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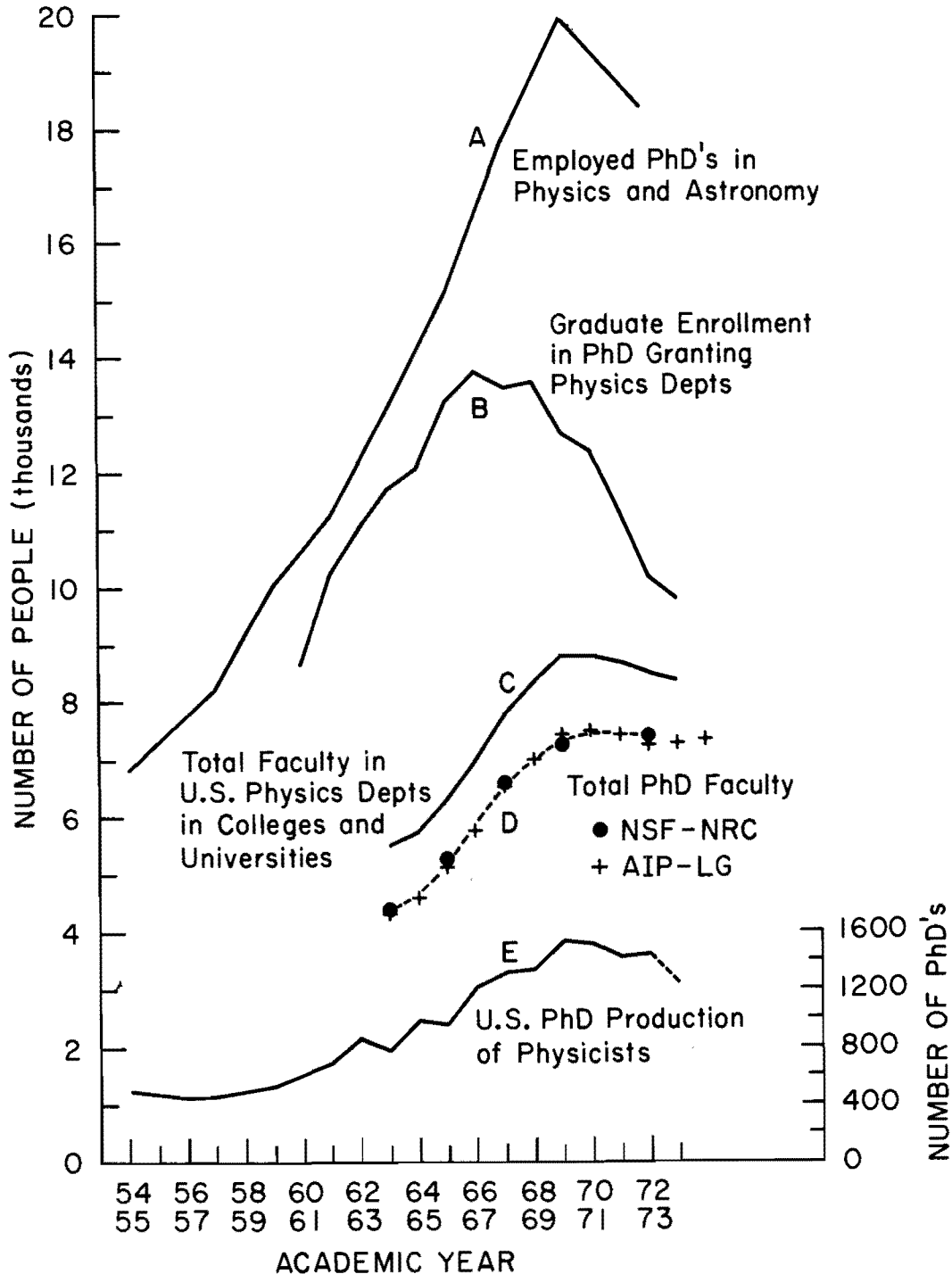


Fig. 1 From: Where Have All the Physicists Gone?

SUMMARY AND INFORMAL PROCEEDINGS

of the

CONFERENCE ON TRADITION AND CHANGE IN PHYSICS GRADUATE EDUCATION

Pennsylvania State University, 19-23 August, 1974

This special issue of the Newsletter of the Forum on Physics and Society is devoted to a summary and informal proceedings of the Conference on Tradition and Change in Physics Graduate Education. The Conference was sponsored by the Forum on Physics and Society and Committee on Education of the American Physical Society, and by the American Association of Physics Teachers. Much of the financial support for the Conference was provided by the Ford Motor Company Fund, Esso Research and Engineering Company, E.I. du Pont de Nemours and Company, and the Corning Glass Works. The Conference Organizing Committee was Ronald Geballe, University of Washington; Roland H. Good, Jr. (co-chairman), Pennsylvania State University; David W. Hafemeister, California Polytechnic University; Roger M. Herman, Pennsylvania State University; E. Leonard Jossem, Ohio State University; Sidney Millman, American Physical Society; Martin L. Perl (co-chairman), Stanford University; Brian B. Schwartz, National Magnet Laboratory; Stanley J. Shepherd, Pennsylvania State University; and N. Frank Six, University of Western Kentucky.

The first two papers by Lee Grodzins and by Martin L. Perl and Roland H. Good, Jr. provide a summary of the Conference. The remaining papers are two page condensations provided by the authors of longer papers given at the Conference. For the complete versions of these papers please write directly to the individual authors. The Abstracts of the Conference appear in the Bulletin of the American Physical Society, July, 1974, pages 763-777.

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WHERE HAVE ALL THE PHYSICISTS GONE?

Lee Grodzins

Massachusetts Institute of Technology

The broad outlines of the continuing crises in manpower in various parts of the physics community are drawn by the curves in the first figures. The number of Ph.D.'s employed in physics and astronomy has dropped sharply in recent years. The top curve, A, of Fig. 1, derived from the American Science Manpower (ASM) series and the 1973 National Research Council - National Science Foundation (NRC-NSF) survey, shows that the number of Ph.D.'s employed in physics was about the same in 1973 (16,500 to 17,500) as it was in 1968.^{1,2}

After a steady 7 to 8% per year growth in employment, the physics community fell into an unprecedented tailspin of job cutbacks and curtailed hiring.³ The effects of the cutbacks on the vulnerable were amplified by the nearly 50% without the job security of real or de facto tenure. And the curtailed hiring, which inevitably accompanied the rollback, created log jams in employment as the new Ph.D.s poured from the full pipelines of the graduate schools. About as many physicists got their degrees from 1969 thru 1973 as did from 1960 thru 1968, curve E of Fig. 1; or, to give a more illuminating comparator, during the 20 years from 1930 thru 1959. Ph.D. production has started downward and will continue to decline, reflecting the drop in graduate enrollments which began in 1966-67, curve B. By the late 1970s the yearly production of physics Ph.D.s from U.S. universities will be well below 1000 and more than 25% of these will be foreign citizens; but even this reduced number may not be completely absorbed into traditional physics occupations unless there are dramatic turnarounds in the markets of physics employment.

More than 6000 Ph.D. physicists are now employed outside traditional physics areas. An analysis of this exodus is a major theme of this paper. We will not chronicle, though we readily could, examples of aborted careers, lost ambitions, and under-employed talents, left in the wake of the massive changes of the past few years. We must not lose sight of them, but neither must we lose sight of the overwhelming success story that has been written

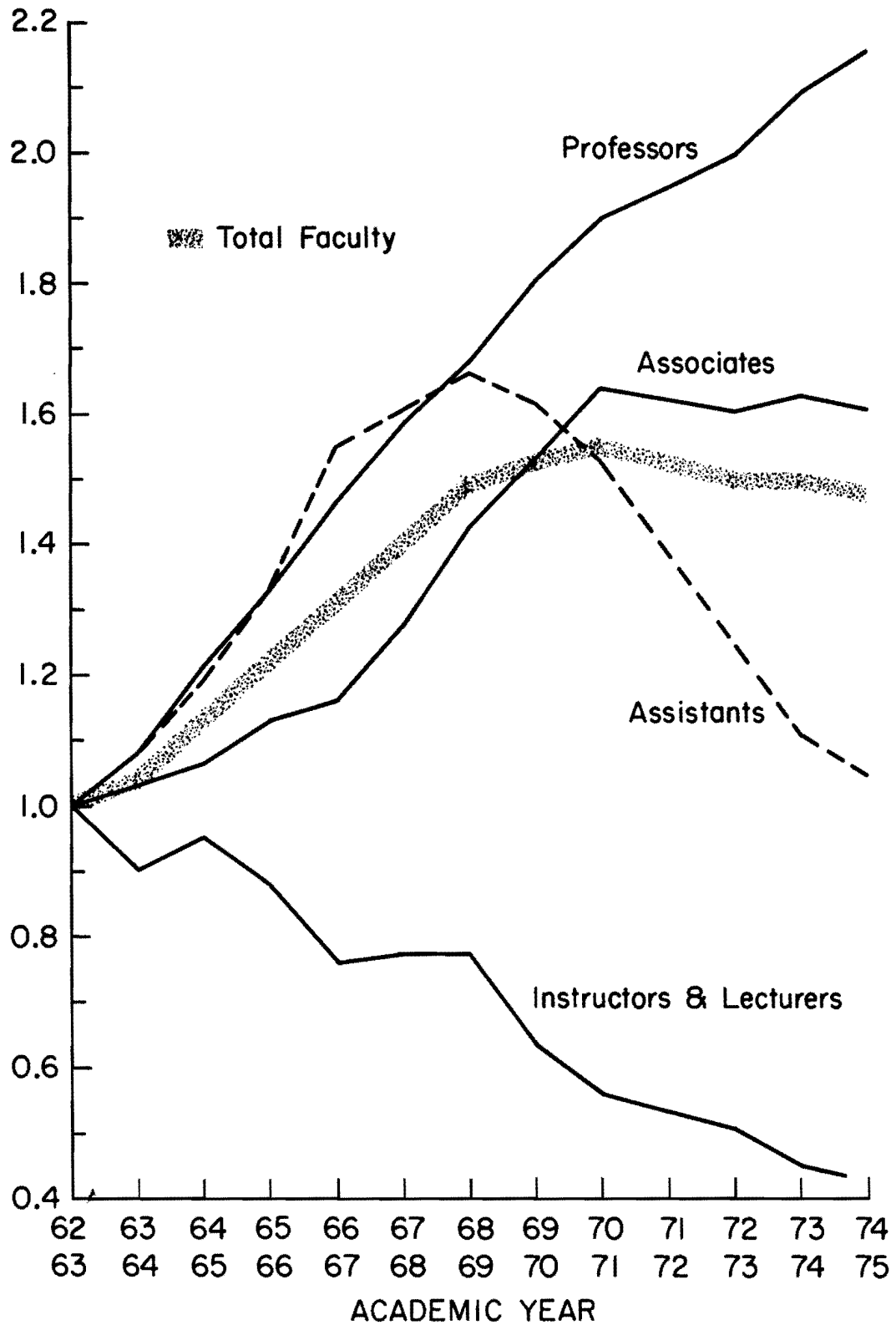


Fig. 2: Real Growth of Physics Plus Astronomy Faculties at PhD Granting Universities for 1962-63 to 1974-75. Data Matched by Successive Years; 1962-63 = 1.0

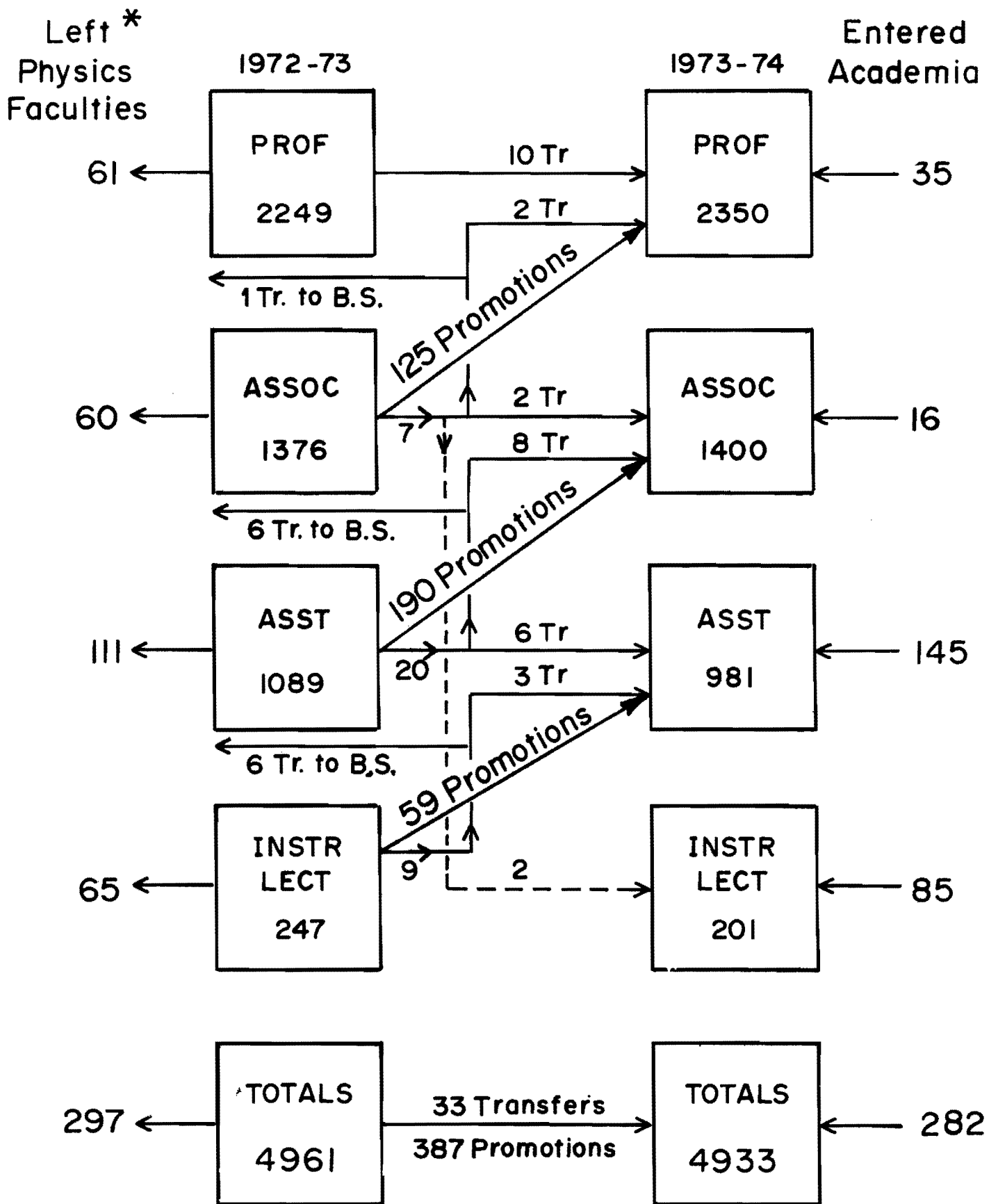
by the thousands of physicists who have found employment in sciences outside of physics. Each physicist has had to find a path thru largely uncharted border areas between scientific fields to obtain a position of intellectual equity with his original expectations. The overwhelming proportion of physicists who have faced that crisis have found such positions, attesting that the new breed "can do" just as well as the old guard ever did.

The number of faculty in the physics departments of the colleges and universities is almost the same in 1974-1975 (data added after talk) as it was in 1967-1968. Curve C of Fig. 1 derived from the AIP physics directories,⁴ shows that the peak was reached during the years 1969-1970. The number of Ph.D.s on the physics faculties has actually risen slightly since 1967-1968, Curve D of Fig. 1,⁵ since almost every new faculty member that was hired had a Ph.D., while many who left the faculties of colleges did not. Overall, then, the employment situation in academia has been similar -- if anything, more positive -- to that for the entire physics community. The facts of Curves C and D go to the very heart of the employment crises. Academia, which employs 50% of the physicists and where 60% of the basic research is done, has not grown. No amount of juggling can change the consequences for physicists.

The direct consequences, in academia itself, have been a decline in the number of new faculty hirings, an increase in the number of tenured professors in response to pressures for promotion of the most desired faculty, an aging faculty.

Figure 2 shows the relative growths, since 1962, in the various faculty ranks of the Ph.D. - granting physics and astronomy departments. The continuous increase in the number of professors, the plateaueing in the number of associate professors, the sharp decline in the ranks of assistant professors and instructors, are trends which are also observed in the growth patterns of the B.S. and the M.S. - granting institutions. (Government fundings of research is not a large factor in the growth of physics faculties.)

Figure 3, derived from a name-by-name matching of physics faculties,⁴ presents an input-output diagram of faculty changes in Ph.D. - granting departments between the



* Includes Retirement to Emeritus Rank

Fig. 3: Faculty Migration in Physics PhD Granting Departments (176 Schools)

academic year 1972-1973 and 1973-1974. Analogous diagrams for other years and other classes of physics departments will be described separately. The following are highlights from the wealth of information in these manpower flow charts.

1. There is a rapid turnover in the junior faculty ranks. From the flow charts can be deduced the mean length of time for the average faculty member to hold an instructorship, about 2 years; an assistant professorship, between 3 and 4 years; an associate professorship, between 7 and 8 years.

2. The number of new hirings has declined sharply. In the fall of 1968, between 1100 and 1200 new faculty were hired by the 700-odd physics departments of the country and most of these were hired for faculty growth. In the fall of 1973, only about half that number were hired and most were for the replacement of junior faculty. About one-fourth as many associate professors were hired from outside academia last year as were hired in 1968.

3. The probability of being promoted, defined as the ratio of the number promoted to the total number who left a particular faculty rank in a given year, has remained close to 60% since 1965 for the Ph.D. - granting departments, with wide variations depending on school and time. Contrary to folklore, the probability for promotion from assistant professor to professor is lower (near the 50% mark) for B.S.-granting department. It should be obvious that the average probabilities for promotions must decrease if faculty sizes do not grow.

4. One of the most disquieting changes revealed by the flow diagrams is in the whereabouts of those who were not promoted. When an assistant professor was not promoted in the mid-1960s, there was a good chance that he would find a faculty position in another school; for all the Ph.D. - granting departments the odds on this happening were about two out of five, for the ten most "prestigious" schools the odds were close to three out of four (i.e. three stayed in academia by being hired by another school, out of every four who left the ten "prestigious" departments at the assistant professor level). In the last years these odds have dropped to one in six for all schools and one in four for the "prestigious" schools.

WHERE HAVE ALL THE PHYSICISTS GONE?

So far we have shown that the physics community did not expand despite the pressure from new graduates to enlarge the physics population by at least 5% per year. By 1973 there should have been at least 23,000 physicists employed as physicists, instead there were around 17,000.

Very few of the 6,000 "displaced" Ph.D. physicists are unemployed. Most have found positions in the sciences though nearly 1,000 have left the sciences altogether.

Figure 4 presents many of the details of the story derived from the NRC-NSF 1973 survey data.⁶

A principal point to notice is that about 15% of the Ph.D.s employed in physics got their Ph.D.s in other fields; the largest groups from engineering and chemistry. Inward migration has dropped in recent years, especially from chemistry Ph.D.s, but competition continues from the engineering fields. Of those leaving traditional physics, 10% are in the biosciences, 6% are in the computer sciences, but the largest group, 45% are in various engineering fields.

Figure 4 is but one view of the situation. Others, not included, show that industry houses 38% of those leaving physics compared to 19% for staying in physics, basic research is a primary activity for only 13% of those leaving physics, compared to 28% for those who stay. The fine field of the Ph.D. makes little difference; 11% of all physicists have Ph.D.s in elementary particles, 10% of those leaving physics were elementary particle physicists. Other parameters, such as year of Ph.D., citizenship, and the entire subject of switching within the subfields of physics, will be dealt with elsewhere.

Other recent studies on the employment of physicists tell a similar story to that of the NRC-NSF survey.⁷ We prefer the latter, carried out by a disinterested party, because it is the only one which preserves unitarity by considering all scientists in a single survey. There are substantial differences in some of the specifics of the two surveys but we cannot emphasize too strongly how unimportant are the differences in the light of the undisputed stagnations of employment in academia (and, we might add, in government laboratories since 1968.⁸ That stagnation leads most observers -- including this one -- to

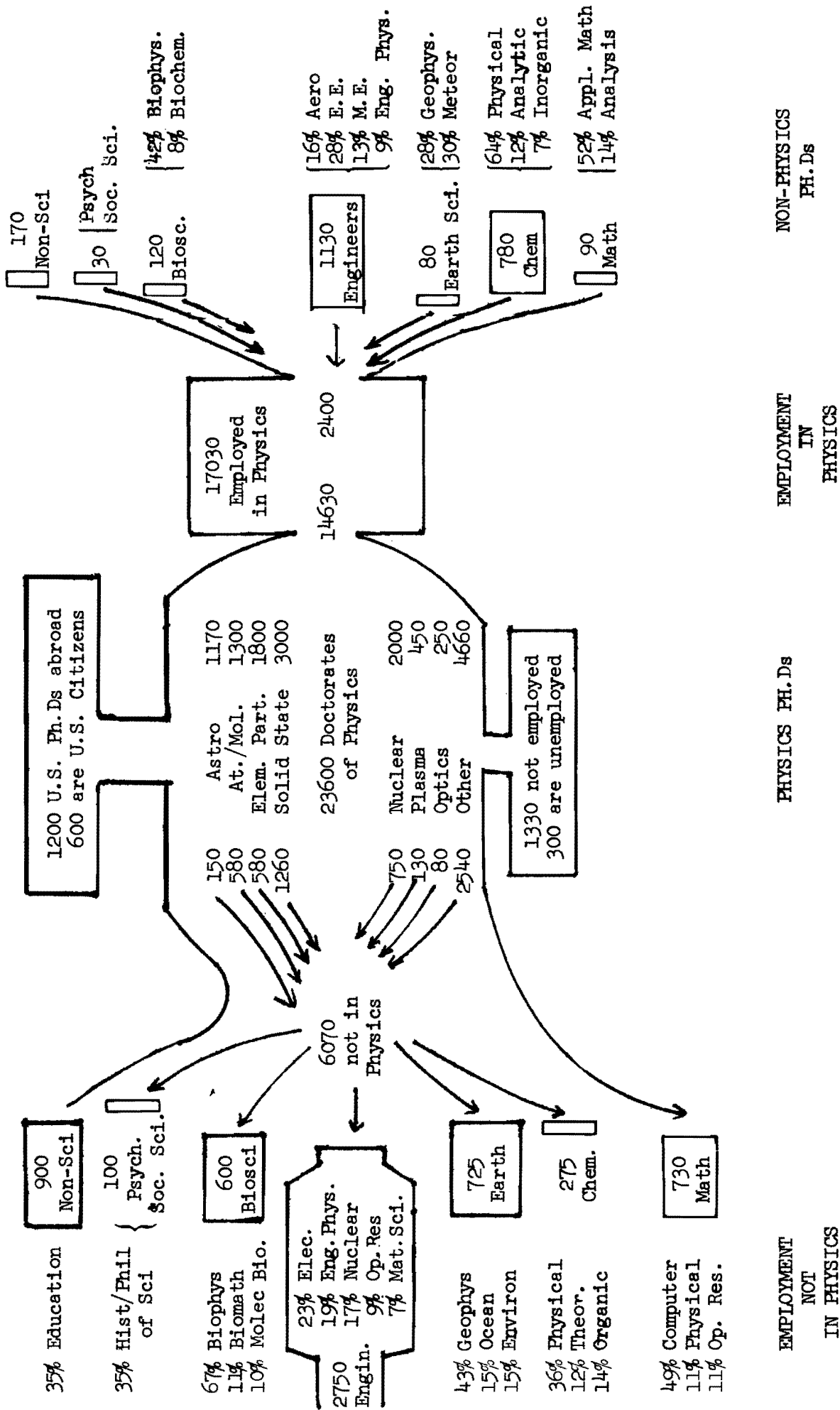


Fig. 4

conclude that sizable employment growth will be in applied areas, not in basic research; in industry, not in academia. If that conclusion is correct then we must consider changing the research training patterns of our Ph.D.s, for the present distribution of Ph.D. thesis subjects correlates neither with the distribution of employment in the applied physics sectors of physics, nor with the distribution of employment in industry. There has been little change in the distribution of Ph.D. thesis subjects during the last decade, and little evidence of forthcoming change. For some time to come, the research training of our new Ph.D.s will not match well with the opportunities for long-term employment.

I would like to thank Porter Cogishall for valuable insights and help, especially with field migrations. I would like to thank Dr. William Kelly of the National Research Council for complete cooperation in providing data from the National Research Council Survey of Doctoral Scientists in the U.S.

1. The American Institute of Physics (AIP) carried out an extensive survey of the physics community in 1973 with results which are in reasonable agreement with the 1973 NRC-NSF survey, a profile of which has been published by the National Academy of Sciences under the title "Doctoral Scientists and Engineers in the United States". The differences, in our view, are mainly definitional or interpretive. Thus, on the basis of an 85% response rate, the AIP reports (unpublished) that as of 1973 there were 18,300 Ph.D.s in physics; but about 1700 of these were employed in the subfields of biophysics (410), medical physics (400), chemical physics (470), and geophysics (460), all sub-fields which the NRC-NSF survey consider to be part of non-physics employment fields. A disagreement, however legitimate, over whether there were 16,500 or 17,100 or 18,300 Ph.D.s employed in physics in 1973 does not alter the real issue since the upper number is not significantly larger than the number of Ph.D.s, 17,600, employed in physics in 1968 (from the ASM, 1968; see Physics Review in Perspective, Vol. II Part C, National Academy of Sciences).

2. The disagreement described in Footnote 1 above points up a general caution against taking any number in this report too precisely. For bookkeeping purposes, we often retain a significance to the nearest person or tens of people, but in fact, almost every number has accumulated from many sources including statistical variability, response biases, differing interpretations of definitions of fields, of position or of activity -- especially when information comes from different sources. Consider, for example, that the AIP tabulations of the number of physics Ph.D.s awarded per year, derived from a census count made by the Ph.D. departments, has been consistently lower, by as much as 10% than the number of physics Ph.D.s awarded during the same fiscal years as tabulated by the Doctorate Record File (DRF) from their census of individual doctorates; the DRF totals for 1968 through 1973 are 5% higher (476 Ph.D.s in Physics) than the AIP number.

3. The Manpower Crisis in Physics, L. Grodzins. Bulletin of the American Physical Society, July, 1971.

4. Directory of Physics and Astronomy Faculties, issued yearly from 1962-1963. Published by the American Institute of Physics.
5. The solid circles on the dashed Curve D, Figure 1, are from the ASM series, assuming an 80% response rate, and, for 1973, from the NRC-NSF survey. The crosses are from the Directory of Physics and Astronomy taking into account the percentages of faculty that have Ph.D.s, known from refs. 3 and unpublished surveys of Grodzins and Viola. The agreement between the two completely independent approaches to the growth curve adds a great deal of weight to our confidence in the data basis for the present study.
6. Figure 4 is from an early draft of a monograph on career migration by Porter Cogishall, Lee Grodzins, and Elizabeth Maxfield, to be published.
7. The 1973 AIP survey, still unpublished, finds that about 6000 physicists, assuming an 85% survey response, were principally in the following fields (compare with Fig. 4): Bio-sciences, including biology, biophysics and medical physics, 903; non-sciences, 880; earth sciences, including environmental sciences, 700; math plus computers, 450; chemistry including chemical physics, 600; engineering, 770. The large discrepancy between the AIP survey, and the number of physicists in engineering given in Fig. 4, seems to be largely a matter of different definitions, i.e. the AIP lists 560 in electronics a group the NRC-NSF survey puts into engineering and the 500 NRC-NSF physicists in nuclear engineering are likely considered to be nuclear physicists in the AIP survey.

A recent survey of the whereabouts of nuclear physics Ph.D.s is also in reasonable accord with the main features of outward migration given in Fig. 4. That survey, as did the AIP, used a more restricted (chauvinistic?) view of field switching and concluded that only 17% of the nuclear Ph.D.s had left physics but, when we reclassify the reactor, and medical physicists, then we too conclude that 23%-25% of the nuclear physicists left traditional physics.
8. The 1974-1975 Directory of Physics Faculties shows that for the fifth year in a row, the sum of all physics department faculties did not grow, see Fig. 1; a 1% loss at the Ph.D.-granting departments was just compensated by a gain in the M.S.-granting departments. As a result, the migration of physicists to non-physics employment probably now stands at close to 7,500.

A Review of the Conference

Martin L. Perl and Roland H. Good, Jr.

The future of physics and of the physics community is strongly influenced by the present style and content of physics graduate education. In graduate school the young physicists acquire the basic knowledge, the experimental techniques, and the mathematical techniques involved in doing physics. And they learn and often accept the values, traditions and customs which govern the profession and set the standards for the physics community.

Of course other factors also influence the future of physics. That future depends upon the technical and scientific progress in the field. It depends upon the general economic and political health of the nation, upon the money allocated for the support of applied physics, basic physics and physics teaching. However the special property of physics graduate education, as emphasized by Geballe,* is that physics education is under the control of the physics community. To the extent that graduate education determines the future of our field and community, we can influence that future. It was with this thought in mind that the Conference on Tradition and Change in Physics Graduate Education was held in August at the Pennsylvania State University. The questions were: To what extent should there be changes in the graduate education process and to what extent should the traditions that have served so well in the past be maintained?

The Conference, proposed by the Forum on Physics and Society and sponsored by the Forum and the Committee on Education of the American Physical Society and by the American Association of Physics Teachers, was larger than expected. Over 150 attended although the original planning was for 50 or 60. In spite of the diversity of institutional affiliations, of physics interest, and of ages; a surprising consensus was reached on the nature and extent of the problems faced by physics community. Proposed solutions to these problems were extended in detail, fallacious or overoptimistic solutions were exposed, useful solutions were amplified. The Conference constructed a coherent picture of the state of physics graduate education; and developed a set of proposals for change in that education and in the physics community. Yet the picture and the proposals were not developed by a system of sub-committee, draft reports, and plenary ratifying sessions. They came about through a close and warm interaction between the conference participants, in the formal sessions, at the communal meals, on the picnics.

There were three areas of discussion at the Conference. First there is the data on the employment and economic situation of the physics community in the United States. This data is summarized in the preceding paper by Grodzin. The second area consists of proposed solutions; we try here to report the judgement of the physics community, as represented by

the Conference participants, on the value of the various proposals. Although there was consensus in the above two areas, in the third area, that of certain basic and important issues described in Section VI, there is no consensus. Social responsibility questions were also discussed to some extent at the Conference; but the economic questions were completely dominant, and this review is restricted to the economic problems.

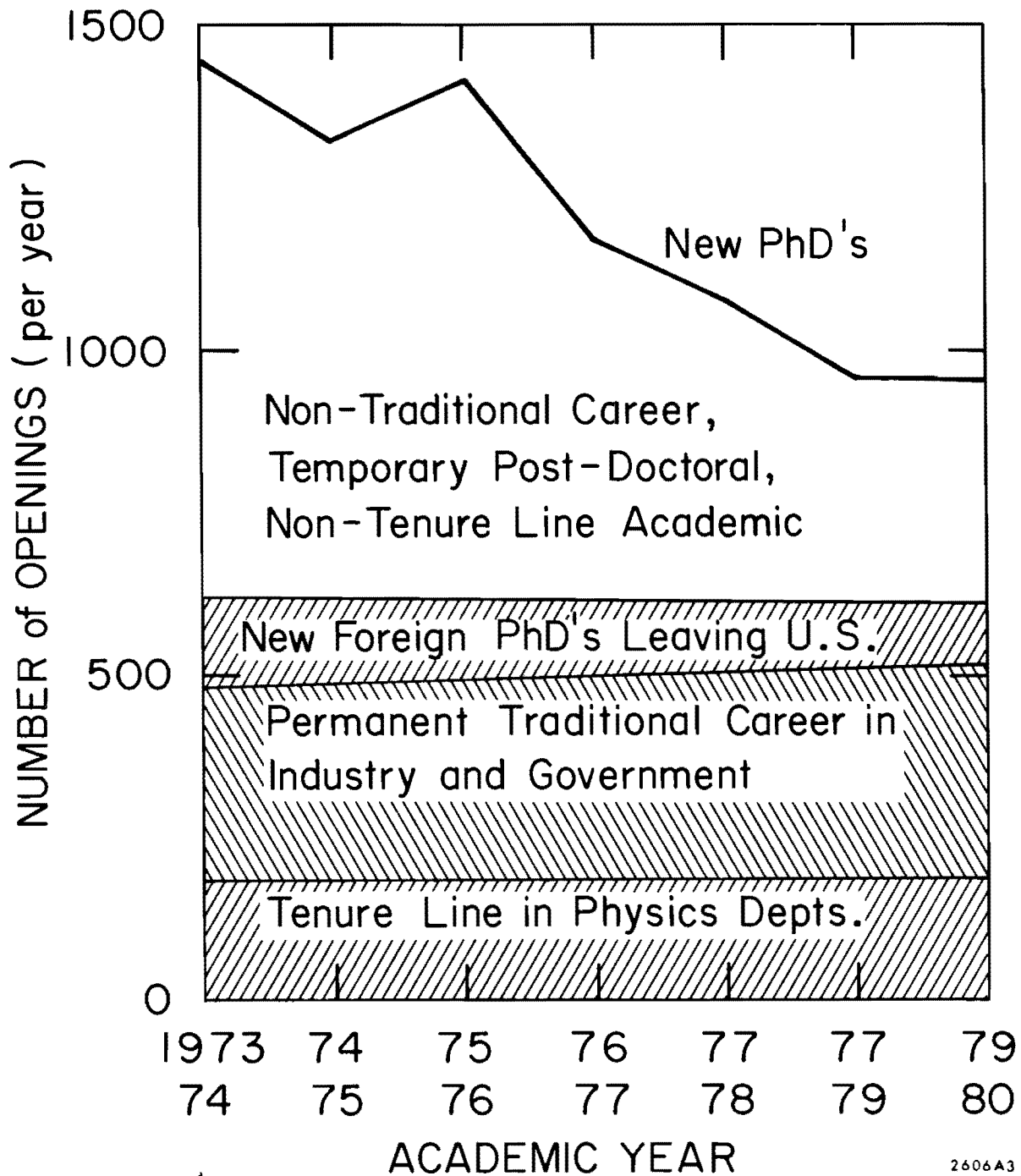
I. EMPLOYMENT AND CAREER PROBLEMS

A. The Young Ph.D. Physicist

The preceding paper by Grodzins provides a full picture of the employment and career problems faced by physicists. Our primary observation is the following: More than half of all new Ph.D. physicists will not be able to establish permanent traditional careers in physics. We mean by traditional the traditions accepted, reinforced and relied upon by the generations of physicists coming after the Second World War. For example, teaching physics in colleges and universities is a traditional career. Incidentally about 48% of all employed Ph.D. physicists in the United States are in college and university teaching, about 23% are in industry, and the remainder work primarily in government agencies or in federally supported laboratories. Also most employment of physicists in industry is considered traditional because it involves the traditional high-technology industries -- aerospace, nuclear and electronic. As emphasized by Rosenblum, these high-technology industries have matured and no longer have an increasing need for physicists.

We also use the term traditional to identify careers in solid state physics, nuclear physics, elementary particle physics, astronomy and astrophysics, atomic and molecular physics. On the other hand we classify as non-traditional, careers in geophysics, biophysics, medical physics, environmental physics, public interest physics, engineering, chemistry, computing, mathematics. We do not mean that in the past physicists never went into these non-traditional fields; we only mean that traditionally most physicists did not go into these fields.

But let us be more quantitative. Using the data of Ellis,¹ the work of Grodzins² and Hartman, and the basic paper of Porter, et al.³ we have the following basic numbers: There are about 20,000 employed Ph.D. physicists in the United States. If there is no growth in an area, the annual rate of job openings which can lead to a permanent career in that area is 2.2%; 1.2% for death and retirement -- we are a young community -- and 1.0% to replace those who leave the area voluntarily. Assuming no growth in higher education and a, possibly optimistic, 2% per year growth in industry and government employment, the projected number of job openings leading to permanent careers in traditional fields is about 500 per year, Fig. 1. Also shown in Fig. 1 are the number of new physics Ph.D.'s awarded per year in the United States in 1973; and the projected rate for the next five years. Our projection is based on the first-year graduate student classes of the past few years.¹



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Fig. 1 Projected number of new physics PhD's awarded per year, and physics career openings per year for the United States. The new PhD projections are based on assuming 0.44 of first year graduate students in PhD granting institutions will obtain their PhD. This fraction is lower than the 1960-1970 average. Permanent traditional career openings in industry and government assume a 2% per year growth rate in addition to the 2.2% per year retirement and death rate. No physics department faculty growth is assumed. The post-doctoral and non-tenure line openings provide immediate employment; but, of course, they do not provide permanent careers.

It is clear from Fig. 1 that for the foreseeable future a majority of new Ph.D. physicists will have to establish permanent careers outside the traditional areas of physics. We observe that the existence of several thousand temporary post-doctoral research positions and academic positions not in tenure lines does not change this conclusion. According to Merzbacher and to Grodzins about 500 of these positions become vacant each year, providing temporary employment for that many new Ph.D.'s. But most of these positions are in the traditional fields, and unless they are converted to permanent positions they do not provide permanent traditional careers. Thus the problem faced by the young Ph.D. physicist is not a temporary employment problem; it is the problem of building a permanent career using his physics graduate education.

B. The Older Physicist

The employment problems of the older physicist were only discussed obliquely at the Conference. While the unemployment rate is relatively small, being at the few percent level,³ there is clearly increased concern about career security. Questions about seniority, unionization, tenure arose on several occasions, but the Conference was not prepared with the basic numbers or the experts to examine these issues.

C. Origins of the Permanent Career Problem

The origins of the permanent career problem are two-fold. First, as discussed by Gruner, the age distribution of the U.S. population will not support further growth in the facilities for physics education in the U.S. The high birth rate in the 1940's and 1950's and the "democratization of higher education" led to the growth. The reduced birth rate and a saturation of that democratization ended the growth.

The other origin of the problem, applying especially to physics but shared by all sciences and engineering, was the rapid post-war growth of high-technology industry. Of the industries using Ph.D. physicists; aerospace is in decline, and the electronics and nuclear industries have matured. The latter industries often employ new Ph.D. engineers rather than physicists. And, as pointed out by Rosenblum, there is no new high-technology industry on the horizon.

None of this is new. We have had the early warnings of Cartter,⁴ and the later but still pessimistic⁵ analyses of Wolfe and Kidd,⁶ of Moses,⁷ and of Aaron et al.⁸ The essentially new information that we have is that no massive increase in federal support for physics has occurred or will occur in the next few years. In particular, neither the environmental crisis nor the energy crisis will by themselves provide hundreds of new jobs each year for Ph.D. physicists. These crises are not the equivalent of the launching of Sputnik.

II. THE SEARCH FOR SOLUTIONS IN TRADITIONAL FIELDS

A. Applied Physics in Industry and Government

An obvious question is whether the total number of traditional careers in applied physics or management in industry and government can be increased. Basic discussions of industrial prospects were provided by Loucks, Moss and Loebner; of federal prospects were provided by McLucas and Craig. There are opportunities for the properly trained and motivated physicist -- we shall get to the meaning of those phrases in the next paragraph -- but no substantial growth is expected. For illustration in Fig. 1 we use 2%. Much of the discussion of how to increase employment in applied physics, and even of how to maintain that employment in the face of competition from Ph.D. engineers hinged upon a generalist versus specialist concept. And we turn next to that concept.

B. Generalist Versus Specialist and The Matching Problem

The Conference returned several times to a study of the desirability of being a generalist when it comes to doing applied physics. Let's first define the term: a generalist-physicist is prepared to work in several fields, to do product development as well as research, even to do marketing. The converse is a specialist-physicist prepared only to do research in a single field.

At first this sounds like a good concept and it seems desirable that schools should attempt to produce generalists. However extensive discussion of how to train generalists showed that there was a good deal of vagueness in the generalist versus specialist concept. The ideal young generalist would seem to be a new Ph.D. who has done a one-person experimental thesis involving everything from vacuum systems and machining, to integrated circuits and computer programming. However a student who did a mathematical thesis in a very restricted field might also turn out to be a generalist, if once in applied physics he learned quickly, was flexible and creative, and was deeply interested in the special problems of his company or laboratory. Thus to some extent the generalist versus specialist concept seems to be a matter of attitudes -- always a murky subject.

If industry and government are not employing as many applied physicists as they might because of attitudes -- whose attitudes are wrong? The first snap judgements at the Conference seemed to be that the attitude of the new Ph.D.'s was wrong; the new Ph.D.'s were too inflexible, too interested in basic research, too determined to make careers out of their thesis subjects. However a remarkable property of the Conference was its high degree of self-examination. Further discussion of attitudes showed that the new Ph.D. was often very flexible, that he often took the lead in looking for ways to use his physics in applied work, that he often led the way into non-traditional fields.

The final judgement of the Conference was that attitude problems are closely tied to the hierarchy of values of the physics community. In this value hierarchy, pure

research leading to fundamental discoveries is held in highest esteem, with theory honored more than experiment on the average. Interdisciplinary work, applied science, and engineering appear much lower in the hierarchy. If new Ph.D.'s are to be encouraged to go into the latter fields, the hierarchy of values must be modified. And it is primarily the physics faculties -- the transmitters of physics tradition and values who must carry out this modification. This can only happen if there is a change in the attitudes and values of the faculty.

The generalist versus specialist problem overlaps with what came to be called at the Conference -- the matching problem. As introduced by Widgoff, the matching problem is that today's job seeker often finds a potential employer requiring one specialty, the job seeker having been trained in another specialty. In the rosy years, the matching problem was not apparent; job seekers had many offers, and employers could afford to spend several years retraining scientists into the desired specialties.

On a deeper level the matching problem results from a substantial difference between the physics research areas which predominate in Ph.D. thesis and those which predominate in industry. For example in industry, electromagnetics, acoustics, optics, fluids and plasmas are important fields of physics research; but these areas are proportionally much less important in university based research. Partial solutions to the matching problem were considered by Merzbacher who discussed the placement services of the American Institute of Physics; and by Millman who discussed the Visiting Physicists Program of the American Physical Society.

C. Teaching in Non-Ph.D. Granting Institutions

In the past few years there has been hope that substantial opportunities would be found for physics teaching careers in non-Ph.D. granting institutions, four-year colleges, junior colleges and high schools. Using the data and exploratory work of Hafemeister, Kahn and Hansen, the Conference found that such opportunities were selective rather than substantial. As emphasized by Hafemeister the new career opportunities in these institutes are for physicists who know and can teach oceanography, atmospheric physics, biophysics geophysics, fluid mechanics...the non-traditional fields. There are also teaching career opportunities in junior colleges and high schools. But a Ph.D. will often be too expensive for the school district. Physicists heading for those careers might better stop at the bachelor, master or doctor of arts level.

III. THE SEARCH FOR SOLUTIONS IN NON-TRADITIONAL FIELDS

There is no systematic way to classify the permanent opportunities in non-traditional fields. The opportunities are spread over many areas, some not even on the boundaries of physics. The movement into these fields has been incoherent, even random. Young physicists are going into these fields out of necessity; older physicists are going perhaps

because of boredom with a traditional field. An important factor has been an increasing awareness of social responsibility; of the need for physicists to work on environmental, health and technological assessment problems. We shall simply report a few examples and make a few remarks:

Biophysics and Medical Physics. Lapidus, a particle theorist who has gone into biophysics pointed out that less than 25% of the members of the Biophysical Society are physicists! Yet the basic training that a physicist receives in mathematics and in instrumentation must give him some advantages in doing biophysics.

Legislative Aides and Technological Assessment. At both federal⁹ and state¹⁰ levels there is a slowly but steadily increasing demand for physicists to aid legislators and legislative committees with technological public policy decisions. Cooper, one of the first Congressional Science Fellows of the American Physical Society, described such positions.

Public Interest Physics. Careers in technological public policy assessment and advice are but one kind of career in the potentially vast field of public interest physics. The field was recently reviewed by Perl et al.¹¹ and by Sullivan.¹²

Other Fields. On the principle of a picture being worth 10,000 words, Fig. 4 of Grodzins paper shows how 6,070 physicists have found careers in non-traditional fields.

IV. GRADUATE PHYSICS PROGRAMS AND ECONOMIC CONSTRAINTS

The many physics department chairmen and representatives at the Conference and a panel of departmental chairmen and representatives provided a full picture of the ways in which the departments have responded to the employment problems.

Graduate Enrollment. Compared to the 1967 peak, most departments now find themselves with smaller first-year graduate classes. The reductions are due to deliberate action by departments, to less student interest, and to decreased financial support for graduate students. The last two factors seem to have been the most important.

Core Curriculum. A core graduate curriculum now consists of quantum mechanics, advanced electricity and magnetism, and some mathematical physics. Perhaps advanced classical mechanics, and/or statistical mechanics has been retained. But the core has been pruned.

Applied and Interdisciplinary Courses. The pruning has permitted the addition of more courses in applied physics, environmental problems, science and society, biophysics, energy...There are problems however. Financial and pedagogical considerations demand some minimum number of students in a course -- somewhere between 5 and 10. With smaller enrollments it is difficult for a department to add non-traditional courses. Students like to take special courses related to their doctoral research topic. Hence special courses not associated with available research areas often fail for lack of students.

Foreign Students. About 20% of physics graduate students are from abroad, hence foreign students continue to form a substantial portion of our graduate student community.

Moravcsik discussed the special needs of students from the less developed countries.

V. PROPOSED SOLUTIONS

The Conference made no formal recommendations. Yet a consensus developed on the value of quite a few proposed partial solutions, which we report here. Few of these proposals are new -- some have appeared in the "Bromley Report,"¹³ others were recommended by the 1971 Battelle Memorial Institute symposium, The Education of Physicists.¹⁴ None of these proposed measures provide a complete solution of the economic problems. We may never see anything like those good old days again. The proposals are however practical suggestions which tend to provide some help during difficult times. We emphasize that these are not resolutions adopted in a formal way at the Conference. They are ideas that were fully discussed and that, in our opinion, had the support of the meeting.

A. Graduate Enrollment: There should be no increase in physics graduate enrollment in the foreseeable future. We have no present knowledge of the capacity of non-traditional fields to absorb physicists 5 or 10 years from now. And it is these fields which must already provide 500 new permanent careers each year. The American educational machine has a very quick response, and a sudden need for physicists, if it should develop, could be filled in 4 or 5 years.

As emphasized by Schwartz, the tragedy of the commons¹⁵ concept applies and provides valuable understanding here. Any single physics department or physics specialty can benefit itself by increasing the number of graduate students it trains. But if all or even many do this, the community of physics suffers.

B. Annual Manpower Reports: Physics manpower reports with projections of the type made in this article should be issued annually. Every physics department should have a faculty member expert in the manpower statistics and projections, so that the student has an immediate source of information.

C. Program Variations: Physics departments should continue to experiment with different variations on the traditional graduate program. Economic constraints prevent a single department from trying out too many different variations.

D. Faculty Attitude: The attitude of physics faculties toward careers in applied physics, engineering type physics, and public interest physics should change toward a greater acceptance of these careers. They should be accepted as equal to the traditional careers in the hierarchy of values of the physics community. A change in the reward structure of physics to reinforce the change in attitude should be considered.

E. Applied Physics: Physics departments should establish ties with applied research laboratories in industry, government and other institutions. These ties may influence the selection of research areas at the university departments, may lead to greater awareness by the faculty of emerging technologies, and bring about a greater involvement by faculty and students in cross-disciplinary contacts.

F. Non-traditional Fields: It should be made clear to each student early in graduate school that there is at least a 50% probability that he will have to build a permanent career in a non-traditional field of physics or in a field completely out of physics. The student should design his graduate program accordingly.

G. Career Mobility Among Older Physicists: For example: during his sabbatical a professor might be required by his institution to work in an area outside his specialty. He might end up liking the new area, leave his old career, and make a job for a young physicist. Department policies might, through the offer of seed money or reduced course load, encourage faculty members to try non-traditional fields, thus producing openings for young physicists in a traditional field.

VI. UNRESOLVED QUESTIONS

A. Island versus Empire Concept of Physics

Underlying many discussions at the Conference were some basic questions concerning the future of physics. Chief among these was the question of the purity of physics, of the extent to which applications of physics and interdisciplinary fields are still physics.

At one extreme is what we call the island concept of physics. In this point of view, as described by Schroeder, physics should consist primarily of pure research in the forefront areas. The reward structure should emphasize achievements in pure research; our models should be Newton, Maxwell, Einstein, Heisenberg, Fermi; too much attention to applications, to the demands of society, would reduce the quality of physics. In this view only, or at least predominantly, pure research is carried out on the island of physics. Applied physics and the applied physicists are shipped out in canoes to other lands. They populate those other lands -- but those lands are not in the realm of physics.

In contrast, there is the empire view. Here physics is, or should be an empire retaining its applied areas and its interdisciplinary areas as colonies. Of course too large a colony will become independent. But we should retain the smaller colonies. To quote Loucks, "The next field we discover, let's keep it."

Obviously the size of the physics community depends upon which concept is adopted -- an island supports a smaller population than an empire. It is also obvious that the overall nature of graduate education depends upon which concept is adopted. For example, many of the solutions presented in this paper are dependent upon the empire view of

physics with many of the young physicists going out to the boundaries of the empire.

B. Depth, Breadth and the Growth of Physics Knowledge

A related question has to do with the extraordinary growth in the amount of known physics. Roy and others at the Conference pointed out that it is no longer possible for the ordinary physicist to be proficient in more than one branch of physics at one time. If a physicist desires real depth in a branch of physics, he cannot have breadth in several branches. The Conference wrestled with this issue several times, usually in the guise of the generalist versus specialist argument. But the issue was never fully analyzed. Many participants felt that, at least in the first few years of graduate education, acquiring breadth in physics knowledge was the primary objective. The more general question of how to best stimulate the growth of physics knowledge was only discussed peripherally, particularly in connection with the talk by Yaes.

C. Social Responsibility in Science

There was little exploration of the relation of the social responsibility of science to physics graduate education or to the future of physics. Clearly the effective exercising of that responsibility through public interest physics requires an empire view of physics. And while new employment opportunities are provided by public interest physics; there is also some rocking-of-boats involved. This boat-rocking could adversely affect other support for physics. The physics community has not yet developed a working philosophy for dealing at the same time with the economic problems of the profession, with its social responsibility, and with the position of the physics community in the political process.¹⁶

ACKNOWLEDGMENTS

Some of this review is based on the paper¹⁷ and midpoint rapporteur talk of Alex Green and we are indebted to him. We are also greatly indebted to Lee Grodzins whose data and figures we have used extensively.

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REFERENCES

- * Names given in this review without further reference, refer to abstracts of this meeting published in Bull. Am. Phys. Soc. 19, 765-777 (1974).
1. Some of the data used at the conference was based on the Physics Manpower Reports of the American Institute of Physics prepared under the supervision of S. Ellis. See for example AIP Pub. No. R-151.11, May (1974).
 2. L. Grodzins, Bull. Am. Phys. Soc. 16, 737 (1971). This is a Special Report of Economic Concerns Committee of the American Physical Society entitled The Manpower Crisis in Physics.
 3. B.F. Porter, S.F. Barisch and R.W. Sears, Physics Today, April (1974), page 23.
 4. A.M. Cartter, Science 172, 132 (1971); contains his earlier references.
 5. For a criticism of Cartter's and similar pessimistic projections see T.R. Vaughan and G. Sjoberg, Science 177, 142 (1972).
 6. D. Wolfle and C.V. Kidd, Science 173, 784 (1971).
 7. L.E. Moses, Science 177, 494 (1972).
 8. R. Aaron, K. Ford and B. Schwartz, Newsletter of the Forum on Physics and Society, March (1973) page 8.
 9. J.T. Ratchford, Physics Today, June (1974) page 38.
 10. S. Chapman, Physics Today, June (1974) page 43.
 11. M. Perl, J. Primack and F. von Hippel, Physics Today, June (1974) page 23.
 12. J.B. Sullivan, Physics Today, June (1974) page 32.
 13. For a summary see D.A. Bromley, Physics Today, July (1972) page 23.
 14. S. Kasden et al., Report on The Education of Physicists Symposium, Batelle Memorial Institute, Seattle, 1971 (unpublished).
 15. G. Hardon, Science 162, 1243 (1968).
 16. J. Haberer, Science 178, 714 (1972); Politics and the Community of Science (Van Nostrand, New York, 1969).
 17. A.E.S. Green, Bull. Am. J. Phys. (to be published).

TRADITION -- NECESSARY BUT NOT SUFFICIENT?

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A tradition is defined as a long-established and generally accepted method of procedure, having almost the force of a law, an immemorial usage. In effect, a tradition is something we can take for granted. That there is indeed a "generally accepted method of procedure" is confirmed by a search of University catalogs and Peterson's Annual Guides to Graduate Study. It is reasonable to assume that the holder of a Ph.D. has broad-based knowledge in standard areas of physics, as demonstrated in comprehensive examinations, and specialized knowledge in the area of the thesis, with skills, judgement, maturity developed by independent work on the thesis problem itself. It is interesting that recently established programs such as that at Stony Brook also follow the conventional pattern of examination and research.

This tradition, far from being immemorial, has evolved in a rather short time. The first graduate school or graduate department in this country was established with the opening of Johns Hopkins in 1876. Although graduate studies had existed at many universities before 1876, there were no formally organized programs of graduate study before the establishment of Johns Hopkins and not a single Ph.D. degree had been awarded by an American university, in any field. The German system of graduate education had the greatest influence on the American system, and the Ph.D. degree from the beginning placed emphasis on research and independent investigation. By 1900 there were 50 institutions in the United States conferring earned Ph.D. degrees, and about 500 had been granted. At the turn of the century, graduate education became "interested in standardization and in the protection of the standards which had emerged during the beginning stages of its development. Much of the pressure for standardizing the requirements for the Ph.D. came from former students and from outside groups.... The Federation of Graduate Clubs, consisting of former graduate students, wanted universities to protect the doctoral degree by taking steps to outlaw unearned and honorary awards, as well as by doing something about different standards for identical degrees at different universities."¹ The similarities in graduate programs might lead one to suppose that some form of accreditation and accrediting body exist. However, although there are various professional organizations concerned with graduate study, including the Association of American Universities, its offshoot, the Association of Graduate Schools, and the Council of Graduate Schools, there is no formal school-by-school evaluation of graduate programs. This is a matter of policy, designed to avoid imposing a set of specific guidelines and standardizing the Ph.D. degree from outside, as is appropriate for professional schools such as law and medicine. The similarities we see among graduate programs are thus not imposed from outside. They are the result both of historic development, each generation acting on the next and passing on the procedure which it followed, and also of the fact of peer pressure. Dependable certification by departments is necessary; the existence of a degree can only be justified by its significance as a symbol of achievement and of ability to do independent work in the field.

The tradition has served well in the past, but events of the past few years have led to doubts of it. I think that the chief problem is not with the pattern of graduate education itself, but that we interpret too narrowly what its result is. Students and employers seek to make a perfect or a very close match between thesis subject and subsequent research. This is especially true of academic postdoctoral appointments, but holds for employment in government and industrial labs also. This

¹Grigg, Charles M., Graduate Education, pp. 5-6. (The Center for Applied Research in Education, New York, 1965).

narrowness of interpretation is a development of the last twenty years or so and probably arose because of the plentiful supply of new Ph.D.'s and of jobs, which made such close matching feasible. It is realistic to consider that the new Ph.D. has had a general education in physics, his thesis research being an example of how he can apply his general knowledge in the formulation and solution of a specific problem. The thesis should not close off other paths in which his general knowledge could be applied. Going into a different field would usually mean a few months of training in new skills, but it should be an easy and natural step. Students and institutions must change their attitudes on this. In order to achieve a broader interpretation of Ph.D. training, better communication is needed among the institutions and individuals involved in physics. People from industry feel that academic departments tend to create in their students a frame of mind antithetical to industry. There seems to be a feeling of "two cultures" in physics, which I think comes from a lack of understanding rather than from a substantive division between kinds of work.

Some formal channels of communication² have been set up between industry and university departments. These should be expanded to include fairly long term exchanges--for a semester, a summer, a year--between academic, industrial and government institutions, including some non-traditional potential employers of physicists. Such exchanges should include students.

Any change in graduate study itself should be in the direction of greater generalization, without sacrificing the experience of original research. The thesis should be independent work, should involve working through a problem from the beginning formulation and refinement of the question through to an end. The aim of graduate education is to produce the able scholar, not necessarily to publish a definitive paper. What is essential is that the student has taken the responsibility for bringing a particular problem to a reasonable conclusion.

The question is frequently raised as to the need for the emphasis on research, for students who will not be going on to do research, either basic or applied. This concern applies especially to college teachers. Should there be a Doctor of Arts program? Two reservations must be expressed about such a degree. First, I believe that physics can best be taught by someone who has done and is doing research in physics. Not that being able to do research, automatically makes one a good teacher, but doing physics means doing research, at some level, and something will be lacking in any expositor of the subject who has not been a participant. So the need is to help researchers to be good teachers. One step in this direction is to require that our students do some teaching, and that this should be considered a serious part of their training. The second reservation about having a different kind of degree is that where there is more than one degree, one will have greater prestige than the other, and history so far has shown that the Ph.D. will be more prestigious. It would be a mistake to encourage establishment of a degree that would be fated to be considered second-class. Colleges have sought Ph.D.'s as teachers, because of outside pressures from financial contributors and from accrediting organizations, because the number of Ph.D.'s on the staff is, rightly or wrongly, taken as an indication of quality.

These points should be emphasized: 1. The tradition as it stands is useful, and is able to provide training for a broad variety of activities, including those to which Doctor of Arts programs are more specifically addressed. 2. Changes should be in the direction of emphasizing the general nature of the physics training in the Ph.D. programs, and the thesis should be regarded as an example of how one applies this broad preparation to the definition and solution of specific problems. 3. The main problem is one of interpretation and communication. Students and employers must learn to regard a Ph.D. as a physicist, able and ready to turn his or her hand to a broad variety of problems. The search for a close match between thesis problem and subsequent employment is likely to be destructive, because it almost guarantees the perpetuation of established ways of looking at problems, rather than allowing cross fertilization of ideas in various branches of physics. We can do a great deal to help by establishing communication, by means of exchanges among academic, industrial, foundation, and government institutions.

²Millman, S., Conference on Tradition and Change in Graduate Education, August, 1974.

A Contrast: The Environment In Which We Grew and That In Which We Must Live.

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The physics discipline flourished and rapidly expanded in the environment of the fifties and sixties. Our present environment is different and we will have to adapt to it to even hold our own. What we do will depend on our assumptions about the changes in the environment. It is worth discussing these changes as explicitly as possible. I will consider three aspects.

A) Before World War II, few people heard of physics and very few would want to spend much money supporting it. But then came radar, the Bomb, the transistor and the nuclear reactor — and finally the laser, in quite rapid succession. Physics (by doing pure research — it was so often emphasized) discovered the ideas which led to these "wonders."

Consequently (And the causal relationship here should be appreciated!), money for a rapid expansion of physics was easily available. These dollars came with the expectation that still new "wonders" would appear as a result of still more basic research. Those expectations have not been fulfilled nearly as well as the funders of physics had hoped. (It's been almost twenty years since the laser.) Certainly something big might happen next year — but it's just not expected, and that's what counts. Sputnik was important too. But, alas, a repetition seems unlikely. We will have to adjust our behavior so that people who are not interested in physics for its own sake will find it worth supporting.

(Some society might support a scholarly activity just because competent people wish to engage in it. Ours should — and eventually will. However I am not optimistic about the prospects for the next few years. If we expect physics to be supported for the same reasons that philosophy and history are supported, we had better expect support at comparable rates.)

. . . .

B) After World War II colleges and universities were crowded. The huge increase in the fraction of young people opting for college kept enrollment expanding. Physics departments grew even more rapidly than

others, and a good fraction of our new Ph.D.'s were able to follow the footsteps of their faculty advisers into academic careers. These were the students most often in mind as Ph.D. programs developed. (Many other students were going to be able to work at research projects not that different from those acceptable in university physics departments.)

In this heady atmosphere of the fifties and the sixties the faculty could emphasize in the training of Ph.D.'s those things which were most interesting and prestigious for the faculty. It was simultaneously best for many students. A most fortunate overlap. This affected the courses taught, the research projects selected and the attitudes instilled.

Physics graduate programs became narrower, in a certain sense. The natural inclination of physicists, when "given their heads," and allowed to "follow their noses," was to put an extreme emphasis on the very frontiers of the discipline — the very "pure." It was often left for the engineering departments or the departments of materials or applied science to do the "mopping-up operations" in areas that were "only" of technological significance. [An unfriendly critic might claim this emphasis of the "pure" included the esoteric and the baroque (physics turning in on itself), and point to the similarity of some kinds of purity to sterility.] Many of those bread and butter subjects that were once part of the background of every physicist were no longer considered worth the time. And, to a large extent, undergraduate programs became graduate school prep. We had to sacrifice breadth to get the depth.

This was all a natural and reasonable response to this aspect of the environment of the past. But here, too, the situation has changed. The peak in the number of freshman-aged Americans is only a couple of years away, and there is an interesting downturn in the fraction of college age Americans who are electing to enter and stay in college. Colleges and universities have serious problems ahead. And physics departments, which are large in proportion to their number of undergraduate majors, will soon be looked at in a cold new light. Certainly they will be hiring few new faculty. No longer can graduate students expect to follow in the footsteps of their

faculty advisers. (Even those non-academic jobs in which Ph.D.'s could once continue academic style research will be less frequent.) No longer is there the fortunate overlap of the natural inclinations of the academic physicist with what is best for his students. No longer will what is best just come naturally. It will require explicit thought.

. . .

C) Almost immediately after the Second World War three new technologies emerged: the nuclear technology and modern electronics, and aerospace a bit later. It was often not clear in just what ways the goals of these technologies were to be accomplished, and new scientific avenues received a lot of attention. There was a belief in "basic research."

But this situation, too, did not last. Partly, there has been a gradual disillusionment with such scientific work because it was often supported under the illusion that fundamental investigations would almost inevitably lead to radically new and important technology. But in addition, certain quite straightforward investigations were often surprisingly successful. Searches for radically new approaches now seem less pressing.

The post-war technologies that once needed physics (as physics) matured. The physics departments matured in an orthogonal direction. The large scale, fortuitous coming together of "pure" physics and technology might well be a phenomenon that will not be repeated for decades. There is still plenty of relevant research to do, but, wisely or not, mature technologies usually find the physics far less pressing than the engineering.

One last historical point: As the three technologies developed, new fields of engineering were defined -- for example, integrated circuit engineering, nuclear reactor engineering and computer engineering. Engineering graduates now often appear to be the appropriate technical employee where previously a physicist would have been hired.

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A general summary: The physics discipline grew because it was felt to provide a needed service to society. In the past we did not have to give this much thought. What we naturally wanted to do was fine. But society's perceived needs have changed and we had better evolve accordingly if we hope to be allowed to continue in our moderately large and expensive style. Think about the dinosaurs.

We have to recognize that major technological "break-throughs" in the near future from pure physics are no longer a big incentive for funding; academic jobs will be very few; and industry will want primarily mission-oriented research for which sophisticated engineers are also being trained.

. . .

Does all this mean that there need be a small demand for physicists? It does not.

In our increasingly technological society new problems involving widely different physical phenomena will continue to be extremely important. Education in physics emphasizes first principles and the basic nature of problems. The physicist can look at problems differently, more broadly and more flexibly than one trained in a specific engineering discipline. This is so true that a very strong emphasis on specific applications would be out of place in a physics program.

There should be plenty of jobs for people with good and broad physics training, and the proper attitudes, and the right interests. There is good evidence that these are, in fact, available.

If the spectrum of careers available to physics Ph.D.'s has changed, physics programs should respond to this change. After all, the present nature of these programs is partly a response to that career spectrum of the past. The general rule, the "touchstone," for this response would be to consciously modify programs so that they would be most appropriate as sound education for today's students with the opportunities available to them. An obvious conclusion? Perhaps, but I wonder how accurately it describes our present behavior.

A Nuclear Physicist Survives in a Hostile Environment

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The experience of a nuclear physicist who strayed into mission-oriented research (MOR) fifteen years ago may be of value to young physicists who now must adapt to a MOR environment. We describe a series of MOR studies which drew heavily on the phenomenological-theoretical modeling techniques developed in nuclear physics.¹ These include (1) Studies using the data-phenomenology-model approach to help solve societal management problems;² (2) Studies of optical absorption and scattering in the Earth's atmosphere;³ (3) Studies of charged particle degradation in the Earth's atmosphere⁴ and in radiation biophysics;⁵ (4) Calculations of detailed atomic and molecular cross sections needed for these studies;⁶ (5) Calculations to provide a global ultraviolet climatology for assessing changes in skin cancer incidence⁷ due to the impact of an SST fleet upon the Earth's ozone layer. Fig. 1 shows a composite of several uses of the Wood-Saxon function of nuclear physics for modeling a variety of MOR problems.

These studies suggest that a person trained in a highly quantitative discipline can apply his tools to a variety of important MOR problems thereby exercising and developing his quantitative skills so that he could, in principle, go home again. There are, however, serious problems of parochialism, territoriality and mismatches between acadynamic and bureaudynamic practices which impede such interdisciplinary problem solving endeavors.

1. A. E. S. Green, C. E. Porter and D. S. Saxon, Editors, Proceedings of the International Conference on the Nuclear Optical Model, Florida State University Studies (1959).
2. A. E. S. Green, Physics Today 18, 32 (1965).
3. A. E. S. Green, Applied Optics 3, 203 (1964).
4. A. E. S. Green and C. A. Barth, Journal of Geophysical Research 70, 1083 (1965).
5. A. E. S. Green, J. J. Olivero and R. W. Stagat, Biophysical Aspects of Radiation Quality, IAEA Vienna, 79 (1971).
6. A. E. S. Green, D. L. Sellin and A. S. Zachor, Physical Review 184, 1 (1969).
7. T. Mo and A. E. S. Green, Photochemistry and Photobiology (to be published).

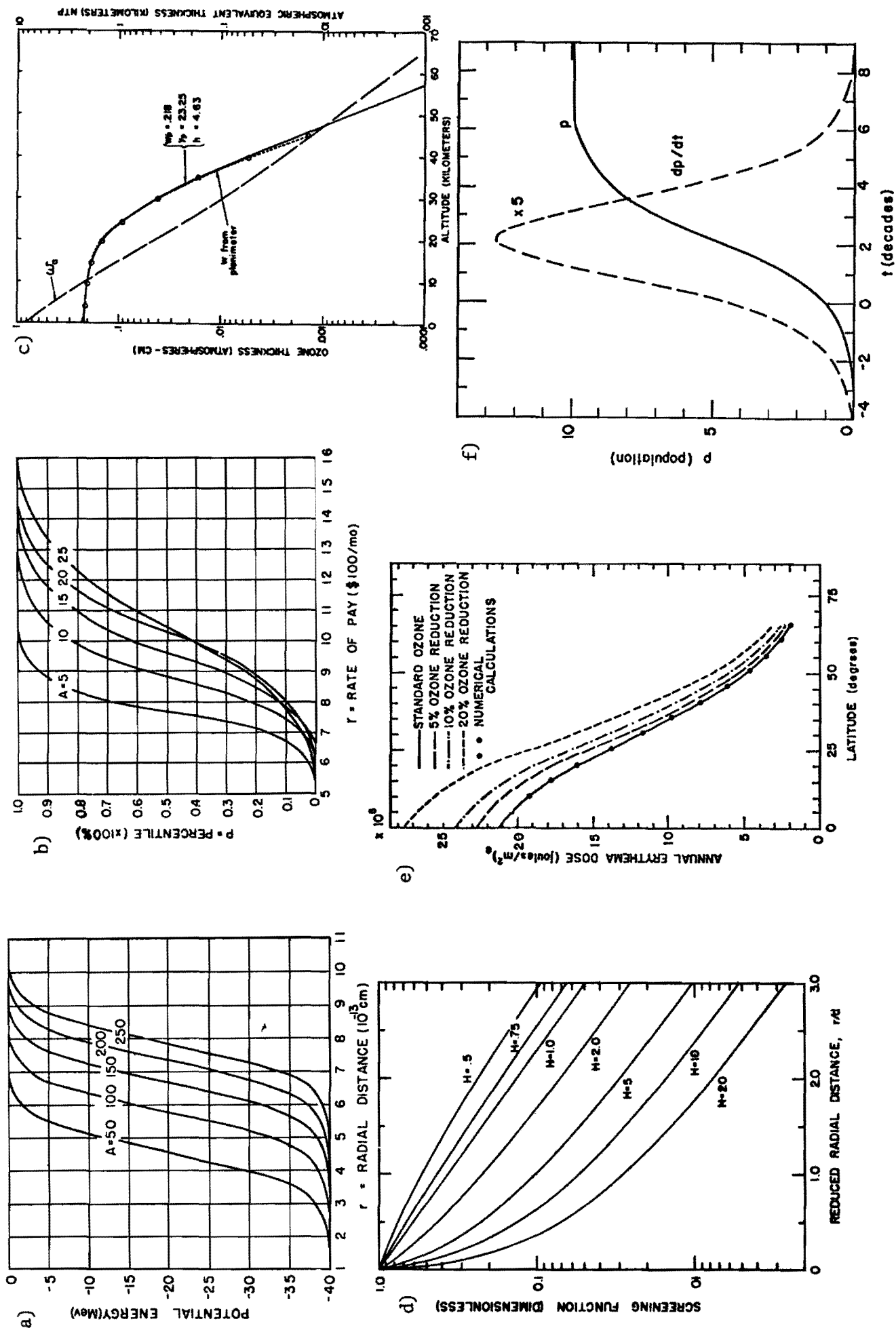


Fig. 1 a) Wood-Saxon function of the nuclear independent-particle model.¹ b) Salary progression curves for scientists.² c) Ozone and air optical thickness vs. altitude.³ d) Atomic screening functions.⁶ e) Annual erythema doses vs. latitude.⁷ f) The Verhulst or logistic function (and its derivative) which contains a to e as special cases.

The Role of Classical Physics in Graduate Education*

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If there is a consensus on any aspects of graduate education in physics, it is that its aims must include the following: 1. To provide the students with a thorough knowledge of the basic areas of physics; 2. To give them an awareness of unsolved problems currently considered important and of areas of active research; 3. To provide them with the basic knowledge of research attitudes and techniques, and, through a thesis, with the experience of their application to a particular problem. These aims are intended to give the students both an understanding of physics as an intellectual endeavor, designed to further our understanding of nature, and to prepare them for the professional activities to be encountered after termination of their formal education. To what extent does the present treatment of classical physics in the graduate curriculum--both in course and textbook content, and through faculty attitudes--indeed contribute appropriately to the fulfillment of these aims?

Most graduate curricula maintain with little change the traditional course requirements in classical physics established at the beginning of the century--one or two terms of mechanics and of electrodynamics, some classical statistical mechanics, occasionally a course in optics or in the theory of elasticity. The only subject not taught half a century ago which has found its way into a significant fraction of the curricula is the theory of relativity. The persistence of a core curriculum by itself does not indicate stagnation. Clearly in one respect everybody agrees on a changing role of these subjects: contrary to the expectations of the 19th century, they can not provide a full understanding of microphysics, although they are indispensable as a preparation for the understanding of quantum theory. On the other hand, the general attitude is that they have hardly any other function, that the aspects needed for fulfilling this function were all developed in the last century and that there are no more important problems left, nor any significant research going on (apart from general relativity and, to a lesser extent, statistical mechanics). A corollary of this attitude is that, unlike the expertise expected for courses in basic and applied quantum mechanics, a faculty member supposedly does not need any expertise in, say, mechanics or electrodynamics to teach a course in the subject, and that thus any faculty member must be expected to be able to teach these courses; when these courses then are taught (and frequently even the textbooks written) by scientists ignorant of modern developments, the impression that indeed none exist is of course reinforced.

The most neglected area is mechanics. Its development can be divided into three stages.¹ The first one is characterized by qualitative investigations, culminating in the work of Kepler and Galilei. This was followed by the period of quantitative theory (1687-1889), developed principally by Newton, Euler, Lagrange, Hamilton, and Jacobi; The third stage, from 1889 to the present, is the neo-qualitative one, pioneered by Poincaré, and continued by Birkhoff, Moser and others. Our courses are concentrating on the second stage; the third one, which has yielded both mathematical and physical results comparable in importance to those of the preceding one, is universally ignored.

It is difficult to incorporate this stage in a course, due to the large amount of unfamiliar mathematics needed. But surely even if the subject can not now be

* The full text of this talk is available on request; a more detailed version will be published later.

¹ For a more detailed discussion, see the Introduction of R. Abraham's Foundations of Mechanics (W. A. Benjamin, New York 1967).

treated adequately in a course, one would expect the teacher at least to be aware of these developments--just as one would expect a teacher of a graduate course in quantum mechanics to be aware of, say, von Neumann's Foundations of Quantum Mechanics or of axiomatic field theory, even if he makes no use of them, so that he can convey a sense of the vitality, scope, and sophistication of the subject to the students.

But there are also large areas of modern developments in classical mechanics which do not require so much mathematics unfamiliar to physicists; many of these are also of great value as preparation for quantum mechanics or special relativistic mechanics. To mention but a few: Galilei invariance, a detailed discussion of which requires the concepts of Lie groups and Lie algebras fundamental for elementary particle physics; its connection with conservation laws through Noether's theorem; classical theory of spin and of elementary particles. Most of these topics are not even mentioned in the texts currently used.

Another major development has taken place in continuum mechanics²; major advances were achieved both in the general foundations of the subject, and in the development of a general theory of constitutive equations. The modern theory can not be separated from thermodynamic considerations; this, however, may be a pedagogical advantage, since it emphasizes the unity of physics as well as provides a reminder of the fundamental role of thermodynamics, which tends to be forgotten by most students after they managed to survive an undergraduate course in the subject.

Furthermore, continuum mechanics provides much of the conceptual basis of field theory, in particular of electromagnetic theory, as well as the foundation for a description of the macroscopic electric and magnetic behavior of materials, whereas our electrodynamics courses almost exclusively deal with the behavior of a non-existent material of constant ϵ and μ . Other neglected areas in these courses include the integral formulations of Maxwell's equations, and new mathematical developments in boundary value problems and in the theory of electrons.

I have tried to give a few examples of very active research areas in classical physics which are almost universally neglected in the curriculum. Although much of the pioneering work in these areas now is done outside the physics departments of our universities, it is basic physics, of which we must be ware and which we must be able to use, and which is frequently carried out by displaced physicists who had to find a home in other departments. While it is almost impossible to give a quantitative estimate of the fraction of physics research which is in classical areas, it is comparatively easy to give such estimates for the numbers of physicists trained and employed in these areas. 24% of all physicists employed in 1971 were working in predominantly classical areas, as compared to 30% in predominantly quantum ones. On the other hand, the percentage of Ph.D.'s granted in 1967-72 in these areas was 4 and 73, respectively³. A similar disproportion exists in every single subfield as well as in the number of institutions offering doctoral programs in the various areas. Clearly, graduate departments overemphasize research training in areas of quantum physics as compared to classical physics by about an order of magnitude.

The figures also illustrate the well-known fact that most Ph.D.'s can not expect to keep working in the areas of their thesis research. This in turn emphasizes the economic need for a well-rounded education, quite apart from the intellectual need. However, the intention of my talk was to stress the scientific and intellectual arguments for the need for new attitudes toward the teaching of classical physics; the figures provided were given only to show that these arguments do not exist in a void, and that their acceptance would not increase the economic difficulties of our graduates.

²For a detailed summary, see the article by C. Truesdell and R. Toupin in Encyclopedia of Physics, Vol. III/1 (Springer-Verlag, Berlin, 1960).

³Calculated from data in Physics Manpower, 1973 (A.I.P. Pub. No. R255), Tables 32 and 69.

What the "little u" wants from the "BIG U"

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Most all of us work at institutions now entitled the "University", however as we all know there are differences in what we do; at the "little u" (the non-Ph.D., B.S.-M.S. producing academic institutions) undergraduate teaching is our main concern and at the "Big U" graduate education and research is the main concern. I have participated in both areas and would like to comment on the interplay between the little u and the BIG U. This meeting is of interest to those of us from the little u because it is the BIG U that supplies us with our future faculty members. I am the self appointed member of the little u to tell the BIG U some of our thoughts.

In the past, we physicists of the little u have seldom been consulted by the BIG U as to the kind of profiles that we might like to hire as future faculty members. Certainly the Grodzin's numbers from this meeting (only 2000 of the past 7000 Ph.D.'s have been employed during the past five years in academic, industrial, or government physics) would imply that the physics community had better listen to the purchaser-employers of Ph.D. products. In the future we of the little u may well hire more of your students than the BIG U. For some bench marks let's look at the ratio u/U for the physics and astronomy faculties of the public universities of California and Wisconsin. For the state of California, the ratio for the 19 California State University campuses to the 8 University of California campuses is about $u/U = 253/367 = 0.69$. If one adds in the contributions from the private educational sphere, the ratio goes to $u/U = 377/526 = 0.72$. For the state of Wisconsin, if we compare the faculties of the Madison and Milwaukee campuses to that of the other little u campuses of the University of Wisconsin, we obtain $u/U = 114/88 = 1.30$. Again, for the state of Wisconsin, if we add in the private sector we obtain $u/U = 151/100 = 1.51$. How will this ratio u/U change with time? It probably will rise. The evidence from the "motion of the feet" of our 1974 class of ten B.S. degrees in physics is as follows:

- 3 - Ph.D. programs in oceanography and geophysics
- 3 - M.S. in Education to teach high school physics
- 1 - M.S. in instrumentation of physics
- 1 - M.S. in computer science
- 2 - industry
- 0 - Ph.D. in physics

From what I can observe, this trend away from the physics Ph.D. programs is quite universal. Our strongest students who would be readily accepted are going elsewhere. We continue to justify the B.S. degree to the students as the "no-nonsense" approach: physics is good education, and that it is good legal tender easily negotiated when transferring into other disciplines or professions. We have not been saying the same thing about the physics Ph.D. degree to our students. My recent experience with interviewing prospective faculty members at an APS "slave market" distressingly confirmed to me the above thoughts.

So what does the little u want from the BIG U? Hopefully, we of the little u desire primarily to become excellent teachers and guides of the youth. In loco parentis is not dead at the little u and we eagerly look forward to prospective teachers who are capable and willing to work with both mind and humanistic spirit of the 18 to 22 set. Secondarily, we of the little u want faculty members who have a continuing interest in performing some kind of research. An interest in some research project does rekindle the skills and

enthusiasm of the little u faculty members. However, we define research in a much broader context than does the BIG U. Building a wind mill; studying the history, philosophy, and politics of science; playing with an analog computer; writing undergraduate texts; performing energy studies; and so forth are certainly as valuable to the little u as the more traditional Physical Review topics.

Do we want Ph.D. degrees or D.A. degrees? Certainly we will hire the Ph.D. degree because that program draws the strongest candidates and the D.A. research is too minimal.

Do we want any modifications in the Ph.D. degree? Yes, greater breadth and less sameness. Who teaches courses at your BIG U out of Jackson's, Kittel's, Messiah's, Merzbacher's, Goldstein's, etc. texts? Who does NMR and bubble chambers at your BIG U? Let's face it, basic physics comes from a few sources; all of the foundations can be easily written on one 3 5 card. This sameness of curriculum shows up in spades when interviewing candidates at the APS Meetings and on campus; the candidates have a certain sameness and what our departments need are faculty members who can add new strengths and not just reinforce the old familiar ones. We already can teach the traditional courses. In the past two years in our department we have added Ph.D.'s in oceanography, atmospheric physics, biophysics, geophysics, fluid mechanics as related to reactor thermal discharges. This past year we even considered hiring an electrical engineer so as to increase our capabilities in the area of instrumentation; an area where many of our "young" Ph.D.'s are somewhat weak. If we had a lacking in the area of "public-interest science" we would probably hire a Ph.D. in that area which has been discussed by Martin Perl. It is our feeling that much of basic physics can be learned by studying some of the application areas.

How have the esoterically trained theoretical Ph.D.'s adapted to the little u? I am delighted to report that most of our abstract phenomenologists have been able to introduce new courses in the areas in which the students are interested, and primarily they have done a very good job. Yes, we should look at the man, and not shy away from the Regge Pole; you can be proud of their adaptability. However, I am not sure that I can promote another Regge Pole to the faculty as they want a candidate who is ready to jump into the areas of the application of physics.

In conclusion, we of the little u want breadth, dedication, application, verve, and in loco parentis. Please consult the little u for further details, we will be glad to work with you.

On a somewhat different tack, I would like to close with a reading of Friedman's "Metamorphoses: A Fable"*) so that we might all be able to consider some of the evolutionary roles that science has played in our society.

*B. Friedman, Impact of Science on Society (UNESCO) 21, 102 (1971).

Physics From Another Perspective, A Cynical Overview

Robert J. Yaes, Physics Dept., Memorial University, St. John's, Nfld., Canada.

(A more complete version of this talk is available on request from the author.)

It has been one of the central mistakes of modern western industrial societies to regard all progress as both beneficial and inevitable. The benefits of automobiles, superhighways, pesticides, industrial automation and the like have been widely touted while their social costs have been belittled or entirely ignored and we are now paying the price. In recent years, the physics "community" has suffered even more progress than society as a whole.

Since World War II there has been an unprecedented massive infusion of federal funds into physics, largely as a result of the contributions of physics to the war effort, particularly, the atomic bomb. It has been accompanied by the hope, seldom explicitly stated but always implied, that additional basic research would lead to more contributions to "national defense", a hope that physicists have not gone out of their way to dispell. Not only have they readily accepted military funding for their "pure" research, but some very well-known high energy theorists have even become what one might call "dilettante war criminals", picking up extra pocket money by working directly for the military on Vietnam counterinsurgenc/ studies for the JASON division of the Institute for Defense Analysis.

The amount of money involved is truly astronomical. The construction costs of high energy accelerators run into the hundreds of millions of dollars; \$250,000,000 for NAL, \$113,600,000 for SLAC, \$51,400,000 for the Argonne ZGS, etc. The annual operating expenses are also quite large; \$60,000,000 for NAL, \$24,700,000 for SLAC, ... In fact, over the lifetime of a machine, the accumulated operating expenses are usually an order of magnitude greater than the construction costs. If one estimates a 15-year lifetime at its full budget, NAL will cost the taxpayers well over a billion dollars. Nevertheless, when NAL was proposed, only the \$250 million figure was mentioned in public. Even more important is the fact that these annual operating expenses must be met year after year even if the total funding for physics, measured in constant, non-inflated dollars is declining as has been the case for the last few years. The effect on the rest of physics, and particularly on University-based research groups, should be obvious. Nevertheless, the "Bromley Report" recommends not only that existing "major facilities" be given the highest funding priority, but also that additional ones be built. Needless to say, the members of the committee that prepared the "Bromley Report", like the members of virtually all government science advisory committees, all hold secure, lucrative tenured positions at prestigious institutions and thus are not overly concerned with the state of the physics job market.

The exponential growth in funding in the '60s has been matched by the growth in both manpower and publications. Phys. Rev. has grown so fat that many people have stopped subscribing for lack of shelf space. Nevertheless, the amount of real progress that we have recently made in the understanding of nature seems to have been less than was achieved in the first three decades of this century when both relativity and quantum theory were developed. It is necessary to ascertain the extent to which this stagnation has taken place not so much in

spite of the increase in funding as precisely because of the elitism, competitiveness, "grantsmanship", bureaucratization, business management mentality and concentration of economic and decision-making power that have entered the field along with the federal money.

The makers of government science policy seem to think that the amount of "scientific progress" achieved by a given project will be proportional to the money spent on it. One can give many counter examples. In the 1930's the only laboratory that had large accelerators, producing beams of unequalled energy and intensity was E. O. Lawrence's radiation laboratory in Berkeley. However, the most significant discoveries of the time, including nuclear disintegration, artificial radioactivity and nuclear fission, were not made by the Berkeley group but by Europeans who were still constructing their apparatus with string and sealing wax. Today, there are no more "string and sealing wax" people left. The most significant single scientific paper of this century was written by a clerk in the swiss patent office in his spare time. In terms of money meant for the support of scientific research, it cost absolutely nothing. If the \$100,900,000 that the AEC will spend on its five largest accelerators in fiscal 1975 leads to a discovery of equal import, I would not be the only one to be surprised.

In the absence of sustained progress in any particular direction, high energy theory has been dominated by a succession of fads, dispersion relations, double dispersion relations, N/D calculations, relativistic SU(6), U(12), superconvergence relations, and finite energy sum rules, to name a few, that have become as popular as hula hoops and maxi-coats, and that have usually lasted about as long. Statements that we are finally on the verge of a breakthrough must be regarded, at best, as premature, particularly in the light of similar statements in the past that turned out to be overly optimistic.

Exponential growth could not, of course, go on forever and the chickens are now coming home to roost. The recent downturn in government research funding has created the worst unemployment situation in physics since the depression that is virtually decimating the next generation of physicists. Even now, I do not expect to see any major policy changes made as those who are in the best position to bring about such changes are those with the greatest stake in maintaining the status quo.

A Graduating Student's View of Higher Education:
The Professor's Attitude Toward Teaching and the Student

Ronald Stein, Penn State University*

In my talk, I will focus on the process by which I became educated in physics concentrating on the earlier portion of my graduate education. I am receiving my Doctor's degree next week (8/31/74). It is clear to me that when the physics academic community, taken as a whole, is talking about changing physics graduate education, it is, in fact, talking about changing the content of the physics graduate program in order to meet the needs of society, which usually means getting graduates jobs. This tendency to look at the needs of society, and to look toward changing the content of the program as opposed to the process of a program (meeting the needs of the student as he learns) is reflected in the professor's attitude toward teaching and the student. Even in a physics graduate program, the professor's picture of his role with student is usually one of a "giver" of knowledge. In the classroom situation he asks himself the question: "Let's see how I can force the student to learn what I think he needs to know." A more humane role would be a "provider of a stimulating environment." Asking the question: "Let's see how I can develop curiosity, interests, and the 'need to know' in the student so that he will want to learn and then giving him the access to the knowledge he seeks." The present methods of teaching physics, substantially unchanged for more than 70 years, foster the present attitude.

I will now discuss my experience in graduate school in relation to the above picture with a strong emphasis on the classroom interactions between professor and student. When I entered graduate school, I was given a long list of required courses which outlined the things I was expected to learn, and also the exams I was expected to pass with their associated time limits in order to get into some thesis research. In the courses, the professors would give out tremendous amounts of material (normally in the lecture mode) trying to get all the material possible across in the time allotted. Getting a good grade was very important. My response to that situation was to work very hard and give the appearance of learning quite a lot, but after a period of time finding out that I had forgotten a large amount of what I thought I had learned when I went back some time later. It is my opinion that a student will work very hard and learn very little when he is forced to learn. A game is being played. You have an adversary relationship: the student versus the professor, where the professor would try to force the student to learn and the student would respond by giving the appearance of learning to get a good grade. Rather than having the student learning with the professor, it was a relationship of the student versus the professor. Also, no matter how poor the lecture, or how badly or weakly the material was presented, as long as the material that I was expected to know was laid out, I'd figure it out. I'd learn it.

The adversary interaction between student and professor is kind of destructive. In this situation I felt that I was pleasing the professor rather than pleasing myself when learning a large part of my course material. It is my opinion that a student will more than please his professor if, in fact in his course material or related graduate studies, he is pleasing himself. This pleasing of self will lead to a more fulfilling type of interaction where he is doing what he wants to, to become an educated person with the professor as the guidance person, the helper, the moderately reliable source of information, the facilitator.

In my course work on the graduate level, my motivation often was pushed under; was discouraged. I operated from the point of view that I needed a good grade. I worked whether or not I was interested, and learned the same kind of quality of learning where I would forget even the things I was interested in knowing about, simply because I would use the same general approach to learning that I had in any course. This scares me quite a bit.

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Now when a student gets further into his graduate program this kind of thing usually happens less and less. In my research, I had almost complete freedom immediately. So I went from a tightly controlled education to almost no control quickly. I felt adrift at times. The student should be allowed to have as much responsibility for his own education as he can handle as soon as he enters graduate school. Initially this might be very little, but it should grow very quickly.

This might happen by simply informing the entering student that he is a junior colleague. "You are capable. Learn. You are interested in physics and have the responsibility for your own education. We are here to help you and act as resource material. Pick a professor to help you and guide you in your studies. Meet with him regularly for planning and guidance."

The adversary classroom interaction is fostered by the fear of being flunked out by failing certain exams. The student usually has relatively short time to learn the material for these exams. So he has little freedom to begin to please himself and learn what he is interested in early in his graduate program. Reducing these exam pressures could reduce the adversary classroom interaction. On occasion, I have seen a professor who wanted to break down this adversary relationship and try something a little different. Grade pressures on the student and pressures to put energy into research on the professor tended to keep these attempts from being very successful.

With time pressures, the professor often feels that he can take only a very little time to give the student anything but course content. But as the creator of a stimulating environment, he should give the student the possibilities of the usefulness of the content at various points. Normally, it is entirely up to the student to understand the value of that content. I found many of my more pedestrian professors taking an interesting subject and drying it out very nicely. Rather, a good professor should perhaps come to class excited with the feeling of having something neat to tell the class. The professor should give the student the flavor of the subject rather than just the content of that subject itself. Perhaps the professor could take his class to a nearby large laboratory. Any number of things can be done to provide that stimulating environment which I think in a large number of physics departments is very much missing.

There is no trouble in giving the student material, it is a matter of meeting his needs in the learning process; and rather than reducing his motivation to learn, enhancing it; and, instead of the department and professors taking the responsibility for the student's education, giving the student as much as possible the responsibility for his own education; and, instead of forcing the student to learn, giving the student the environment in which he can become interested and excited and begin to please himself; and, instead of someone pushing him, allowing him to begin to push himself.

I have two concrete suggestions on how a student's graduate studies could be enriched early in his graduate program which involve guided independent studies. In a required course, with the core material reduced somewhat, the student could be given a choice of additional topics for study. These topics would be done on a sort of mini-independent study with the careful guidance of the professor. The second idea involves a concept oriented guided independent study extending over a longer period of time. The student could plan his study with the careful aid of a professor to investigate the physics of, say, lasers. He could move both toward the practice of laser research and design, and toward the theory involved in laser operation. This would require the learning of several different topics in physics and would probably require taking some courses. Here, the student would have the chance to get involved in his graduate work and learn the material as he acquires the "need to know."

How can a physics department develop a richer and more interesting environment for the student as he learns? I have attempted to give my experience and ideas which relate to why this is desirable and some possibilities on how this might be accomplished.

Education for Institutionalized Knowledge

by

César D. Cordero, Graduate Student in
Physics at Penn State University

As Thomas S. Kuhn has written,¹ the educational initiation of a natural scientist involves a higher degree of use of textbook literature than does initiation into other fields of knowledge like the arts or the social sciences. The use of textbook literature involves the recapitulation in brief and systematic form of the contents of original works in the field, and it is possible because of the confidence of scientists in their present paradigms, which are defined as "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners." As natural science has a storage of accepted theories and solutions to problems, there is little need to be made constantly aware of and to evaluate competing solutions to the problems that the scientific community has attempted to solve in the course of time. Textbook education has been a very effective training for the solution of the puzzles of normal scientific work, and even though it may not be so for the solution of problems that may produce changes in the paradigms, it is not incompatible with it and progress in the sciences is generally the outcome.

It would seem that the essence of such textbook education would be the exposure to presently accepted paradigms but that the rigor and discipline of this study does not need to follow a sequence of fixed curricula and certification through several stages of advancement, or even a fixed teacher-student relationship. This is, nonetheless, the practice in most countries' educational institutions at the present time, both capitalist and socialist.

There are analogies between this graded procedure and the industrial assembly line. And, increasingly, more governments and industries are seeing it in this light as the training for normal scientific work is viewed as part of furthering technological capability. Scientists are seen more and more as highly skilled, sophisticated and certified manpower, the end products of an educational process. Talks on technology transfer between the American Association for the Advancement of Science and the Mexican Government, and the latter's increasing support for scientific research are an example. Applied research curricula, interdisciplinary programs and mission-oriented research contain, along with their potential benefits, at present similar perspectives.

Because of the implications of its uniform emphasis on grading and certification, and through its increasing direct relationship with the governments and industries of our time, scientific education becomes itself another training stage for the production of institutionalized scientific knowledge, for the industrial mode of production of knowledge.

Institutions that practice the industrial mode of production have been analyzed by Ivan Illich² and his co-workers in Mexico. Such institutions are enterprises "that produce a service or artifact commodity, are organized as public utilities, and define their output as a basic necessity." They market packed consumer goods for the satisfaction of distorted goals: cars and highways for higher speeds rather than low speed vehicles for high mobility,

graded instruction instead of free access to educational tools. They include compulsory high-speed transportation systems as well as the compulsory school system. The first puts down and makes unsafe bicycle speeds and walking; the second promotes feelings of inadequacy in those that have been schooled less, and invalidates self-education as the accumulation of educational resources in the school system makes these inaccessible to most.

These institutions do not allow alternative ways of satisfying needs but only those they can produce. These are usually expensive, sophisticated and patented or accessible only through previous certification. For them all types of scientific research are a tool in the continuing sophistication of the individual units they produce, and in their rapid obsolescence.

Thus, scientific education is at present serving such institutions in so far as it is a part of the multinational school system and as it trains for multinational institutionalized research.

This type of scientific research undermines the people's capacity for decision and is therefore anti-educational. The accumulated scientific information appears as a sacred text of knowledge, serving as an argument of authority for accepting the introduction of unfulfillable promises of abundance for all through science. Some abundance does result for a few, leading to social polarization and to fictitious energy crises, as the available energy is centrally controlled and overspent. The people in general are forced to compete for the promised affluence and lack the means of facing and dealing with the scarcity of natural resources, prevented from using imagination for their most effective development and sharing. One way this imagination is curtailed is by the lack of educational value of many of the extremely sophisticated consumer goods and the inaccessibility to the curious of the knowledge and experience reserved only for the certified and by the logic of authority of institutionalized science, that only the complex results of costly research are good and make life more enjoyable.

The redirection of both institutionalized education and research will happen fully only as the people lose their faith in the unfulfillable promises of all such enterprises. Yet guidelines will be needed for such a transition as technologically deprived societies, two thirds of humanity, try to bypass the industrial mode of production and reach, along with over-industrialized societies, a post-industrial balanced mode. A new type of research into alternative institutions must include the search for alternative ways through which scientific research can help us enlarge our capacity for initiative, with limits on our expectations that robots will do our work for us.

References:

1. Thomas S. Kuhn. The Structure of Scientific Revolutions. (University of Chicago Press, Chicago, 1962).
2. Ivan Illich. Tools for Conviviality. (Harper and Row, Publ., New York, 1973). The present paper is based on Illich's ideas as they apply to scientific education and research.

Analysis of Faculty Position Applicants

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The University of Nevada, Las Vegas is a small, relatively new institution, which has been growing at a rate of 3-6% for the past several years. During this period, the Physics Department has also grown at a moderate pace. As a result the instructional and research programs have been constantly strengthened and improved. We now have a reasonable balance between teaching and research, and a faculty dedicated to continual improvement of the entire program.

We anticipated a large response to our advertisement that appeared in the November and December, 1973, issues of "Physics Today". In addition we expected to receive many applications from exceptionally well-qualified individuals. The precise needs of our department and the direction in which we planned to develop the department were left open and unspecified so that we would have as much flexibility in filling this position as possible.

This search for applicants was conducted in compliance with the Equal Opportunity/Affirmative Action Employer mandate. As a result we believe that the candidates were reasonably representative of the physics community. Possible measures which allow such a comparison are field of specialization, institution granting doctorate, geographical distribution, etc. Comparing the fields of specialization of our applicants to data presented in the "Physics Manpower Survey", published by the American Institute of Physics, we found the following:

	<u>UNLV</u> <u>Applicants</u>	<u>Physics Manpower</u> <u>(Table 32)</u>
Astronomy & Astrophysics	9 %	4 - 5 %
Atomic and Molecular	7 %	10 - 12 %
Elementary Particles	15 %	15 - 18 %
Nuclear	14 %	16 - 19 %
Solid State	33 %	26 - 32 %

Thus, the spectrum of applicants we considered compares reasonably well to that of the profession.

The advertisement that appeared in "Physics Today" and elsewhere specified the type of department we have at UNLV, i.e., small, new, and service oriented. Research opportunities and facilities are available, but this is not the primary thrust of the department. Since the department is still in an early stage of development, we desired an individual who would help formulate the direction of the department and take an active part in developing it. Therefore the tone of the advertisement was one of openness, that is, we would consider any individual regardless of research speciality or academic rank. Essentially the advertisement said we were looking for an individual who had something besides technical skills to offer.

In the light of our very candid advertisement, it was amazing the number of lackadaisical responses we received. Since the initial criterion for selection was the impression conveyed in the cover letter and resumé, we were surprised that

so few applicants comprehended that this information was the sole source upon which preliminary judgments are made; with so many applicants we had to make many preliminary judgments. The applicants for this opening fell into four distinct categories that seemed to provide considerable insight into the individual and his graduate education.

In the first category we found those people who were going through the motions of seeking employment. They had read the advertisement, perceiving only that we had a position available, and they responded mechanically. Typically, their cover letter said only to send an application. This individual was telling us, perhaps unwittingly, a very significant fact about himself. Although he may be highly trained and skilled, he has a very simplistic attitude toward his future and his profession.

In the second category were those individuals who conveyed an immediate interest in either research or teaching, but not both. These candidates were considered inappropriate for our type of institution and situation. Supposedly, graduate schools are teaching people to read and analyze problems critically, that is, to think and act creatively. However, this group was not able to apply their education in analyzing our advertisement.

The third category consisted of those candidates who had some understanding of the meaning of the advertisement and had attempted to make some specific response to it. However, the majority of these individuals responded only vaguely, many attempting to exploit topics of current popularity. Outside of a general initial statement, little information of substance was conveyed. This represents a failure of the person to utilize his research ability to find out more about the school and/or the situation, to think about it as a specific problem, and to find some way in which he might be the specific solution to that problem.

The candidates in the above three categories conveyed little motivation to succeed as physicists, teachers, researchers, or creative individuals. Their letters were impersonal and did little to establish their individuality. Such candidates are not acceptable at an institution where every member must convey enthusiasm for his profession.

The category of applicants which we deemed to warrant further consideration represented only 20% of all applications received. An applicant placed in this group had conveyed some enthusiasm or had said something about themselves as a person that made them stand out. These candidates seemed to have been successful in applying the principles of their graduate education to analyze our advertisement; they had given some thought to our needs and had then responded in a coherent and humanistic manner. It was to these individuals that application forms were sent. Those that conveyed further information about themselves and how they could help the department were considered seriously for the position available.

We believe that a well educated physicist should be one who can analyze a topic critically, research that topic, and communicate his findings effectively to others. When one applies these criteria to those applicants who applied for the position at UNLV one quickly sees that graduate schools are not doing an entirely effective job in this respect. These individuals may be good technological specialists, but in applying the basic concepts of their profession to other endeavors, most seem to fail miserably. This ability to analyze and communicate in a humanistic manner is very important to the physics community. Increasingly, we are being called upon to interact more closely with the public, and a person who cannot do so will not survive the new demands placed upon him. If we continue to educate people who cannot operate under these simple guidelines, we are doing them and the profession a great disservice.

Moving Out of the Traditional Mainstream of Physics

I. RICHARD LAPIDUS, Department of Physics, Stevens Institute of Technology Hoboken, New Jersey 07030 (Presented at the Conference on Tradition and Change in Physics Graduate Education held at the Pennsylvania State University, 19-23 August 1974.)

SUMMARY

In this talk I will examine some of the career opportunities for physicists trained to work in areas out of the traditional mainstream of physics, such as biophysics and medical physics. Biophysics encompasses a very wide range of activities. Because it is not well-defined by its subject matter, the nature of the field is really determined by the interests of the people who are working in it.

At the present time most scientists who call themselves biophysicists are not physicists! But there is increasing interest of physicists in biology. Several new journals in biophysics or biomathematics have appeared recently. A large number of Ph.D.'s in physics are applying for post-doctoral fellowships in biological fields and to medical schools.

Perhaps the most serious problem facing the physics community is not merely that the number of students majoring in physics is rapidly declining, but that this attrition is proportionately higher among the better students. A combination of cuts in funding, shortages of jobs and a greater concern for "humanitarian" endeavors has tarnished the "romantic" image which enabled physics to attract the best young minds in the past.

A central thesis of this talk is that training in physics should be broadened to permit the brightest students to receive the excellent training in thinking provided by the study of physics and at the same time to prepare

these students for biologically and medically oriented careers as physicists. Most physics departments now regard biophysics as a sideline endeavor and few departments have serious programs in this area. I believe that it is time to move away from this historical position.

I have a few suggestions for how this might be done. First, more physics departments should offer biophysics programs - both theoretical and experimental courses and research to train scientists to work as physicists in biology and medicine. Second, physicists in academic departments should make students aware of the opportunities in biophysics and medical physics. Third, physicists who are working in biology should exert a more active influence on the direction of research in biophysics. Many physicists who have moved to biology have become biologists rather than physicists working on biological problems.

The physics community may be able to produce a disproportionate share of new ideas in biology and medicine by training physicists to work in biological and medical physics through a combination of the rigors of a physics education and the stimulation and excitement of the new problems in biology at the microscopic and molecular level.

PHYSICS AS A CAREER IN THE SEVENTIES

Eugen Merzbacher

University of North Carolina at Chapel Hill

(Two extracts from this talk are reproduced here)

* * * * *

In 1973-74, a small ad hoc working committee of the Forum on Physics and Society undertook a study of the existing placement services at the American Institute of Physics. In the course of this study, graduate physics departments were questioned about their attitudes toward these services and especially toward the Doctoral Employment Information Service (DEIS). Both, department chairmen and representatives of the graduate student body were questioned. It was gratifying that responses were received from more than half of the department chairmen. The Committee also heard from some graduate students but not as many as it had hoped.

Although the questionnaire was principally designed to elicit opinions about the placement services, the responses did also provide some information about vacancies that can be expected in the Ph.D. granting departments in the fall of 1974. Roughly, on the average, there will be one faculty opening and about three postdoctoral positions per department. This suggests that 500-600 physicists will find temporary or permanent employment in graduate physics departments this year. (However, this is not a net gain of positions, since many of the vacancies result from turn-over in non-tenured positions.)

Generally, the Committee found a reasonably supportive attitude toward the placement efforts of the AIP, but also a good deal of skepticism about the efficacy of any

method to locate jobs other than the "buddy" system.

Any discussion of placement services starts with the gratuitous observation that these activities can never create jobs that do not exist. There are many responses to this, of which the most trivial is that an effective employment service will at the very least reduce the dead time during which the jobs that are available remain unfilled.

The ad hoc Committee concluded its work with a number of technical recommendations: To unify the several different placement activities at AIP (Employment Referral Service, Placement Service, and DEIS); to expand and generalize DEIS and to get its compilations into the hands of industrial employers and the administrations in the smaller colleges; to encourage (by low rates in PHYSICS TODAY) advertising of all physics jobs; and, greater emphasis in talks at meetings and in articles in PHYSICS TODAY on models of the kind of different careers young physicists might find in industry, and especially in smaller firms.

* * * * *

I conclude with a plea for more discussion about these matters. Talk in physics circles about the employment situation, about placement, and about the aging faculty is often considered merely a lot of mindless chit-chat, a palliative that serves no good purpose and conceals on part of the "establishment" its inability or -- worse -- its unwillingness to cope with the real problems confronting the next generation.

As for unwillingness, it is worth pointing out that the people who run the American Physical Society have become persuaded that the majority of members of the Society favors an increasingly active role of APS in public affairs and more attention to the professional concerns of the membership. Still, the criticism that there is much talk but little action may appear to have substance. But it seems to me that such talk, even when it is groping and tentative, is not at all wasteful. Rather, it is an absolute precondition to any change whatsoever.

Regional Cooperation in Physics Graduate Education

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I will discuss a method of operation that should be considered (if only to be rejected) by schools with small and medium size physics graduate programs, regardless of the particular type of degree program they feel is an appropriate response to our times. The ideas I suggest are personal and do not necessarily represent the thinking of any other person or the program of any institution.

One of the three recommendations that is made in the Bromley Report under the heading of Graduate Education calls on physics departments to "... select those areas in which they have the faculty and facility resources to achieve or maintain excellence, and if necessary, sacrifice marginal programs to permit the development of those selected areas." The recommendation concludes with the following statement:

"Obviously such actions at the same time place a high premium on the development of local or regional cooperative arrangements among institutions whereby the specialized training and research facilities of each are available to all. Otherwise there is a real danger that graduate education can become even more specialized and inflexible than it frequently is now."

There are other cogent reasons why a number of the institutions in the United States that grant the Ph.D. degree in physics should seriously consider regional cooperation. It seems clear that, no matter what kinds of changes we make in the nature of physics Ph.D. preparation, the production capacity well exceeds the number of graduates that will be effectively utilized. Yet there are forces impelling institutions to keep up the numbers of graduate students in their programs. Oftentimes the number of graduate students working under his direction has been used as a measure of the success of an individual professor. A program needs to display at least some minimal average number of graduates per year in order to justify its existence to regents or other governing bodies. In the basic courses of graduate study, the pace and tone of the class can quickly descend to that of the lowest common denominator if there are too few people involved to let anyone be left behind. It requires more than a student or two every couple of years to provide the freshness of viewpoint, questioning of standard techniques and assumptions, and desire to learn that make a university research program an exciting and productive enterprise.

These pressures insure that endeavors to recruit graduate students will be a major concern of physics departments. But it is immoral and in the end counterproductive to seduce the uninterested, unprepared, and unable into graduate education just to keep up the numbers. The regional pool of qualified and motivated prospective graduate students is not likely to meet the demands of all the schools in the area having physics graduate programs. This will lead to competition for desirable students, which I have seen become intense indeed. A cut-throat recruiting war seems a very misdirected application of regional resources.

One can, of course, propose that the weaker, less distinguished schools cease offering a physics Ph.D. program. But few departments are likely to volunteer the demise of their own program, and existence of some Board of Accreditation that could declare a program to be deficient and close it down is a pipe-dream.

In many situations, regional cooperation may provide a means to assuage many of these difficulties. The impetus for regional cooperation must exist at the grass-roots faculty level. It can be fostered and guided (or killed) by the Administration, but it cannot be imposed from above.

What specific things can be done? This is not a simple question, because in any proposed cooperative enterprise the local situation must govern, and each local situation will have its own peculiarities. To be specific, I will address the situation of Kansas State University and some nearby institutions.

Kansas State University, the University of Kansas, and the University of Nebraska form a group of institutions with sufficient geographic proximity and pedagogical and administrative similarity to make cooperation in physics graduate education (as well as in other endeavors) a worthwhile thing to consider. Examination of the figures on number of faculty and number of graduate students indicates that no one of the schools is a priori going to dominate or be dominated by the others.

Before anything can be done, there must be agreement by the physics faculty members of the schools, acting at the Departmental level, that cooperation is desirable

and should be a conscious part of Departmental planning. The Departments could then begin immediately, through Department Heads or designated individuals, to exchange information and coordinate plans concerning development of major research areas, with regard to both equipment and personnel, with the goal of emphasizing mutual complementarity and regional broadness.

The Schools could begin immediately to share special seminars and colloquia by means of leased telephone lines. Such a system, under the name "Telenetwork", is at the present time sponsored by the state colleges and universities of Kansas and reaches twenty-four locations in the state. The system allows for voice communication among all stations and has the possibility of transmitting overhead projector type transparencies. It should not be an insuperable task to bring Nebraska into the system.

The Departments could immediately begin a joint program for the recruitment of physics graduate students, selling simultaneously for the three schools a single broad, complementary research program. This would require that mechanisms be developed for a student easily to transfer from one campus to another should he decide to pursue research in a field not represented at the school where he originally enrolls.

Within a year it should be possible to arrange a reasonable mechanism for the use of major unique experimental facilities on one campus by faculty and students from the other schools. Such use might be for a day, a weekend, a week, or the entire summer. It should also be possible to institute a system of faculty exchange among the schools, distinct from their programs of sabbatical leave, for purposes of graduate teaching, research, or a combination.

After some experience is gained with the telenet system for colloquia and short seminars, it should be possible to use it for the presentation of advanced courses that emphasize the specialized research expertise of one or another of the schools. It is important that such courses exist if regional cooperation is to serve as an effective means to combat narrowness and overspecialization in the education of individual graduate students.

The library purchases of the three schools could be coordinated, particularly with regard to reducing overlap in subscriptions to expensive but relatively little used journals. Such a plan would require development of a fast and efficient interlibrary loan system.

Other developments that might advantageously grow out of cooperative association of the physics graduate programs of the three schools include multicampus supervisory committees for graduate students who have significant portions of their work on more than one campus; common examination procedures - or better common examinations - for qualifying exams, prelims, etc; common purchasing of items where a saving can be realized on the basis of volume; a common research computer facility; perhaps a television hookup to supplement or replace the telenetwork system; and a joint placement service to assist graduates in finding jobs.

There is another possibility that I feel should receive consideration as a means of ameliorating some of the problems associated with small numbers of students. That is to have the entire freshman graduate physics class for the three schools begin studies together on one of the three campuses, the location to rotate from year to year. Most of the class would stay together during the year-and-a-half or two years when they are primarily concerned with courses and not with individual research projects, perhaps all on one campus, perhaps on several campuses in succession. They would then spend the final two to four years of their graduate study on one or another of the campuses as dictated by their choice of field of major thesis research emphasis. This would help greatly to assure that during the basic years of graduate study the student experiences among his colleagues a mix of aptitudes, interests, personalities, goals, and applications of talents that will help bring vigor and enthusiasm to his individual studies. One can immediately make a long list of administrative and substantive difficulties that would attend a program of this sort. However, I have not encountered any difficulty that seemed so overwhelming as to negate further discussion of such a program.

AN ALTERNATE SET OF REQUIREMENTS FOR
THE PH.D. IN PHYSICS

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I would like to discuss an alternate track to the Ph.D. degree in physics that we recently introduced at SUNY Binghamton. This program was arrived at and developed in bits and pieces - it is not one persons idea or program. Furthermore, no one in our department looks at it as any sort of panacea - it is not designed to replace the traditional program - it is merely an attempt to provide another set of requirements for the Ph.D.

Some people might say that we are barking up the wrong tree. Maybe it is not the correct approach - maybe one should not try to tamper too much with the basic workings of graduate programs in physics - maybe there are other more appropriate and better modifications that should be made. Nevertheless, we feel that some attempt should be made and this is one attempt. The first point that should be raised is - why did we think an alternate track was needed? The short-coming of physics graduate education have already been brought out at this meeting by others. So knowing that there are short-comings, what does one do about it? One can try minor revisions of the traditional program, but we believe that is not sufficient. The short-comings of physics graduate education are such that we believe an alternate set of requirements is needed. It is not that we want to abandon the traditional program; we would like to see the traditional program and our alternate program co-exist in our department.

The following is a list of the basic features in our traditional program and what we believe is in most traditional programs:

- A. Basic Graduate Courses in preparation for comprehensive exam.
- B. Comprehensive Exam.
- C. Dissertation Research.
- D. Additional Courses at the discretion of student and research advisor.

For our alternate program the basic features are:

A and B. The same as in the traditional program.

- C. (i) Two Research Apprenticeships.
- (ii) Three Library Theses.
- (iii) One year teaching internships.

D. Additional courses beyond those taken under A.

Some elaboration of C and D in the alternate program is needed. For each research apprenticeship, the student would spend half a year in one of our experimental research laboratories. In that period of time the student should develop into a contributing member of the laboratory. For each of the library theses, the student will have to write an exposition on a prescribed area of some specified research problem. For the teaching internship, the student will be guided through a teaching experience under the close supervision of a faculty member. Finally, the additional courses in this alternate program are well specified and designed to expose the student to a broad range of classical and contemporary physics.

After completing this alternate track, we believe a student is well trained for college teaching, industrial research or a research post-doctoral position. That is, we think that an individual who has been through our program can profitably contribute to a group research activity and with post-doc experience, he would be prepared to initiate his own research projects. We base these conclusions on our own feelings and those of sampling of individuals from colleges, universities and industry. In general terms, the objectives of this program is to provide the student with a very broad grasp of the fundamentals of physics and to prepare him or her to cope with the problems of contemporary society.

We would strongly encourage other departments to consider other alternate tracks for the Ph.D. As I said at the start of this talk, maybe we are barking up the wrong tree with what we've done. But we feel that physics graduate education should not be locked into traditional programs. Alternate programs, such as ours, should be tried and tested and not just dismissed out of hand.

Graduate Student Panel: "The Psychological Environment
of Today's Graduate Students"

Summary by Deborah Van Vechten

The panel members were Deborah Van Vechten (chairwoman), Joseph Abate, Joe Craig, and Robert McCann with Art West acting as moderator and time keeper. Three of the panelists gave individual presentations, then a series of questions were read and debated with the audience supplying additional questions and comments. While not unanimous, some of the opinions expressed during the discussion were as follows:

1) Given the fact that the economic self-interests of the faculty and students no longer necessarily overlap, if the student's historic trust and cooperation with the educational process is to remain, the student must be made to feel his interests are the basis of most decisions. Toward this end;

a) teaching procedures should encourage the student to exercise his own curiosity, to develop his scientific judgment and problem formulation, as well as solving, ability;

b) the student should play a major, if not dominant, role in deciding what his dissertation topic should be;

c) the faculty member should overtly concern himself with the student's well being, both mental and financial;

d) the student should never be treated as cheap labor; rather the students should be treated as junior colleagues.

2) The faculty member should encourage his Ph.D. students to consult widely with the faculty of their institution. A thesis that is the result of collaboration with three or four faculty members is likely to be better and less delta-function-like than one that results from collaboration with a single advisor. Additionally, the student would be more likely to understand how his work relates to the rest of physics and to be broadly trained.

3) The importance of examples in the attitude formation process should not be neglected, especially in considering the question of why today's student views his training as narrow while the course work and nature of the dissertation has not changed from when the training was perceived as broad. How often does the average graduate student see faculty members demonstrating the breadth of their training by trying to understand and contribute to a colleague's research?

4) If graduate student enrollments are to be cut further, the students should be refused admission to the program in the first place, not dropped after a year or so.

5) The faculty should generally be aware of the human aspects of their work and obey the golden rule (behavior not transition probability).

My own presentation dealt with the question of motivation. My first point underlies opinion 1 above: the faculty can no longer assume, but rather must earn, the trust and respect of the student. It seems self-evident that strong internal motivation and a highly developed curiosity are the keys to the creative flexibility and drive that allows one to change jobs successfully and to be the type of person Dr. Moss was talking about. Nevertheless, when suggestions directed at developing such traits -- for example, the substitution of independent studies and reading courses for some significant fraction of the first and second year course work -- are made, they rarely evoke enthusiastic responses. The students are likely to question the motivation of such a response and the quality of the faculty-student relationship can strongly influence their conclusion. Perhaps the most flattering interpretation is that the faculty does not think students know how to direct themselves with nearly the efficiency the faculty can and that the students are likely to get off onto an unproductive tangent which will just waste the student's and their time and department's money. A less favorable interpretation is that the faculty does not trust its own self-interest will be as well served and isn't willing to make the sacrifice.

A third interpretation of faculty reluctance to encourage such self-reliance is that they view all emotions, even curiosity, as nonscientific and threatening.

I'd now like to spend a few minutes responding to the question addressed to Ron Stein Monday evening, namely "If it hurts so bad (to be a student), why don't you get out?" Having passed the qualifier and joined a research group, I have "gotten out" by getting in. That is, I perceive the main problems as occurring in the first two or so years when the student is new to the department, not yet sure what area of physics he wants to work in and generally feeling unsure of himself. This is also the time during which the faculty tends to view him as unproven and therefore unworthy of much attention. I hope that this willingness to let students fend for themselves arises from lack of awareness of how much psychological difference the lack of economic security makes and not from indifference to such matters. In an era when good grades earned you a big name advisor and almost guaranteed a job, it was sufficient to reward people with good grades. However, this is no longer the case. More immediate rewards -- smiles and other forms of personal recognition, for example -- should be substituted, at least in part.

Finally, I'd like to ask each and every faculty member, particularly at the "big U", to examine his own original motivation for being in a university at all. Does it jibe with how you now allocate your time and from whence you derive your satisfaction? What benefits do you receive from your thesis students? People who came into universities for the money have probably already left for the higher pay of government and industry. Those who came for the security of tenure are discovering that it was illusory and may soon leave. Hopefully these departures will make university departments more cohesive and more dedicated to good teaching.

For it is good teaching that may yet salvage the universities from their economic problems. It is my belief that most people who thought about it headed for academic jobs because they inherently liked to teach. In many cases this positive attitude was quenched by a series of disappointing teaching experiences -- classes that just didn't go the way one would have wanted. Faced with a choice of blaming the students or oneself, the students generally lose and eventually one gives up hoping that each new experience will be better than the last one and stops trying. A more mature attitude would be to take comfort in the fact one had truly tried to be a good teacher and to try to analyze the factors leading to the negative results with the intent of improving the next attempt. The commonness of the first, more negative pattern is what has allowed the importance of good teaching to be so downgraded in many big U departments. (How many times have you heard someone ridicule a student complaint with "What do you expect, good teaching?" No one wants to demand that which he is not sure he can produce.) I feel a major revision in the reward structure should be made so that the ability to communicate one's ideas in a clear and illuminating manner to any audience is as officially rewarded as the ability to publish articles in the journals. The goal of physics should be to clarify the nature of physical reality for all who care to try to understand. Research is necessary to generate the underlying knowledge and awarenesses but without adequate attempts to convey the understanding gained, the research is of little value.

The APS Visiting Physicists Program

Expanded Abstract

Sidney Millman American Physical Society

This paper, presented at the Conference on Tradition and Change in Physics Graduate Education, described the experiences gained by the Education Committee of the APS with a program of short visits by physicists from industrial R & D institutions to university Physics Departments. A pilot program was initiated in October 1973 by the APS Education Committee to promote increased interaction between physicists in industry and academic physics departments.

Invitations to participate in this program were issued to 27 top PhD producing Physics Departments (taken from p. 61 of the AIP Physics Manpower 1973) and about an equal number of R & D institutions selected from the American Institute of Physics Corporate Associates list. The principal stated objectives of the visits by physicists engaged in applied research or development, which were usually of 2 days duration, were:

- a) to increase the interaction between industry and PhD-granting physics departments
- b) to broaden the education of PhD students with respect to opportunities for creative work in industry and
- c) to convey to the professors and graduate students some impression of the role of physicists in industry

About 90% of both academic and industrial institutions invited to participate in the Visiting Physicists Program indicated enthusiasm to participate in the program. As of August 1974 28 specific visits have been arranged on the basis of matching the preference of the visitor nominated by the R & D institution with the desires and interests of the host physics department. Of these all but 5 have already taken place during the period of Feb.-June 1974.

Although the Committee on Education was prepared to reimburse visitors for travel expenses when necessary, no such expenditures were incurred by the Committee. In every case the visitor stated that his or her company will be happy to take care of expenses incurred in the visit.

In order to evaluate the success of the visit follow-up letters were written to hosts and visitors inviting frank comments about the visit, including the adequacy of the length of the visit, the interaction with faculty and students and the interest in repeating the experience. From the responses received so far we would conclude 16 visits were successful, varying from highly successful to moderately successful, 3 borderline and 1 not successful. Even in each of the borderline cases there is interest at least on the part of either the visitor or the host to participate in future visits.

For the 1974-75 academic year we plan to continue with this phase of the Visiting Physicists Program, i.e. visits by industrial physics and universities, at about the same level of activity and to arrange for a few visits by professors and their students to nearby industrial R & D laboratories. We expect this will require some money since we cannot count on the University Physics Department to provide the expenses involved in the travel and two nights at a motel for a professor and his students.

We might cite two advantages of the Visiting Physicists Program over other meritorious mechanisms for providing greater interaction between industry and academic physicists such as sabbaticals for professors in industry, summer employment for graduate students, industrial physicists spending longer periods in the university, joint appointments, graduate students doing their thesis research in industrial laboratories

1. Short visits are more practical. Any busy professor or industrial physicist can take 2 days off.
2. No large funding program is required, particularly when the visits are arranged on a regional basis so that travel distances are kept at a minimum.

TO WHAT EXTENT IS SCIENCE AN INTERNALLY GOVERNED ACTIVITY?

Ronald Geballe

Summary of a Paper Prepared for The Conference On
Tradition and Change in Physics Graduate Education

August 19-23, 1974

This paper addresses itself to broad, general questions rather than to specifics of graduate education or to what kinds of change, if any, are desirable. The paper proceeds by posing a sequence of questions, of which the first and last is: Who is entitled to be heard on this matter. The second is: What is graduate education in physics? What are its components and what are their purposes? We proceed to others: How much of this is merely tradition? Are there aspects we should change? Are there aspects we shouldn't change? Are there aspects we can't change?

In the perspective adopted here, the question, What is physics graduate education? has to do with the form rather than the subject matter content of the curriculum. Thus, the appropriate answer is that the components are: courses, examinations, dissertation and along with all of these a more-or-less unconscious indoctrination. There is point to asking what the purposes of these components might be. From courses, we expect our students to gain background tools. From the core courses, which carry forward the subjects that lie at the basis of physics we expect a common store of information and language which exemplifies the unity of physics.

By stating that 'indoctrination' is one of the components of graduate education in physics, I run the risk of opening the argument more broadly than I would like. In recent years the physics community, along with the rest of the science community, has been accused of indoctrinating students in a political and economic sense, that we have been and are the not-too-unwilling tools of those who run our particular socio-economic system; presumably scientists who live under other systems are no less culpable. Or, at even a more basic level, we who teach and practice science are inducing others to abet the further enslavement of mankind by technology. To these critics this matter of indoctrination might be the crux of the conference, they arguing we should restructure physics education so that it either (a) will be completely value-free, or (b) will serve the cause of humanity. Since physics is made by mankind, the first condition can never be met, whatever our intentions. And as for the second, it might be taken to imply that universities should be cut loose from the society that supports them and be responsive instead to another agency that has a more correct notion of the best course for humanity. But more realistically, there is a call for greater emphasis on values throughout the educational system which, if carried out well might not require change in the discipline-orientation of graduate education. Indeed, it can be argued that the stage of graduate education is far too late in life for the injection of a dose of values.

The next question asks, How much of graduate education in physics is traditional? There is more than one way to tackle physics, but it is a highly structured discipline. The classical theories are complete and polished. Their limits of validity are known, and the paths that lead from them to modern physics are well-trodden. Yesterday's modern physics, now a half-century old, is ready for the designation 'classical.' But even at its frontiers, physics uses the structures and concepts that gained it so much earlier territory. In a sense, then, physics is almost entirely traditional. The most apparent tendency to break with tradition is the introducing as time passes, of successively more abstract formulations which encompass earlier findings and concepts through generalization. It might seem paradoxical that the content of physics is so traditional but it is likely that this will be so indefinitely unless or until we stumble upon a completely different approach to understanding the physical world.

The next two questions are a pair: Are there aspects we should change? and, Are there aspects we should not change? The answer to both, reasonably enough, is "yes" but there can be much argument over the details. The reasons given earlier for retaining a core of courses are sufficient, I believe, to justify the retention of this concept of a background or a foundation which physicists have in common. Should the time come when it fades, physics will have irrevocably divided into fragments which will go their separate ways.

As long as any changes proposed are small ones such as tampering with course syllabi, changing from oral to written examinations, even requiring some experience in an industrial or other kind of applied laboratory, it is certainly within our powers to bring them about through the actions of faculties in individual institutions and perhaps as a consensus view of appropriate Ph.D. education. The theme of the conference ought, however, to prod us into inquiring more deeply, and to ask whether more radical changes should be contemplated. My thoughts have not suggested any that seem promising but they have raised a deeper question: Are there aspects of graduate education in physics that we cannot change? Putting it another way, Are there constraints, lying outside of physics or of science, that impair our supposed autonomy over our subject?

No doubt, the immediate answer will be, "Yes, money" and of course, this is so. However, the kind of constraint I have in mind is conceptual. Science is said to be a social institution; and as such, it has been studied by philosophers and social scientists. Do they have possession of knowledge that can answer the question? Whatever their triumphs, neither the philosopher nor the historian seems to cope with the question of whether social forces dictate the form or content of a science. It is a relatively new subfield of sociology, 'the sociology of science' to which we might expect to turn for enlightenment. The existence of a subject called 'the philosophy of science' is well known, and also 'the history of science'.

There appears to be a main school of thought and research, initiated by the American sociologist, Robert K. Merton, and carried forward by his students with interests principally directed to the interactions among scientists as individuals: their patterns of communication, their responses to what these

sociologists perceive to be the 'reward system,' the internal organization of science as a profession. There is little or no concern with what scientists produce. They base much of their work on statistical data and draw conclusions from correlations. They label people as 'scientist' and expect them to conform, much as we reduce molecules, whatever their structure, to the ideal gas. Indeed, it seems very much as if they are consciously attempting to apply the methods of physics to their subject. Reading their papers, one has the feeling that he is looking back up the microscope.

Most of those who have commenced to investigate the interactions at the boundary between the scientific community and the society in which it is imbedded have taken up "science policy research", the study of the appropriate allocation of resources to science and technology. The thrust of these studies has been economic and political. In a way, the patterns of funding imposed on the National Science Foundation, the Atomic Energy Commission and other funding agencies, by Congress and the Executive branch constitute a de facto science policy, variable with changes in the administration and with economic conditions. These patterns do constitute real constraints on content and scale for science and in particular for physics. They certainly suggest expedient measures to us, having to do with choices of research field and curricula. A pattern maintained consistently for many years could have a significant effect on the course of science, and thus serve as the kind of constraint for which I have been probing. Such consistency, however, ought to be taken as the consequence of deeper social forces. As far as I can see, science policy research is not yet ready to pronounce on these.

The question persists, then, whether there are social determinants of the content of physics which restrict our freedom and social determinants of the education structure that create bounds to the process by which professionals are created and certified. This question is, of course, a start for a major research project; one, whatever its conclusion, not likely to be accepted as the final word on the subject. There was, in the 1930's a Marxist thesis that Newton's physics was mainly determined by the economic and technical tasks faced by the rising bourgeoisie.

There is a group of sociologists which insists that the content of science is important to an understanding of its sociology and that Merton and his school are too intent on studying science in an advanced capitalist society. My amateurish survey has not turned up any other suggestions from this source that there exist basic social constraints for physics. Indeed, one author has reaffirmed this year that there has been since World War II a "virtual disappearance of attempts to explain the content and theories of science on the basis of general social values" (Stuart S. Blume, "Toward a Political Sociology of Science", The Free Press, New York, 1974, p. 7 quoting from Joseph Ben-David, Introduction, International Social Science Journal, 22, 7, 1970).

At this point, I conclude that there is no convincing evidence for absolute constraints on physics or on graduate physics education that we need consider at this time. From an absolute standpoint, we're on our own, and left

to use our own best judgment. While the Mertons like to regard scientists as an isolated species, we are more aptly described as a tagged species interacting with the others of the larger society as well as in special ways with those bearing our tag. We have just seen the example of biologists, on their own, sensing and coping with a social dilemma. Physicists too are aware of the need to integrate scientific, political and ethical consideration, and there are few, if any, among us who fail to see humane value in pursuing the unanswered questions of physics. No other group is as well-qualified to cope with the educational problems posed by these two aims, and certainly, no group is as interested.

WHAT PRICE CHANGE

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The "sociology of science" suggests that there are limitations to how much physics can change; and it can be used to analyze the likely costs to physics of some of the changes proposed at the conference. Our present physics graduate education is "good" for physics as a knowledge-gathering discipline; more good physics is done in the U.S. than in any country in the world. It is to maintain this high-quality physics that many of the traditions and "establishment" mechanisms have been set up.

Physics has problems of quality control. The product of physics research is publications; public knowledge that is dispensed at no charge. We know the product is good when the peers approve. The judgement of success comes internally from the scientific discipline itself; yet the funds come externally from the public. This dichotomy of funding and judging raises the problem of monitoring the quality of the product. Hagstrom states that: "The producer of professional services must be strongly committed to higher values. He must be responsible for his product....Without them (disciplinary social pressures), scientists would tend to respond more readily to the goals and standards of nonscientists." (W.O. Hagstrom, *THE SCIENTIFIC COMMUNITY*, N.Y.: Basic Books, 1965, pp. 20 and 12.) This control on scientists and on the quality of their work is maintained by distributing rewards through the discipline.

Thus the biggest awards in physics, such as the Nobel prize, or membership in the National Academy of Sciences, are decided by fellow scientists. A faculty member gets promoted or tenured by his departmental chairman with advice from his departmental peers -- on the basis primarily of his contribution to physics knowledge (publish-or-perish); and he obtains mobility by national recognition for his physics.

Since the present structure of the physics community has been successful in producing high-quality physics, any changes from tradition will likely have costs as well as benefits, with the costs probably in the quality of physics. Not that this is a priori an unbearable cost, but we should be aware of it.

There has been expressed a demand for broadening the curriculum, for more interest in industry. But applied physics and industrial work are looked down upon by the physics community, because industrial work reduces loyalty to the discipline. (See W. Kornhauser, *SCIENTISTS IN INDUSTRY*, Berkeley: Univ. of California Press, 1962.) In industry it is the solution of the problem that interests the employer, not the quality of physics per se. The industrial reward structure reflects this, as physicists' loyalties are "bought off" by higher salaries, with pay raises and promotions given on the basis of the usefulness to the employer. If we want to maintain physics quality, we cannot be too enthusiastic about increased orientations toward industry.

There has been a call for increased interest in teaching physics. But the act of teaching makes at very best only an indirect contribution to physics as a knowledge-gathering discipline. Thus Hagstrom claims: "This is one way in which the strictly scientific publication differs from the text or the scientific popularization; the response by the audience of the latter are valuable only with respect to the writer's conception of himself as a teacher. These audiences are not, or are not considered to be, capable of criticizing the substance of his work and therefore not capable of recognizing his originality." (p. 210.) Thus we will have difficulty encouraging more interest in physics teaching. The rewards for good teaching show this. A good text may bring royalties, but little credit with the physics community. In the case of the good-teaching award there is the suspicion that the teacher was more interested in entertaining the students than in getting the knowledge across.

More interdisciplinary orientations have been requested. The problem again is quality control. Who is to judge the quality of interdisciplinary work? It is tempting in such areas to do "quickie" work, with confusion between newness and quality-originality. Rewards in such areas then usually come when this interdisciplinary area is turned into a new internally controlled discipline with its own students, degree program, and journal.

More service to society at large has been suggested. The problems with such work is that it appeals to the "great unwashed" public for funding in terms of its usefulness rather than its quality. It raises questions about the scientific reliability (and ability) of the physicists engaged in such work.

If the physics community does decide that it is willing to accept some loss in the quality of physics in order to achieve greater social goals, than there are three approaches that might be taken.

(A) We might change parts of the physics curriculum to add applied-physics, teaching or management courses. But there may be too many different directions to pursue, and I suspect some of the unique attributes of thinking about phenomena as a physicist would be lost for the students.

(B) We might modify the reward structure for physicists, by adding more applied-physics APS prizes, as well as national good-teaching awards. But these changes would require modification of an enormous amount of institutional tradition. Such large changes in scientific institutions would be the most destructive of all for the quality of the physics discipline.

(C) My one concrete suggestion is to indeed broaden the physics Ph.D. curriculum -- just a little. Let us give our graduate students a course to help them view their discipline from the outside by having them take a course on: the external history, the politics and/or the sociology of science. The course would have to be taught in a genuinely outside way to give a critical analysis of the institutions of physics. The students would then understand why physics is structured as it is, and they could make their career choices in a more informed way to minimize their future frustrations. It is a change of attitude that is required, not a change in curriculum. The cost of such a change would be some time loss, perhaps an increase in student cynicism leading to a possible reduction in the devotion to physics that maintains quality, and an outside review of physics. But we must decide what loss of quality we are prepared to bear, and then design institutions to minimize that loss.

"Crisis Brings Scrutiny"

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In spite of increased liberalization of the graduate environment there appears to be an increasing discontent with the practices in physics graduate education. Perhaps the disillusionment results from the increasing disparity between the traditional image of physics as a profession and its contemporary practice. One aspect of traditional practice in physics which is particularly sensitive to economic pressure is the patronage system (in part, senior faculty providing positions by phone call in return for allegiance of graduate students even beyond their degrees). Indeed, when research grants are available and physics departments are expanding their educational base, the patronage system may even be justified during a manpower shortage. It does, however, foster an attitude of dependence and lead to a great deal of inbreeding neither of which fosters development of peer group (faculty and graduate students) attitudes in graduate physics departments.

Coupled with the patronage system are the overriding economic considerations in the form of grantsmanship, which becomes a success criterion for faculty. Often young faculty become so caught up with the acquisition of money that accounting becomes more important than scholarship. Availability of grants to junior faculty becomes more difficult as success comes in improving faculties over a wider geographic distribution.

The apparent lack of fulfillment of the expectations of sufficient numbers of students and younger faculty may have its origins in these economic facts

of life which affect both students and faculty. Is it possible that reduced funds for graduate programs expose the inequities of the graduate student-faculty (patron) relationship by reducing the tolerance of the students? This tolerance may be fading because of a more acute sense of desertion by a system which establishes as its first priority the enhancement of patrons' privileges (release time, summer salaries, etc.). Is it also possible that the concept of "in loco parentis" is disappearing in graduate schools in favor of a vested self-interest mode of behavior? Although vested self-interest may appear cynical, it is a more realistic premise for graduate students to adopt than a faith in altruism of senior faculty. No longer will it be necessary to tolerate poor instruction, irrelevant requirements, unreasonable work loads. The rewards for suffering in silence are quickly disappearing, i.e., placement by the faculty phone call in postdoctoral positions, employment in Ph.D. institutions, utilizing the patrons influence through multilayered generations of cloned research specialists. Even the most optimistic projections see substantial decreases in postdoctoral positions, very few tenured faculty positions, and the need to consider postdoctoral research in areas of applied physics. These conditions tend to sever the umbilical cord which connects the lineage of specialists over the generations and to negate patronage. Although, representing traumatic stresses in the structure of the physics community, these also foster a time when traditional values may be questioned with decreased immunity and the graduate student can emerge from the cocoon of "in loco parentis" to shoulder the full responsibility of colleague status. Thus, they will be able to participate in the forming of their own educational and professional futures as well as rattle the cages of anachronism which surround much of the educational and scholarly activity of the physics community. It is an increased burden for the graduate student at a time when personal long

range goals are difficult to formulate but the circumstances do offer the opportunity to have an impact on what might someday become traditions in physics graduate education.

Since it appears to me that the basic impetus for the review of traditional values of the physics community is economic, it is appropriate to search for economic means to alleviate the problem on the short term (or 5 years) for students who entered a system whose rewards have changed so radically. I would suggest a realignment of research funds to emphasize the broadening of the doctoral physicists into applied physics areas (solid state, acoustics, biophysics, etc.) through postdoctoral training. Specifically, give preference in funding to two year postdoctoral positions in applied areas of research with stipulations to encourage applicants whose research experience was more esoteric. Long term solutions will hopefully eliminate some of the mystique of professor-student relationship and develop a peer group attitude which will foster an emphasis on scholarship rather than accounting in universities.

Attitudes Towards Science in the Congress

Benjamin S. Cooper

Committee on Interior and Insular Affairs
United States Senate

Large numbers of scientists have been employed by the Executive branch of the Government, for example, to staff research efforts, to provide a scientific capability to Federal agencies with technical responsibilities, to direct the disbursement of Federal funds for technical projects or to advise the Executive generally. The Congress, on the other hand, has not employed scientists at all extensively despite a growing feeling that technical literacy is desirable and occasionally crucial for issues the Congress must resolve. The American Physical Society has joined with other professional societies in attempting to increase the in-house scientific capability of Congress by providing interns to work in Congressional offices. This program attempts to provide a communication link at the end closest to the Congress, while hopefully influencing attitudes about scientists as potentially useful contributors to the legislative process. Attitudes of scientists may also require change. Some implications of this interchange for science education will be discussed.

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- * Sponsored, with the AAPT, the August 1974 conference at Pennsylvania State University: "Tradition and Change in Physics Graduate Education." The July 1974 Princeton University summer study in "Efficient Energy Utilization" was also organized by the Forum; and Forum/AAPT will sponsor a symposium on "Course Curriculum in Physics and Society" at the 1975 APS/AAPT annual meeting in Anaheim.
- * Initiated the APS/AAAS Congressional Fellowship Program.
- * Inaugurated two annual awards: the Leo Szilard Award for physics in public interest, and the Forum Award for promoting public understanding of the relation of physics to society.
- * Investigated the effectiveness of the APS Doctoral Employment Information Service, and considered many aspects of the current job market in physics.

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