting your work? (Circle **all** that apply.)

01 Department of Defense
02 Department of Energy
03 Department of Education
04 National Institutes of Health (DHHS)
05 Other DHHS (e.g., HCFA, HRSA, FDA)
06 Department of the Interior
07 Department of Labor
08 Environmental Protection Agency (EPA)
09 National Aeronautics and Space Administration (NASA)
10 National Science Foundation (NSF)
11 Nuclear Regulatory Commission
12 Other, specify ____
13 Don't know source agency

23. Since you received your doctorate, have you ever spent three months or more working in a country other than the U.S.?

01 Yes
02 No

Thank you for your participation.
Please return your completed questionnaire to:

Appendix 4: Results of the AACP Survey of Earned Doctorates (1975-1996)

Introduction

The 1995-96 AACP Research and Graduate Affairs Committee (RGAC) recommended that to "...assist in the strategic planning efforts of all its member institutions, with the cooperation of member schools, AACP should survey Ph.D. graduates (1975-1995) in order to determine their career paths since graduation." Furthermore, AACP should continually update this database and periodically re-survey the cohort to determine the influences of the market on the careers of Ph.D. graduates.

Methods

The AACP Survey of Earned Doctorates (the Survey) was constructed by selecting questions from two National Research Council (NRC) surveys of Ph.D. graduates; the *Survey of Earned Doctorates* (SED) and the *Survey of Doctorate Recipients* (SDR). The SED has been conducted by the NRC since 1958 and is administered to Ph.D. students by their respective universities upon completion of their degree requirements. The SDR has been administered to a stratified random sample of Ph.D. graduates under the age of 76 who hold doctorates from U.S. institutions in science or engineering since 1973, as part of the Longitudinal Doctorate Project. Permission to reproduce NRC survey language in the AACP survey for comparison purposes was obtained. An initial draft survey instrument was distributed to the RGAC members for comments and final approval. Salary data was not collected, since: 1) pharmacy faculty salary data is already collected by AACP, 2) pharmaceutical industry salaries are published annually by the American Association of Pharmaceutical Scientist (AAPS), and 3) it was thought that asking for salary information might reduce participation.

Electronic versions of the survey instrument (Appendix 3) were sent to 54 colleges and schools of pharmacy identified as having at least one Ph.D. graduate from 1975-1996. The addition of a college, school, or university logo to the AACP survey instrument was suggested to encourage alumni participation. Thirty-eight of the 54 colleges and schools (70.4 percent) participated in the survey. Participating institutions were encouraged to include up to two pages of additional questions that were specific to their graduate programs, so they could obtain additional information for program evaluation and planning purposes. The participating institutions collected the surveys and returned them to AACP for data entry and analysis, after removing their college/school-specific questions. Respondents were not asked to identify themselves, although some institutions used a coding system to identify graduates who did not return the survey for the purpose of mailing reminders.

The individual survey question responses were entered into a spreadsheet database (Excel 5.0). The responses were sorted by variable and counted for each institution and for all institutions combined. The AACP population data was obtained from the annual AACP publications of student enrollment and degrees granted. The SDR comparison cohorts were the biological and health sciences subset of the life and related sciences data (SDR-BIO) and the chemistry data (SDR-CHM) from the *Characteristics of Doctoral Scientists and Engineers in the United States: 1995*.[1]

[1] National Science Foundation, Division of Science Resources Studies: NSF 97-319, R. Keith Wilkinson (Arlington, VA 1997).

Results and Discussion

Respondent Demographics

A total of 1,542 survey forms were returned to AACP from the participating institutions. No question was unanswered on more than two percent of the returned survey forms. Colleges and schools of pharmacy awarded a total of 5,411 Ph.D. degrees from 1975-1996. Approximately 28.5 percent of the total number of Ph.D. graduates from 1975-96 returned a completed survey. The response rate of the graduates from the colleges and schools who did participate was approximately 40-50 percent, with a response rate range of 14-93 percent. In comparison, the 1995 SDR sample size was 49,829 out of an estimated Ph.D. population of 594,275. Complete responses were obtained from 35,370 of the 49,829 surveyed.

The gender, racial identity, and graduate discipline demographics of the survey respondents were compared to the 1975-1996 AACP Ph.D. degree population demographics to determine if the survey respondents were a reasonably unbiased sample of the AACP total population of Ph.D. graduates. The demographics of the biological and health sciences (SDR-BIO) and chemistry (SDR-CHM) are included for comparison purposes from related areas of study (Table 1).

Respondent Demographics: Table 1

CHARACTERISTIC	SURVEY	POPULATION	SDR-BIO	SDR-CHM
Male	70.0%	71.6%	70.0%	86.2%
Female	29.8%	28.4%	30.0%	13.8%
White	70.0%	55.3%	86.5%	83.5%
Black	2.9%	1.4%	2.1%	1.5%
Asian/Pacific Islander	26.3%	5.6%	9.1%	12.6%
American Indian	0.2%	0.1%	0.3%	0.3%
Hispanic	2.5%	1.1%	1.9%	2.2%
Citizen/Permanent Resident	91.9%	64.8%	98.9%	99.2%

The AACP disciplinary classifications of Pharmaceutical Chemistry/Pharmacognosy (MEDCHM), Pharmaceutics/Pharmacy (PCEU), Pharmacology/Toxicology (PCOL), and Social and Administrative Sciences (SADS) were used to categorize the respondents' discipline (Table 2). If a survey respondent did not select a discipline on the survey form, or chose pharmaceutical sciences, pharmaceutical chemistry, or pharmacy practice, they were assigned to one of these disciplines based on the description of their thesis research, if possible. Research in pharmacy education, continuing education, or bionucleonics was assigned to the OTHER category. If the research description provided was inadequate, no response was recorded. AACP did not collect Ph.D. graduates' disciplinary areas until 1983. However, approximately 75 percent of the total number of Ph.D. degrees granted from 1975-1996 were granted in the period of 1983-1996 when they were collected.

Discipline Demographics: Table 2

PH.D. DISCIPLINE	SURVEY RESPONDENT	AACP POPULATION*
MEDCHM	27.4%	31.2%
PCEU	40.5%	37.5%
PCOL	23.2%	23.4%
SADS	6.7%	7.2%
OTHER	1.8%	0.7%

*Data from 1983-1996

The gender distribution of the survey respondents and the AACP population were quite similar and indicates that the survey sample is not gender-biased (Table 1). The discipline demographics also indicate that the survey respondents are a reasonably unbiased sample of the pharmaceutical science disciplines from 1975-1996 (Table 2).

Unfortunately, comparison of racial identity or citizenship characteristics between the present survey and the AACP population could not be used to ascertain whether the survey sample is representative of the AACP population of graduates. AACP only collects racial identity data on U.S. citizens and permanent resident Ph.D. graduates in its annual surveys. For example, the figure of 55.3 percent for White in the AACP population data only reflects racial identity of U.S. citizens or permanent residents at the time of graduation. White Canadian, European, and Middle Eastern Ph.D. graduates who were non-citizens at the time of graduation would not be included in the 55.3 percent figure for Whites, but would be included in the White category in the present survey if they became a U.S. citizen or permanent resident sometime after graduation. Another example of effect of time on the survey results is illustrated in the category, Asian/Pacific Islanders. Only 5.6 percent of Asian/Pacific Islanders were U.S. citizens or permanent residents at the time of graduation, but this group constituted 26.3 percent of the respondents of the survey. Apparently, a large number of non-resident Asian/Pacific Islanders graduates became U.S. citizens or permanent residents after receiving their Ph.D. degree.

Since the SDR only samples individuals living in the U.S., almost all the respondents are citizens or permanent residents. This explains the large percentage of U.S. citizens and permanent residents in the SDR results. In the present survey, several participating institutions attempted to contact all their Ph.D. graduates, including those with non-U.S. addresses. The responses of those graduates living outside the U.S. contributed to the lower percentage of the survey respondents who are citizens or permanent residents when compared to the SDR results.

Respondent Employment Status, Employer Category, and Employment Activities

Respondents provided information on their employment status, employer, and employment activities as of September 1996 (Tables 3,4,5,6). The survey included Ph.D. graduates who obtained their degree in June 1996, so recent graduates may not have obtained full-time employment by September. The SDR includes individuals up to the age of 76, resulting in a relatively high percentage of retired respondents (7-10 percent) compared to the percentage of retired survey respondents (0.2 percent). Therefore, the number of retirees was subtracted from the total number of respondents in both surveys for comparison purposes of employment status (Table 3). The SDR employer categories or employment activities results do not include retired respondents.

Employment Status: Table 3

EMPLOYMENT	ALL*	MEDCHM	PCEU	PCOL	SADS	SDR-BIO	SDR-CHM
Full-time	85.4%	81.5%	89.7%	79.6%	91.3%	81.9%	87.2%
Part-time	1.1%	1.0%	1.3%	0.6%	1.9%	4.2%	4.4%
Postdoctoral	9.7%	13.7%	5.5%	15.1%	1.9%	9.6%	4.5%
Unemployed/seeking	1.1%	1.2%	0.8%	1.4%	1.9%	1.6%	2.1%
Not employed or seeking	0.8%	0.7%	0.8%	0.8%	1.0%	2.7%	1.9%
Other	0.7%	0.7%	0.6%	0.8%	1.0%	n/a	n/a

*Some survey respondents did not indicate employment status, so total percent does not equal 100.

Only a very small percentage of all the AACP survey respondents were unemployed and seeking work as of September 1996. The largest difference in employment status among pharmaceutical science disciplines is the percentage of graduates serving in a postdoctoral position. Medicinal chemistry and pharmacology Ph.D. graduates typically serve in at least one postdoctoral position, while pharmaceutics and social and administrative science graduates usually do not.

Employer Category: Table 4

EMPLOYER	ALL	MEDCHM	PCEU	PCOL	SADS	SDR-BIO	SDR-CHM
Business/Industry	51.9%	47.4%	69.7%	37.5%	20.4%	22.1%	55.2%
Pharmacy School	18.3%	15.1%	18.0%	12.9%	53.4%	n/a	n/a
Medical School	9.9%	11.7%	2.7%	22.4%	1.9%	n/a	n/a
U.S. Government	4.3%	4.4%	2.2%	8.1%	1.0%	8.2%	4.7%
Hospital	1.6%	1.9%	0.8%	2.0%	1.9%	n/a	n/a
Self	2.2%	2.2%	2.2%	1.1%	6.8%	3.2%	2.7%
Faculty*	23.6%	21.7%	16.7%	27.1%	60.2%	58.5%	33.1%

*This includes faculty positions at all institutions of higher education, including liberal arts and community colleges.

Almost all of those respondents who indicated employment in the business/industry category were employed in the pharmaceutical/biotechnology industry. There were large differences in the employer categories among the pharmaceutical science disciplines, with a large majority of pharmaceutics graduates employed in the pharmaceutical industry, while a majority of social and administrative sciences graduates are employed as faculty members by pharmacy colleges and schools. The relatively large percentage of medicinal chemistry and pharmacology graduates in medical school is primarily reflective of postdoctoral positions.

Primary Employment Activity: Table 5

ACTIVITY	ALL	MEDCHM	PCEU	PCOL	SADS	SDR-BIO	SDR-CHM
Teaching	12.0%	10.9%	9.3%	10.1%	39.8%	18.7%	16.0%
Basic Research	13.6%	19.9%	4.7%	26.6%	1.0%	27.6%	13.0%
Applied Research	31.2%	36.2%	33.2%	26.3%	23.3%	20.1%	27.4%
Development	10.1%	4.7%	19.9%	2.0%	1.9%	2.7%	9.8%
R&D Management	13.2%	9.9%	18.1%	11.2%	3.9%	n/a	n/a
Educ. Management	2.5%	2.1%	0.6%	2.8%	7.8%	n/a	n/a
Prof. Service	2.3%	2.4%	1.0%	3.4%	1.9%	10.4%	4.7%
Consulting	2.0%	1.0%	1.4%	2.8%	5.8%	n/a	n/a

The most common primary employment activity for medicinal chemistry and pharmaceutics was applied research. Teaching was the primary employment activity for social and administrative science graduates, and for pharmacology/toxicology, basic and applied research was essentially equal. A difference in employment activity among the disciplines was noted in development (equipment, processes, and products) and in the management of research and development. Pharmaceutics graduates often selected these two areas as their primary employment activity. The 1995 SDR survey did not define management in the same manner as the present survey, nor was consulting included as an employment activity in the 1995 SDR survey.

Secondary Employment Activity: Table 6

ACTIVITY	ALL	MEDCHM	PCEU	PCOL	SADS
Teaching	10.0%	9.2%	6.7%	13.7%	16.5%
Basic Research	11.9%	16.1%	9.9%	13.4%	3.9%
Applied Research	19.3%	15.4%	23.1%	15.1%	29.1%
Development	6.0%	6.2%	9.3%	2.5%	0%
R&D Management	13.1%	12.8%	15.5%	12.0%	6.8%
Education Management	0.7%	2.6%	1.4%	2.8%	6.8%
Writing, editing	10.0%	6.9%	11.2%	12.6%	6.8%
Consulting	2.3%	1.4%	1.4%	3.4%	5.8%

Applied research appeared as the most common secondary employment activity, with the exception of medicinal chemistry, where basic research was listed as the most common secondary activity. The appearance of technical writing as a very common secondary employment activity is of interest and affirms the need for good written communication skills development in graduate programs.

Registered Time-to-Degree (RTD)

Survey respondents provided the years spent enrolled as a full-time and part-time student between receiving their first degree (baccalaureate or professional) and their doctorate degree. They also provided the number of years spent in postdoctoral positions. Respondents were stratified into four groups of five-year periods of graduation, and one group of three years to ascertain whether there was any change in the average RTD over the survey period (Table 7). The median RTD for full- and part-time enrollment for the physical, life, and social sciences disciplines and the year the doctorate was granted are provided for comparison purposes with the present survey (Table 8).[2] The RTD was also examined over the same time periods for the individual pharmaceutical science disciplines (Table 9).

Average Registered Time-to-Degree for All Respondents: Table 7

GRADUATION YEARS	FULL-TIME (YR)	PART-TIME (YR)	TOTAL RTD (YR)	POSTDOCTORAL (YR)
1975-1979	4.91	0.46	5.32	1.04
1980-1984	5.28	0.35	5.61	1.24
1985-1989	5.63	0.53	6.14	1.17
1990-1994	5.75	0.39	6.12	1.26
1994-1996	5.83	0.38	6.19	0.65*

*Many of these graduates were still serving in postdoctoral positions.

[2] Henderson, PH, Clarke, JE., Reynolds, MA. 1996. *Summary Report 1995: Doctorate Recipients from United States Universities.* Washington, D.C.: National Academy Press.

Mean Registered Time-to-Degree for Selected Broad Fields: Table 8

GRADUATION YEAR	PHYSICAL SCIENCES (YR)	LIFE SCIENCES (YR)	SOCIAL SCIENCES (YR)
1975	5.7	5.7	5.8
1980	5.9	6.0	6.5
1985	6.1	6.4	7.2
1990	6.3	6.8	7.7
1995	6.9	7.0	7.5

Average Registered Time-to-Degree for the Pharmaceutical Science Disciplines: Table 9

GRADUATION YEARS	DISCIPLINE	FULL-TIME (YR)	PART-TIME (YR)	TOTAL RTD (YR)	POSTDOC (YR)
1975-1979	MEDCHM	5.23	0.52	5.67	1.47
	PCEU	4.90	0.47	5.37	0.41
	PCOL	4.69	0.22	4.82	1.72
	SADS	3.93	2.36	6.29	0.14
1980-1984	MEDCHM	5.24	0.35	5.59	1.83
	PCEU	5.21	0.37	5.52	0.50
	PCOL	5.47	0.13	5.60	1.82
	SADS	5.31	1.56	6.87	0.00
1985-1989	MEDCHM	5.66	0.63	6.27	2.00
	PCEU	5.82	0.43	6.25	0.43
	PCOL	5.37	0.52	5.87	2.06
	SADS	5.50	0.66	5.97	0.11
1990-1994	MEDCHM	5.97	0.23	6.19	2.13
	PCEU	5.83	0.37	6.19	0.44
	PCOL	5.66	0.30	5.94	2.09
	SADS	4.92	1.12	6.04	0.31
1994-1996	MEDCHM	5.90	0.19	6.07	0.88
	PCEU	5.99	0.16	6.14	0.49
	PCOL	5.50	0.99	6.46	0.88
	SADS	5.44	0.64	6.08	0.33

The RTD increased approximately one year for all the pharmaceutical science disciplines over the twenty-year period of the survey. The increase in the time required obtaining a Ph.D. degree is common among all disciplines, and in many disciplines is accompanied by an increase in the time spent in one or more postdoctoral fellowships. Explanations for this increase in the RTD include: 1) increasing complexity and quantity of knowledge required for expertise in a given field, 2) unrealistic expectations for the amount of work that can be completed in a dissertation, 3) inadequate guidance by advisers, 4) poor undergraduate preparation, and 5) postponement of graduation in the face of uncertain employment prospects.

Gender Differences

There was no significant difference (chi-square) in the distribution of male and females graduates among the various pharmaceutical science disciplines. The primary employment activity of males and female graduates was also similar with the exception of R&D management, where males chose it twice as often as females (15.7 vs. 7.4 percent). However, there were significant differences in the employment status and employer category between males and females (Tables 10 and 11).

Gender Differences in Employment Status: Table 10

EMPLOYMENT	MALE	FEMALE
Full-time	88.7%	77.0%
Part-time	0.7%	2.2%
Postdoctoral	8.0%	13.9%
Unemployed/seeking	0.5%	2.6%
Not employed or seeking	0.1%	2.4%
Other	0.6%	0.9%

Gender Differences in Employer Category: Table 11

EMPLOYER	MALE	FEMALE
Business/Industry	55.8%	43.0%
Pharmacy School	18.3%	18.3%
Medical School	8.9%	12.0%
U.S./StateGovernment	5.2%	4.3%
Hospital	1.6%	2.4%
Self	2.6%	2.1%
Foundations	0.7%	2.6%
Faculty	23.8%	23.3%

In most areas of employment activity, there was little or no difference between males and females (Table 5), with the exception of R&D Management, which males indicated as a primary activity at twice the rate as females (15.7 vs. 7.4 percent). Females did not choose the industry as an employer as frequently as males, which might account for some of this disparity. Female voluntary and involuntary unemployment, and part-time employment was also higher than that of males, although full-time employment was greater than 90 percent for both genders, when postdoctoral positions are added.

Source of Graduate Students

Respondents indicated the institutions where they received their college education, plus their undergraduate majors or professional degrees. This allowed examination of the source of graduate students in the different pharmaceutical science disciplines (Table 12).

Undergraduate major or professional degree: Table 12

MAJOR	MEDCHM	PCEU	PCOL	SADS
Biochemistry	8.0%	2.2%	3.4%	0.0%
Biology*	7.8%	3.8%	26.3%	Neg.
Chemistry‡	44.9%	10.9%	10.6%	Neg.
Pharmacy	30.5%	71.6%	38.4%	92.2%

*Includes zoology, wildlife biology, and biology/chemistry majors
‡Includes chemistry/biology and chemistry/other majors

Graduate students in the pharmaceutical sciences have varying academic backgrounds in addition to pharmacy. Medicinal chemistry/pharmacognosy graduates have primarily received an undergraduate major in chemistry or biochemistry, and over a quarter of pharmacology/toxicology graduates received their undergraduate education in biology or a related biological science. However, pharmacy graduates have traditionally provided the major source of graduate students in pharmaceutics, social and administrative pharmacy, and pharmacology/toxicology in graduate programs in colleges and schools of pharmacy. Increasingly, pharmacy graduates pursing a Ph.D. degree have come from non-U.S. pharmacy degree programs. Presently, over half the graduates in pharmaceutics with a previous pharmacy degree are non-U.S. citizens.

Conclusions

The respondents were a balanced sample of the 1975-1996 Ph.D. graduates from colleges and schools of pharmacy, based on gender and discipline distribution. The survey results confirmed that the unemployment rate of pharmaceutical science Ph.D. graduates is very low, even when compared to Ph.D. graduates in the biological and chemical sciences. The primary employer of pharmaceutical scientists is the pharmaceutical industry, but there is considerable variation among the different pharmaceutical science disciplines, with pharmaceutics and social and administrative sciences demonstrating almost a complete reversal of preference for industry and academia.

In its report, "Trends in the Early Careers of Life Scientists," the NRC's Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists concluded that the current life-science training enterprise is producing about 2.5 times the number of Ph.D.s needed to fill the jobs currently available in academia.[3] As a result of this conclusion, the NRC committee recommended constraining the growth of life sciences graduate education programs. The pharmaceutical sciences are a subset of the larger life sciences, but with the exception of the social and administrative sciences, the primary employer has been the pharmaceutical industry, excluding postdoctoral positions. At the present time, there does not appear to be oversupply of pharmaceutical scientists either willing or capable of working in this industry.

[3] Trends in the Early Careers of Life Scientists. National Research Council, Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists. National Academy Press, Washington, D.C., 1998.

The most common employment activity of the graduates, with the exception of social and administrative sciences, was either basic research or applied research and development. Thus, it appears that pharmaceutical science Ph.D. graduates are utilizing the knowledge and skills provided by their graduate programs and are not "underemployed." The two employment activities that appeared relatively frequently and are not typically addressed in graduate education programs were management and writing/editing skills.

The time required to complete a Ph.D. program has continued to increase across all disciplines, including the pharmaceutical sciences. This is a particularly disturbing phenomenon that has no one simple cause. The reasons may vary from faculty members who wish to maximize research results from competent senior graduate students, to graduate students who wish to maximize their research résumé before graduation. The COSEPUP report recommended that a solution to this problem would be to place the responsibility of a student's progress in the hands of the department rather than that of a single faculty member (advisor)[4]. This departmental supervisory committee, including the advisor, would determine if satisfactory progress is being made toward the degree, and also when enough work has been completed to award the degree.

Although the female respondents indicated a significantly higher rate of voluntary and involuntary unemployment and a higher rate of part-time employment, full-time employment of male and female respondents is still very high (96.7 vs. 90.9 percent) when postdoctoral positions are included as full-time employment. Although the percentage of males and females employed in a full-time academic position is almost identical, examination of the employing institutions revealed that a higher percentage of females hold non-pharmacy academic positions.

The future of graduate education in the pharmaceutical sciences will ultimately depend on the quality and quantity of students who decide to pursue the Ph.D. degree The vast majority of graduate students in pharmaceutics and social and administrative sciences for the past twenty years have undergraduate/professional degrees in pharmacy. Although the percentage of U.S. pharmacy students enrolled in graduate programs in the pharmaceutical sciences has decreased dramatically over the past twenty years, the absolute number of these students has not appreciably changed. The growth in the size of Ph.D. programs over these years has been primarily due to an influx of foreign students. The same is true for many of the other biomedical science disciplines, where 80 percent of the increase in the number of Ph.D. degrees granted in the ten-year period, 1987-1996, were to foreign nationals. If enrollment in the pharmaceutical sciences is to grow over the next ten years, it will be necessary for graduate programs to engage in more active recruitment, particularly of non-pharmacy students in pharmaceutics and social and administrative sciences.

[4] Reshaping the Graduate Education of Scientists and Engineers. National Research Council, Committee on Science, Engineering, and Public Policy (COSEPUP). National Academy Press, Washington, D.C., 1995.

Appendix 5: Commission Survey of Industrial Scientists
Results from 34 Respondents

1. Did you receive a degree from a U.S. school/college of pharmacy?
   yes--15 no--19

   If yes, what degree(s)?
   B.S.--6 Pharm.D.--0 M.S.--2 Ph.D.--12

2. Do you work with scientists who have received their Ph.D. degree in the pharmaceutical sciences from a U.S. school/college of pharmacy?
   yes--26 no--5 don't know--4

3. Does your company recruit Ph.D. graduates from U.S. schools/colleges of pharmacy?
   yes--25 no--3 don't know--4

   If no, please provide the reason(s):
   - We would if the candidate was suitable.
   - We're a small company and do little recruiting.

4. What are the most important qualities you seek when hiring for a scientific position, and how well do you think present Ph.D. programs are providing these qualities? Please rank these qualities from 1-10, and indicate how well recent Ph.D. graduates possess these qualities by placing an "x" in the appropriate box: a) very well, b) well, c) not very well, and d) not at all.

Rank		Total # (of a's, b's, c's, & d's)			
1	Specific scientific or technical expertise	a.--18	b.--15	c.--0	d.--0
7	Written communication skills	a.--1	b.--19	c.--14	d.--0
5	Oral communication skills	a.--1	b.--18	c.--14	d.--0
9	Strong management skills	a.--2	b.--1	c.--14	d.--17
4	Interpersonal skills	a.--2	b.--18	c.--13	d.--1
3	Ability to work as a team member	a.--4	b.--9	c.--19	d.--2
6	Broad range of scientific interest and expertise	a.--1	b.--8	c.--20	d.--4
8	Ability to change research directions	a.--2	b.--12	c.--18	d.--1
2	Ability to focus on required research outcomes	a.--4	b.--20	c.--9	d.--0
10	Other - please specify: problem-solving peer recognition (publications) energy level cgmp experience	a.--0	b.—2	c.--2	d.--0

5. The average registered time-to-degree between receipt of the baccalaureate degree and the Ph.D. degree has been steadily increasing and is now seven (7) years in the life sciences. Do you consider this:
   too long--26 about right--8

   If you believe the time-to-degree is too long, please explain your suggestions of possible solutions to shorten the required time:
   - Better advisor - student interactions to manage the research project. If project is not well formulated by a certain point (e.g., after two years of lab work), consider truncating training to end with master's degree.
   - The research problem should be designed to get the student out in four years.
   - Focus research projects around key skills with clear timelines for completion. Post-docs should be used for more extensive studies.
   - Too much coursework.
   - More focus on experimental work.
   - The purpose of a Ph.D. program is to learn how to do research, not to do research.
   - More focused Ph.D. research projects. Professors should not use Ph.D. students as "cheap labor."

- Not familiar with life science Ph.D. program - is it the project that requires this time? Ph.D.s should know how to conduct research, analyze results, develop conclusions - can projects be chosen to allow completion within five years?
- The student should be involved in research early on rather than wait for many semesters. Graduate courses are typically offered every other year which can increase the time to finish courses.
- In Britain BSC much shorter and specialize earlier - specialization earlier in program would allow to complete degrees more rapidly.
- More focused dissertation projects. Less abuse of the system by major professors.
- Cut back on much non-related course work during B.S./M.S. degrees.
- Limit time permitted and/or funded for professors so they emphasize graduation rather than retaining good students.
- One-year class work, three to four years lab work.
- Analysis to find out why seven years. Is it due to getting into the lab late? Address whether the reason is if necessary begin labwork early.
- Insist on defined research projects/proposals instead of open-ended collections of experiments for the Ph.D. thesis project.
- Thesis advisors should give students projects which are more likely to generate publishable data, leave riskier.
- Better definition of research problem; improved advisor-input; clear go/no-go decisions regarding the potential of research to evolve to a thesis.
- Internship programs with academia/industry.
- After a student passes written and oral preliminary exams a thesis committee should be formed for each doctoral candidate. The committee needs to be active to help a student and advisor find a reasonable path and end for their thesis research.
- May be a well defined plan before starting could help for better planning.
- If a student cannot earn a Ph.D. in four to six years it is either the student's fault or a professor's fault. Give them a master's after four years and say good-bye.

6. The average time spent in postdoctoral training is approaching four (4) years in most disciplines, except for pharmaceutics/drug delivery and pharmacy administration. Do you think postdoctoral training is required for success in research in the pharmaceutical industry?

   yes--20 no--14

   If yes, in your opinion, the optimal time in postdoctoral training should be 2.4 years on average.

7. A common criticism of contemporary Ph.D. programs is that they focus on narrowly defined research problems and thus students "learn more and more about less and less." Do you think today's Ph.D. graduates are too specialized in their research abilities and skills?

   yes--16 no--18

   If yes, what do you think should be done to increase the breadth of the Ph.D. degree program?

- I think narrow focus is important to make significant dent on research problem. That is, why a shorter Ph.D. (e.g., average of five years) plus a post-doc (average two years) in separate area is exceptional training.
- The Ph.D. thesis project should be narrow. However, breadth should be provided by rigorous core curriculum to provide breadth to do well in industry.
- More exposure to other research areas (departments).
- More interdisciplinary seminars, courses made available.
- No easy remedy.
- Post-doctoral training should broaden experience.
- Interdisciplinary research and a number of unrelated research projects.
- At the very least, set-up a rotation through the other laboratories in the graduate department prior to choice of major. The graduate department should set-up seminars so that students can present their work to other students.
- Ph.D. graduates should be encouraged to post-doc in a somewhat different discipline or field (i.e., molecular biologists post doc in biochemistry or protein chemistry.
- Greater emphasis on physiology and functional explications of research.

- Provide training related to professional career, team work, leadership, communication, etc.

Table 1.
FY 1997 NIH Extramural Awards (Direct + Indirect Funding)
Total Amount and Amount/#Ph.D. Faculty

Rank	Institution	Extramural Awards	Award per # PhD Faculty	Rank per # FTE PhD
1	UC-San Francisco	$12,684,700	$281,882	1
2	University of Utah	$9,429,318	$209,540	3
3	University of Arizona	$5,880,511	$172,956	4
4	Florida A & M	$4,657,798	$166,350	6
5	University of Kansas	$4,489,798	$132,053	9
6	University of Southern California	$4,023,824	$138,753	8
7	Rutgers University	$3,951,247	$112,893	10
8	University of Michigan	$3,712,096	$168,732	5
9	Purdue University	$3,670,105	$87,383	15
10	Texas Southern University	$3,495,397	$233,026	2
11	University of Washington	$3,421,234	$162,916	7
12	University of Wisconsin	$3,304,473	$106,596	11
13	University of Texas-Austin	$3,204,255	$97,099	12
14	University of Illinois-Chicago	$2,875,759	$61,186	19
15	University of Florida	$2,819,731	$90,959	14
16	Ohio State University	$2,321,591	$66,331	17
17	University of Kentucky	$1,948,440	$59,044	20
18	University of Colorado	$1,920,189	$91,438	13
19	University of Minnesota	$1,781,968	$65,999	18
20	University of Maryland-Baltimore	$1,564,063	$48,877	23
21	SUNY-Buffalo	$1,464,052	$73,203	16
22	University of North Carolina-CH	$1,456,271	$50,216	22
23	University of Mississippi	$1,440,053	$30,639	30
24	University of Connecticut	$957,041	$36,809	28
25	Washington State University	$934,618	$40,636	24
26	University of Georgia	$818,694	$26,409	36
27	University of Pittsburgh	$811,799	$40,590	25
28	Northeastern University	$775,902	$51,727	21
29	University of Iowa	$758,006	$29,154	32

30	Virginia Commonwealth University	$625,169	$23,154	37
31	University of New Mexico	$606,681	$37,918	27
32	University of Oklahoma	$508,704	$28,261	34
33	Wayne State University	$505,595	$36,114	29
34	University of Nebraska	$498,741	$38,365	26
35	Rhode Island University	$489,528	$21,284	40
36	University of Montana	$422,284	$30,163	31
37	Xavier University	$417,657	$19,888	41
38	University of Tennessee	$404,412	$26,961	35
39	Albany College of Pharmacy	$384,827	$22,637	38
40	Mercer University	$369,549	$28,427	33
41	University of Houston	$291,542	$12,148	45
42	University of Cincinnati	$275,173	$17,198	42
43	University of Puerto Rico	$270,587	$22,549	39
44	University of Toledo	$245,156	$10,215	46
45	University of Missouri-KC	$244,534	$13,585	43
46	Oregon State University	$186,781	$13,342	44
47	Philadelphia COP&S	$181,615	$10,090	47
48	Duquesne University	$163,710	$8,186	49
49	Northeast Louisiana University	$157,588	$6,304	51
50	Medical U of South Carolina	$144,631	$9,642	48
51	Idaho State University	$100,000	$5,882	53
52	Creighton University	$98,700	$6,169	52
53	West Virginia University	$90,902	$5,681	55
54	Drake University	$88,854	$6,347	50
55	St. John's University	$87,580	$3,128	56
56	Long Island University	$82,575	$2,580	57
57	North Dakota State University	$58,734	$5,873	54
58	Auburn University	$36,040	$2,253	58

Figure 1. Full-Time Faculty

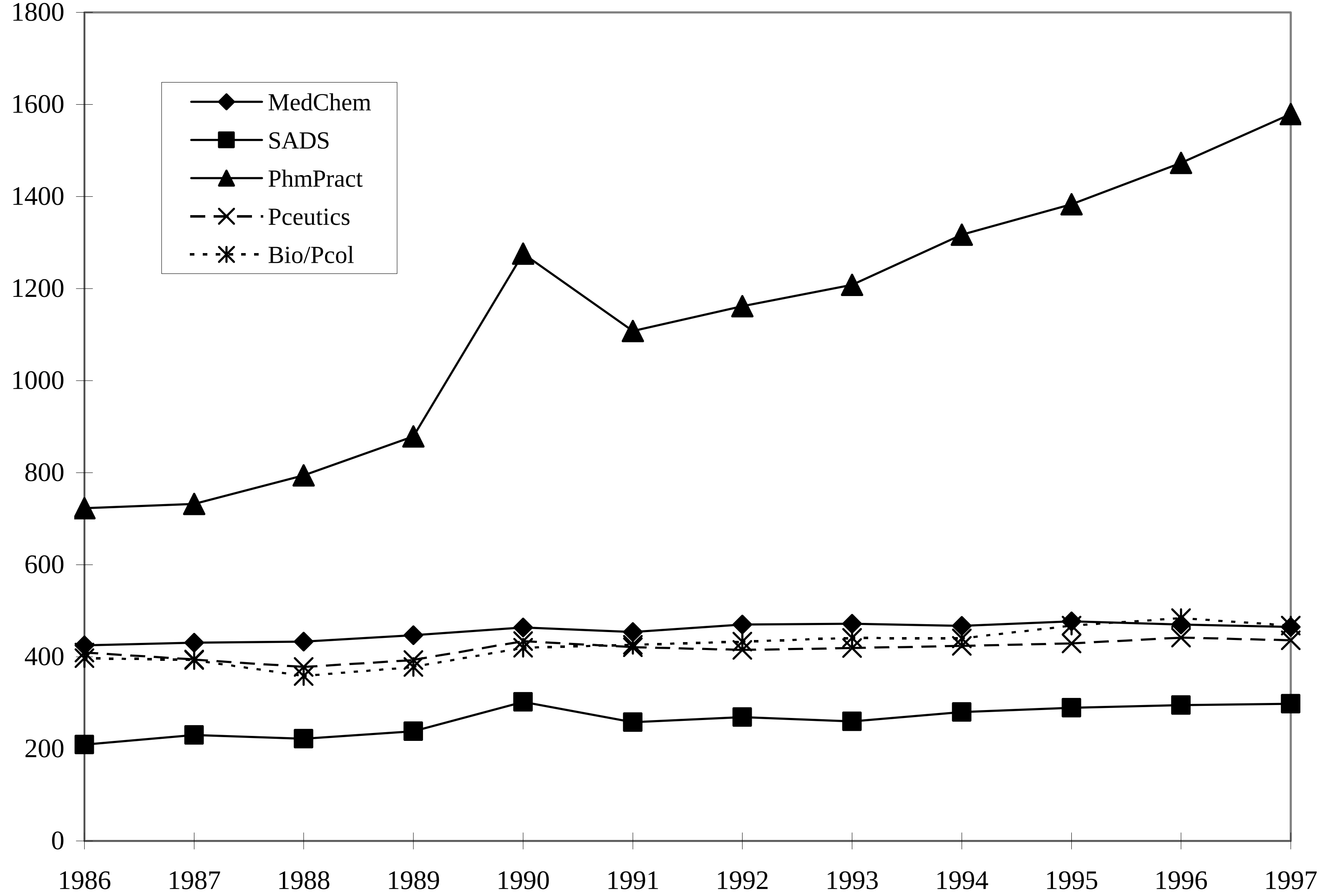


Figure 2. Total (Full- and Part-Time) Graduate Degree Enrollment

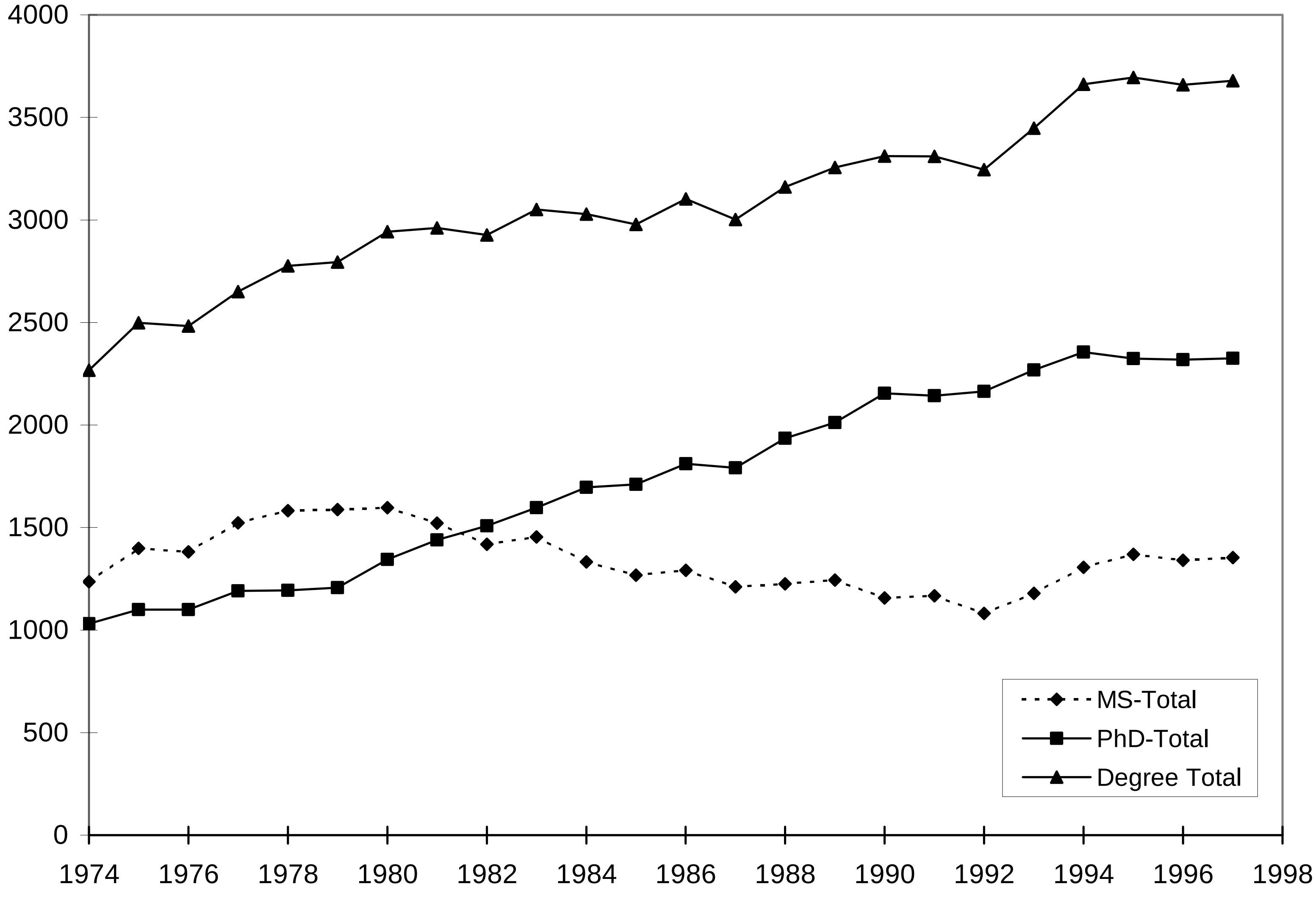


Figure 3. Full- and Part-Time Ph.D. Degree Enrollment

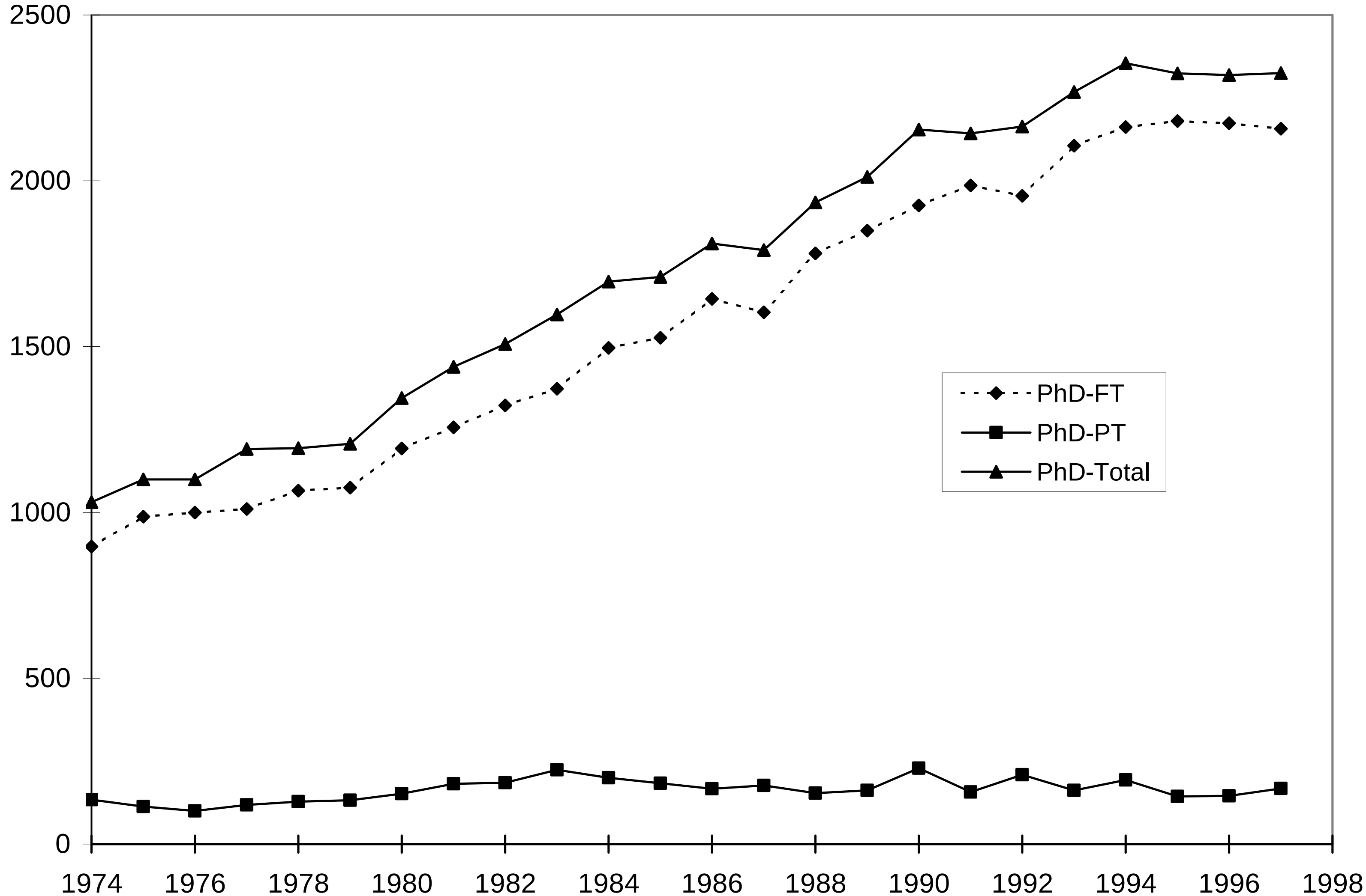


Figure 4. Full- and Part-Time Master's Degree Enrollment

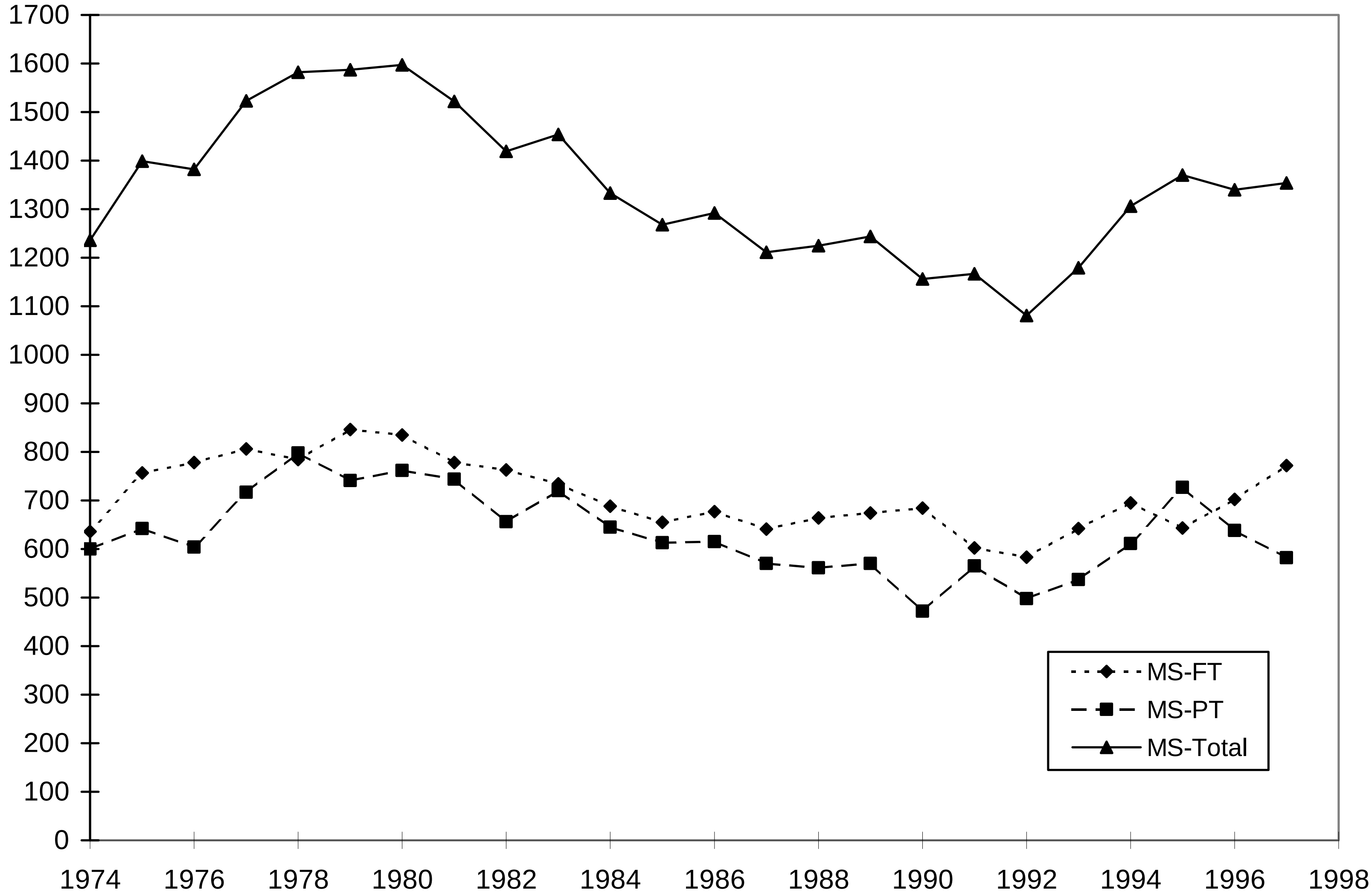


Figure 5. Full-Time Ph.D. Enrollment By Discipline

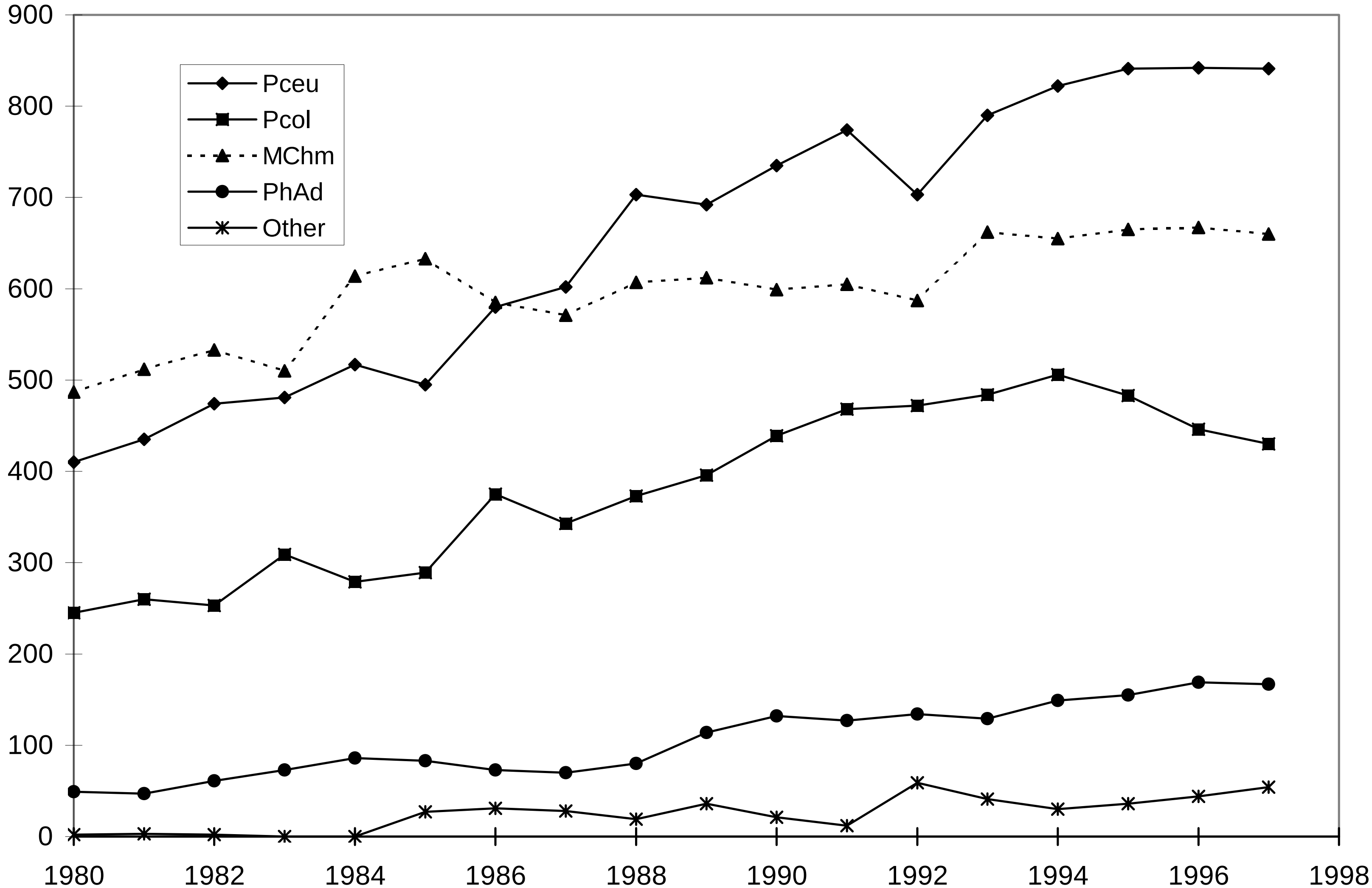


Figure 6. Total (Full-Time, Part-Time) Ph.D. Enrollment and Number of U.S. Pharmacy Graduates Enrolled

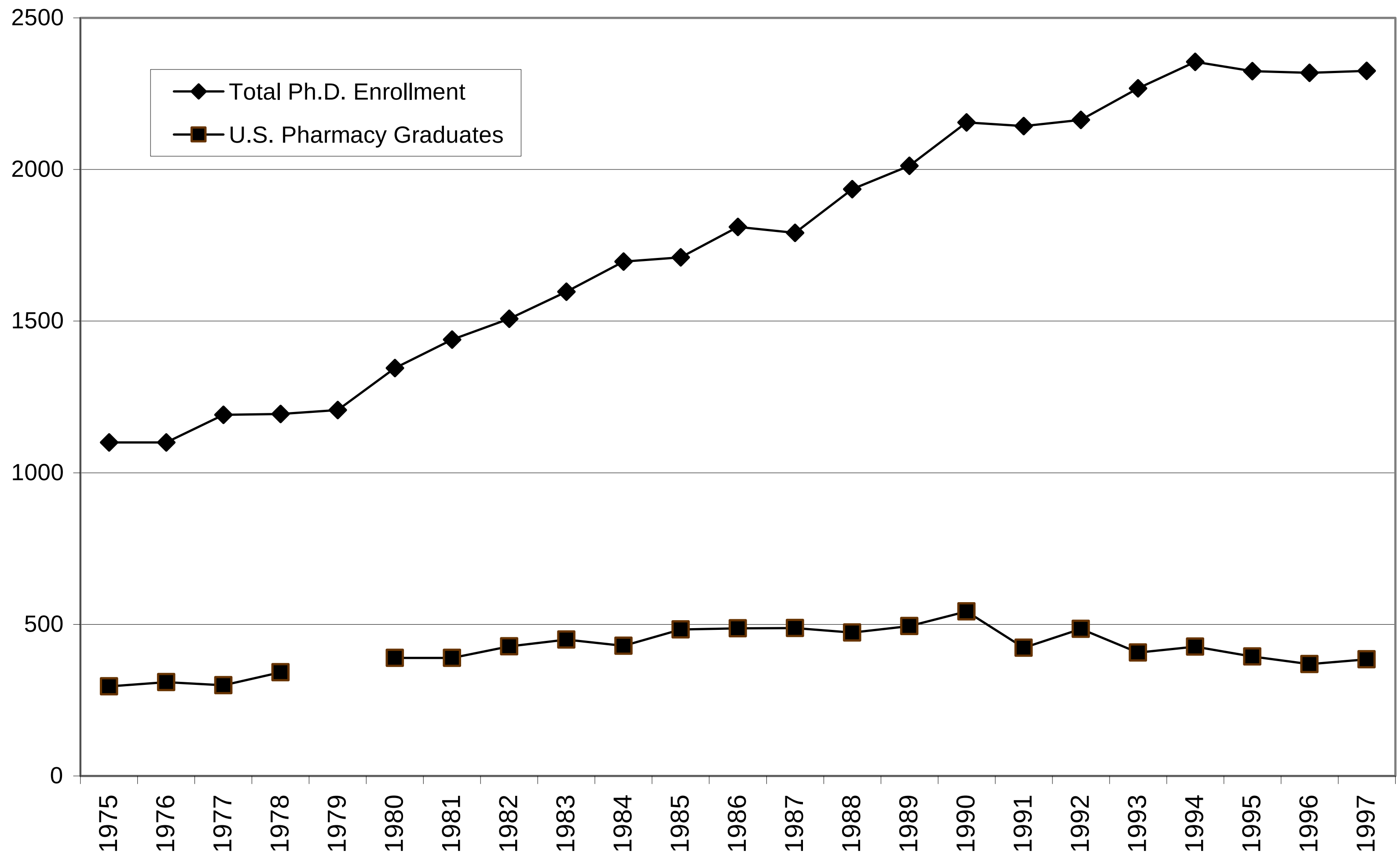


Figure 7. Pharmaceutical Sciences Ph.D. Degrees Awarded 1950-1997

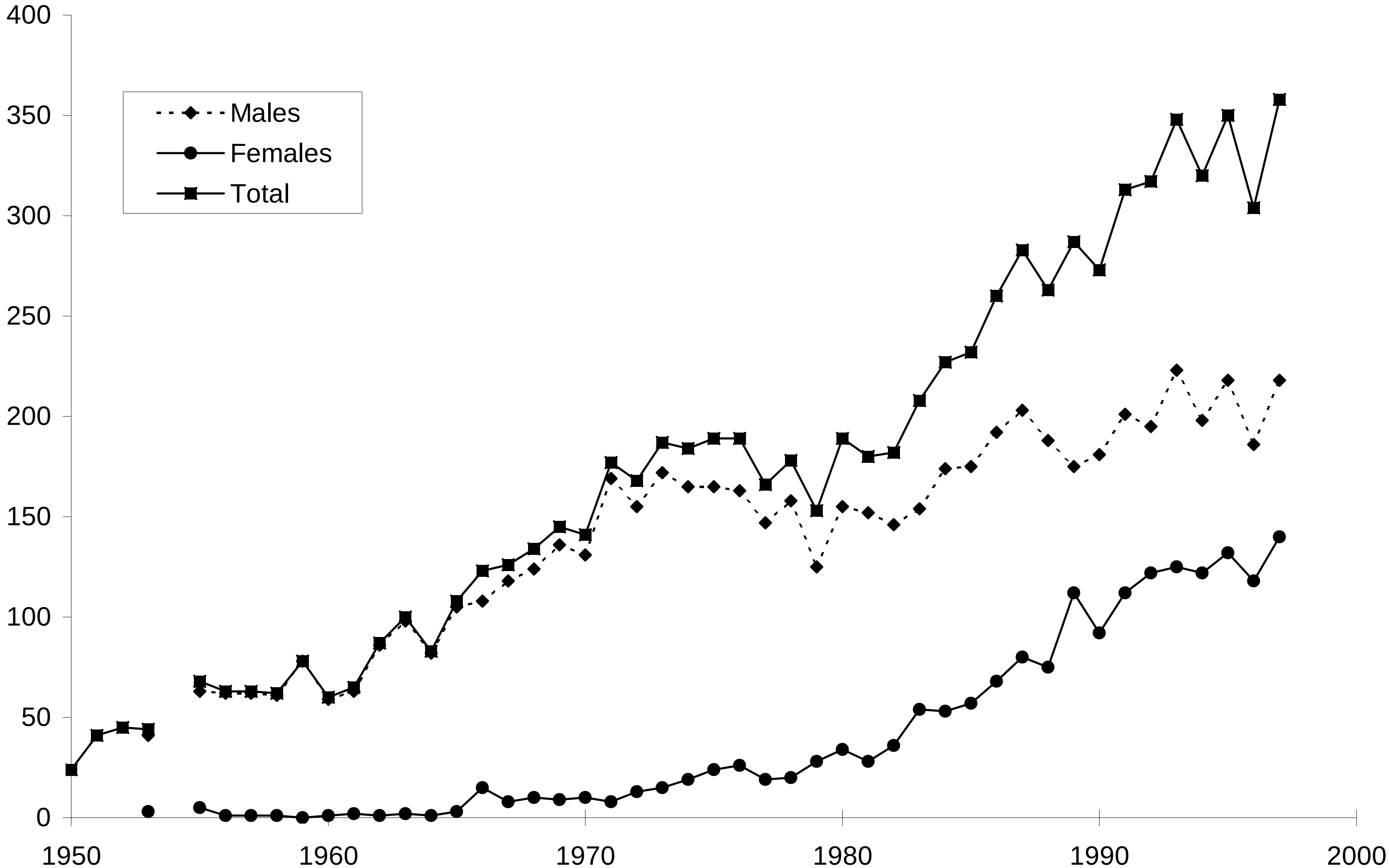
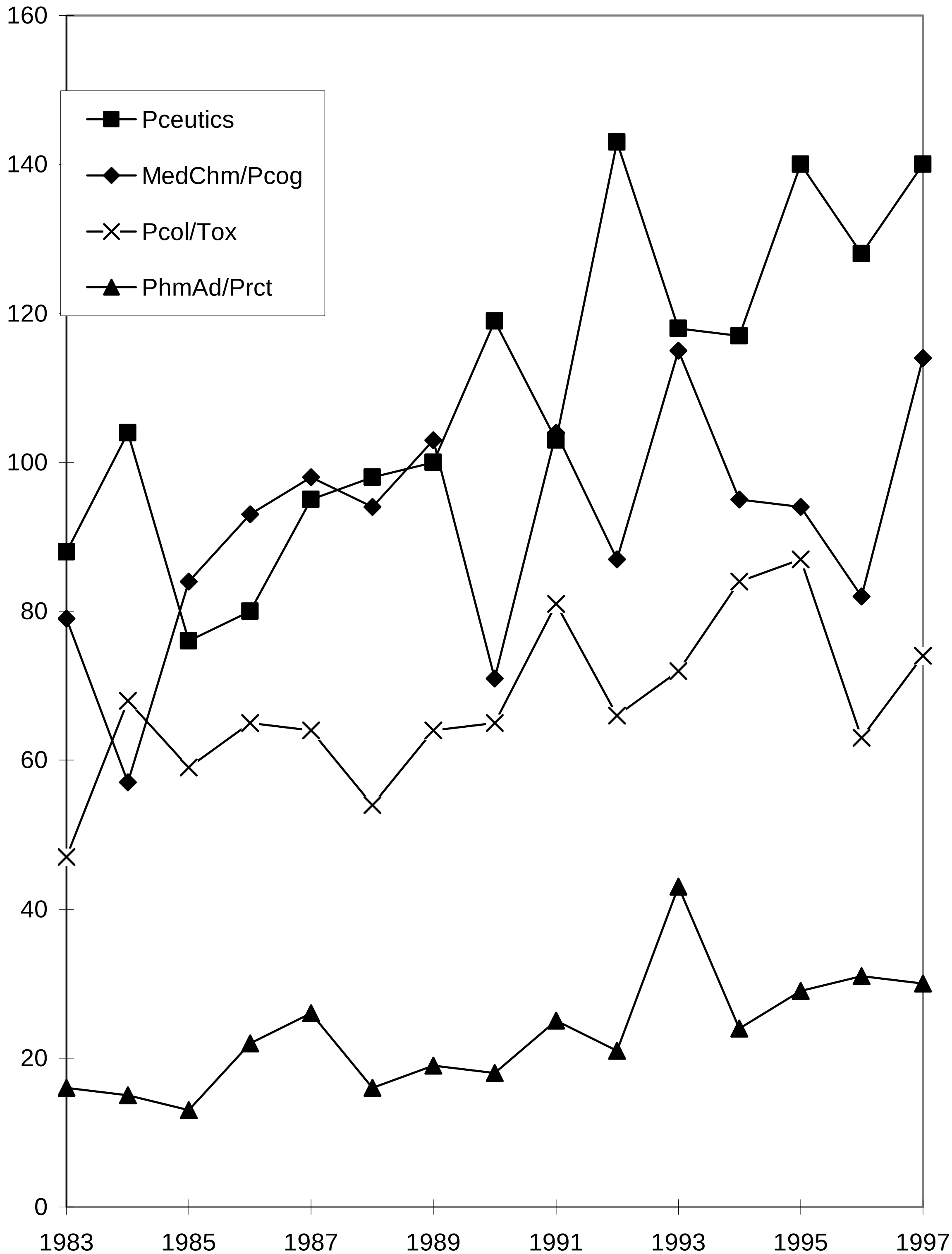


Figure 8. Pharmaceutical Science Discipline Ph.D.s



8. The COSEPUP report recommended internships in industrial, government, or non-academic settings as a way to develop students' abilities and skills to work in a non-academic environment. Recent NIH training grant guidelines also suggest that industrial internships be incorporated into the Ph.D. program. Do you agree that a non-academic internship would be a valuable experience for Ph.D. students?

   yes--28 no--6

   Does your company presently sponsor internship experiences for Ph.D. graduate students?

   yes--17 no--14

   Would you be willing to serve asa internship advisor for a Ph.D. student?

   yes--17 no--16

   If yes, the internship period should not be shorter than 4.2 months and not longer than 9.7 months on average.

9. Traditionally, Ph.D. education is viewed as a full-time endeavor with the initial years of the program primarily devoted to didactic study and the latter years associated almost exclusively with a research project most often defined by the graduate student's advisor. A non-traditional Ph.D. degree program for full-time employees in the pharmaceutical industry would need to be structured to allow the Ph.D. candidates to work on a research project that is cooperatively defined by the employer and the academic advisor and carried out at the work site.

   Do you have any full-time employees who are pursuing a Ph.D. degree in a non-traditional program?

   yes--13 no--21

   If no, would your company be supportive of providing such a program for selected employees?

   yes--12 no--10

   Would your company allow an employee to conduct Ph.D. program-related research on the premises?

   yes--22 no--7

10. Although, this survey focuses on the Ph.D. degree, there is an increasing number of persons in academia and industry who believe that there is a need for more masters degree graduates, rather than Ph.D. degree graduates. Do you believe themasters degree can be better utilized to educate and train individuals for your research and development activities than Ph.D. graduates?

    yes--15 no--19

Should schools develop specific applied science masters degree programs to meet the pharmaceutical industries needs?

yes--21 no--12

If yes, please specify the areas where these individuals are in high demand:

- Animal models
- Assay development
- Biology
- Biochemistry
- Bioassays
- Bioformatics
- Cell biology
- Chemistry
- Cloning
- Combinatorial chemistry
- Electrophysiology
- Molecular biology
- Pharmacokinetics
- Protein chemistry
- Organic chemistry
- Routine organic synthesis
- Scale-up
- Synthetic organic chemistry
- Systems physiology (animal studies)
- Tissue culture