

# WHY THERE IS A JOB SHORTAGE

Careful evaluation of trends in science-manpower needs can indicate the best directions for research support and help us avoid future gaps between supply and demand.

Wayne R. Gruner

FOR SOME YEARS the training of PhD scientists has been advertised as a major goal of public science policy. We all believed that the demand for these scientists was inexhaustible, and increases in federal support for scientific research have often been advocated on the grounds that the research activity was needed to train graduate students, whether or not the anticipated scientific results were urgently needed for any other reason. The largest component of federal obligations for university science, in fact, goes to pay the salaries of research scientists and of their students, so that allocation of manpower may be the most important question in federal science policy. (We, of course, can only provide incentives; people allocate themselves as they wish.)

The hypothesis of an insatiable demand for PhD scientists has recently begun to look somewhat less plausible than before, and this situation has serious implications for the rationale of research support. We need to look carefully at the statistics that indicate what the market for physicists is likely to be in the next few years, as a guide both to universities and to government policy.

University scientists have taken an attitude toward self-reproduction that is very different from that of the American Medical Association, the Philadelphia Plumbers Union or the San Francisco Harbor Pilots Association. Many physicists of my acquaintance are rather critical of the training and accreditation policies of these and other organizations that seek to limit their numbers. But, whatever else you can say about them, such policies at least show some regard for the principles of supply and demand. The academic science community, by contrast, has devoted a very large fraction of its capacity to self-reproduction, to the increase of graduate teaching capacity. Everyone worked to satisfy the recognized need for faculty expansion as rapidly as possible. Because it was said not only that there was a shortage of PhD scientists, but also that this shortage was certain to continue, that it was in the nature of things because "we live in an increasingly technological society and our technology is science based."

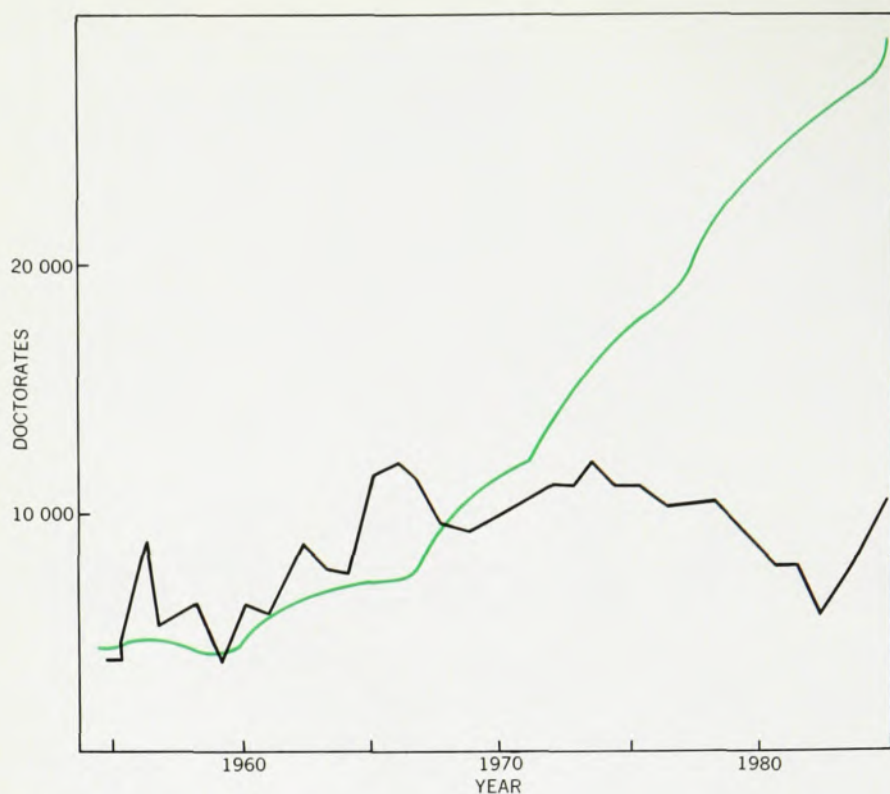
We have to be rather careful about these generalizations. Just think how, at the turn of the century, someone might have forecast future needs for

farm labor. If he had been farsighted about the growth of the US population, he probably would have concluded that a very large increase in the total number of farmers would be needed by 1970. As a result of the industrialization of farming, of course, the needs turned out to be very different. No trend lasts forever; there

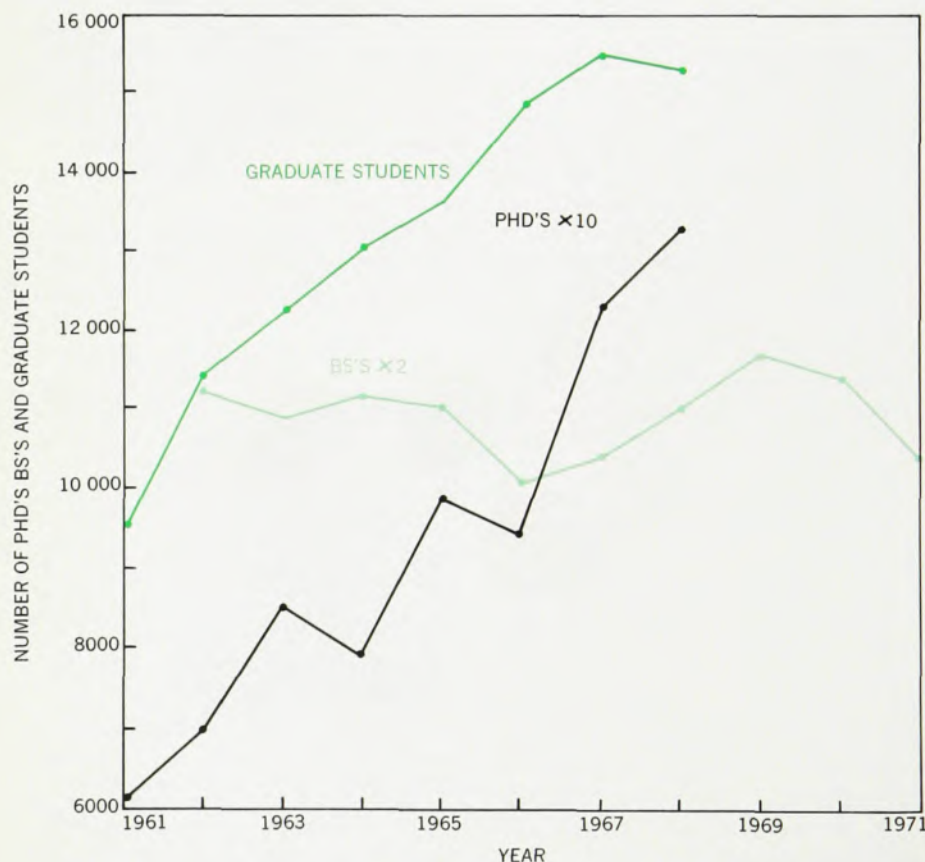


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**SUPPLY AND DEMAND.** PhD's available (color) and required (black) to meet needs for faculty growth in all disciplines, as predicted in 1965 by Allan Cartter. Note that supply was predicted to exceed demand by the year 1968. —FIG. 1



**PHYSICS STUDENTS.** Available data for combined physics-astronomy enrollments indicate continued PhD production (black, multiplied by ten) of about 1300 per year. Graduate student enrollments (dark color) and bachelor's degrees (light color, multiplied by two) appear to be leveling. Data for 1969-71 are estimates. —FIG. 2

are breaks in historical trends, and these breaks may greatly alter the need for various kinds of activity. One currently significant transformation of this kind appears to be the onset, in our society, of what economists and social philosophers call<sup>1</sup> a "post-industrial condition," and this situation deserves some thought.

### Evaluating evidence

We ought to pay tribute to a very foresighted paper in the past literature that "glows in the dark." In 1965, Allan Cartter, now chancellor of New York University, presented<sup>2</sup> a "faculty-growth forecast model" (see figure 1). Cartter's analytical workmanship was superior, and his conclusions were, in part:

"The preceding analysis suggests that educators have been too pessimistic about the adequacy of both the present and future supply of college teachers. . ."

"... if the projections of total college enrollment and of doctorates to be awarded are even approximately correct, the sellers' market for college faculty will quickly disappear in the early 1970's. This has many implications for public policy and for the nation's colleges. . ."

"Given the time lag between entrance to graduate school and completion of doctorate, it is conceivable that graduate education facilities might be expanded too rapidly by basing decisions on degrees awarded in the recent past. . ."

"... a serious question of public policy may be whether or not it is desirable to encourage many new institutions to enter the doctoral field."

Cartter's conclusions were not sufficiently heeded at the time. About two years later in 1967, however, many of us began to sense some change in conditions, and we began to suspect that Cartter might be right. There remain some skeptics who point out that much of the evidence for a dislocation is of the kind described as "anecdotal." Certainly anecdotal evidence is not the very best kind, but, just as certainly, a skilled policy maker has to look at such evidence and judge ad hoc whether it is meaningful or merely eccentric. This scrutiny is particularly necessary for scientific manpower



## APS VIEWS THE FUNDING CRISIS

In the past 25 years strong public support for scientific research has assisted this country to achieve preeminence in science and in its applications to industry and human welfare. Recent interruptions, uncertainties and cancellations of this support are now producing increasingly severe difficulties for American science. Within physics, every major field of research has been affected. The immediate consequences are severe: orderly programs stopped, resources inefficiently used, many highly trained scientists suddenly unemployed. The long-range effects will be even more serious, for productive research in physics cannot be turned off and on by the year. To recover ground lost by disruption of such work will cost far more, in the end, than to carry on an orderly program.

In the universities, research and the training of scientists are interdepend-

ent. Termination of research support cuts down the supply of scientists five to ten years later; it can affect the future even more profoundly by discouraging students at an early stage from seeking careers in science.

Turning off fruitful research means fewer discoveries, fewer new ideas and slower progress in the technologies nourished by new scientific knowledge. Opportunities in physics are as challenging as ever. We can look forward to striking advances in our understanding of the fundamental laws of nature and to wider application of new physical knowledge to human welfare. Science has illuminated our world and applied science has given man opportunities for a better life. The problems we face as a nation call for more knowledge, not less, and better technology. Better technology must be based on more extensive understanding of sci-

entific facts and possibilities.

The emergency has received recognition in the Congress. Its implications have been plainly described in statements by the Committee on Science and Astronautics and its Subcommittee on Science, Research and Development. The action initiated by the Committee to augment the funding of the National Science Foundation is a significant step in the preservation of our vigorous national program in science. Other steps are needed.

The health and development of science over the past 25 years has been an indispensable source of strength for the country. Present policies with respect to research and training will profoundly affect the nation's welfare and economy a decade or more from now.

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policy because of the degree of anticipation required; scientists remain in the work force for 30 to 40 years, and current policy can exert influence over a very long time. Changes in policy, moreover, do not produce substantial effects until several years after they are instituted. On the other hand, policy makers can scarcely afford to wait until a problem has been perfectly documented by statistics gathered post facto.

It is true, however, that anecdotal evidence can be especially misleading in an academic employment market. The psychological leverage is enormous, and Mr Micawber's famous observation about supply and demand is very appropriate. When things become a little uncertain, universities withhold job offers while they wait to see what will happen, and prospective employees flood the market with multiple applications. The visible evidence, then, is of an enormous shift in the ratio of applications to announced vacancies. There is also a domino effect. Suppose university A considers adding an assistant professorship, for which a postdoctoral associate at university B has applied. Suppose that a graduate student at university C has applied for the postdoctoral position at B. If, for some reason, A delays a decision on appointment of the assistant professor, B will delay about filling its postdoctoral position, and the student at C finds himself in doubt about his future. The chain of contingency can be even longer and the psychological multiplication factor corres-

pondingly greater. Numerical estimates are extremely desirable.

### Estimates

Can we estimate, although in a crude manner, what a reasonable person could expect the physics manpower situation to be like for the next few years? If this crude estimate agrees reasonably well with our subjective perception of the situation, then our confidence in both will be increased. If the qualitative conclusions are so strong that they can withstand considerable changes in the assumptions or magnitudes involved, we can feel that we have some basis for action. If the results are borderline, we can always go back and try for a more refined estimate.

Whenever we try to count such things as PhD physicists, or physics faculties, or undergraduate student en-

rollments, we encounter many ambiguities. Where do physicists end and chemists begin? Are fiscal years or calendar years more appropriate? Do we convert part-time students to "full-time equivalents" or not? And no one quite knows how to count the foreign-national students, many of whom do remain in the US. The difficulties are legion, and the statistics are crude and unsatisfactory by the standards of a physical scientist. They are, nevertheless, worth examining.

Bachelor's degrees in physics, graduate-student enrollments and PhD awards are shown in figure 2. (These data, and the others we will consider, combine physics with astronomy.) Trends here strongly suggest several years' PhD production at a steady level slightly greater than 1300 per year. Table 1 shows the physics faculty at various kinds of academic institutions.

Table 1. Distribution of Faculty Members by Type of Institution

| Institution | Number of physics faculty members |      |      |      |      |        |
|-------------|-----------------------------------|------|------|------|------|--------|
|             | Academic year                     |      |      |      |      |        |
|             | 1963                              | 1964 | 1965 | 1966 | 1967 | 1968   |
| Type 3      | 2928                              | 3149 | 3570 | 3980 | 4491 | 4854   |
| Type 2      | 893                               | 903  | 935  | 1025 | 1194 | 1225   |
| Type 1      | 1685                              | 1675 | 1827 | 1944 | 2101 | 2277   |
| NPM         | 703                               | 783  | 836  | 906  | 821  | 840    |
| 2-Year      | 728                               | 841  | 851  | 1000 | 1176 | 1248   |
| Technical   | 133                               | 145  | 133  | 142  | 149  | 131    |
| Total       | 7070                              | 7496 | 8152 | 8995 | 9962 | 10 575 |

Adapted from American Institute of Physics Directory of Physics and Astronomy Faculties, AIP Publication No. R 135. Types 3, 2 and 1 offer physics major to doctoral, master's and bachelor's level respectively; NPM refers to those four-year institutions that offer no physics major.



Note that the entry for academic year 1967-68 is about 10 000. Undergraduate enrollments are projected by the US Office of Education. The size of the 18 to 22-year-old group is, of course, knowable with great precision in advance, and the Office of Education has projected undergraduate enrollments increasing with approximately double the logarithmic derivative of the size of this group. (This projection assumes that a steadily increasing fraction of the appropriate age group will attend college.) In the fall of 1967, the enrollment was 6.22 million; the office predicts an enrollment of 7.73 million in 1972 and 9.39 million in 1977. This estimated increase is 24% in the first five-year period and 21.5% in the second five-year period.

Age distribution is very critical for this kind of discussion. Table 2 shows the age distributions of those people who listed themselves as physicists or physics teachers in the 1968 National Register of Scientific and Technological Personnel.<sup>3</sup> Because these figures refer to the spring of 1968, I have identified them with academic year 1967-68. (This identification is not as exact as we might wish.) Figure 3 shows, in graphical form, the age distribution of those physicists and physics teachers who have PhD's. Superimposed on the same chart is a plot of the age-specific death rate. We can see that, when we set out to estimate the rate at which physicists die or retire, we are really computing the overlap integral of two functions whose magnitudes are nearly complementary. That situation is very familiar to physicists, but usually they find more solace in it than we are going to be able to find.

From Table 2 we can estimate the rate at which job openings occur due to death or retirement of PhD physicists already employed. From 1968 to 1973, about 650 positions might be vacated in this way. We have not included transfers into or out of physics, and have made the simplifying assumption that everyone who is 65 or older in 1968 would retire during the next five-year period.

These assumptions do not make a great deal of difference for our purposes, because 650 is just one tenth of the number of new PhD's in physics that we might expect to produce in the same period. In consequence of the strong skewing of the age distribution, a new physicist has only about one chance in ten of finding employment

this way, and it clearly does not matter whether that chance is slightly greater or slightly less.

Some stronger assumptions are probably of interest, so we have also estimated the total numbers of deaths and retirements of all people who responded to the National Register as physicists (see figure 3) whether or not they have PhD's. That number is about 1140. Because of the incompleteness of the register, we can estimate the total attrition rate arbitrarily at 1300; this figure corresponds to a total physics population of about 37 000.

To make a very optimistic estimate of the employment situation for new PhD's, we assume that everyone calling himself a physicist in the register is replaced upon death or retirement by a new PhD, whether or not he himself held a PhD. We assume also that the total physics faculties of all colleges, universities, junior colleges and technical institutions grow by an amount proportional to the increase in undergraduate enrollment projected by the Office of Education. This increase in faculty is 2400 in the 1968-73 period. Suppose that all of the faculty growth occurs solely by addition of new PhD's to physics faculties. In this limiting model then, only PhD's are appointed as college physics teachers, and every person calling himself a physicist in the National Register will be replaced, upon death or retirement, by a PhD. These assumptions correspond to hir-

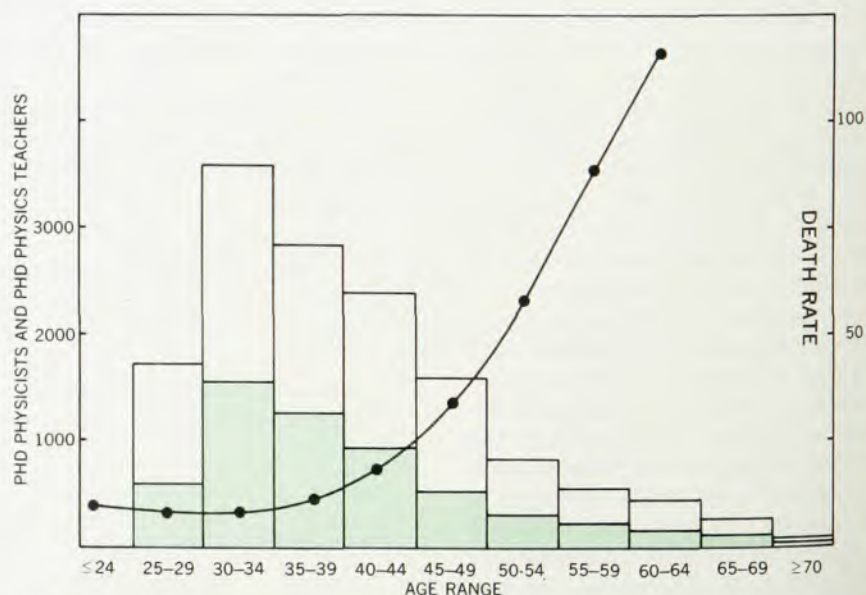
ing of about 3700 new physics PhD's in the five-year period. (About 1400-1500 of these physicists will be enriching the PhD mix above what has been conventional.)

In that same period, however, we expect to award about 6500 PhD's. This number may be held down artificially by, for example, lack of employment opportunities or the draft, but the response time to these factors is slow. Thus it is likely that 2300 to 2800 new physics PhD's will have to find new jobs that are not in post-high-school teaching.

### Nonacademic jobs

Some new jobs of this type are, of course, being created all the time. But the required rate is decidedly at the upper limit of the rate of expansion that prevailed in the preceding five years; this expansion we estimate at 2100 to 2300 over the period 1963-68. These five years, we must remember, were a period of rapidly growing federal research and development budgets. The new jobs, moreover, must be found in competition with a rising tide of engineering PhD's.<sup>4</sup> And industry says that it is not at present increasing the rate at which it hires new PhD's in physics; if anything, the contrary is true. We get some feeling for these factors by looking through Susanne Ellis's *Work Complex Study*, recently published<sup>5</sup> by the American Institute of Physics.

We are now about two years into



AGE DISTRIBUTION of PhD physicists (full bar height) and PhD physics teachers (colored portion) in 1968. Superimposed curve shows age-specific death and retirement rate per 5000 man years. Overlap between curve and bar graph is very small. Data are from National Register.

—FIG. 3



the 1968-73 period, so it is certainly not surprising that we are beginning to sense a serious dislocation in the supply-versus-demand situation for physics PhD's. Our estimates here indicate that the discomforts will intensify. The assumptions used are perhaps unrealistically optimistic, and really extreme assumptions would be needed for us to reach any other conclusion. Moreover, at the onset of a situation such as the one we have been considering, the system uses some of its elasticity, temporarily at least, to ease the perceived pressure. Thus we hear that physics departments have created a substantial number of temporary academic positions, that students have deferred completion of their doctoral work, and so on. Consequently the actual dislocation at this moment may exceed what we perceive.

### Projections

We can guess at the configuration three years into future. A rough idea of how the age distribution of physics PhD's might look in the spring of 1973 can be seen in figure 4. This forecast depends on PhD's being produced and finding employment as physicists according to the assumptions of the preceding sections. We can estimate death and retirement rates of the new distributions and try to estimate the market for new PhD's in physics in the five-year period between 1973 and 1978. This estimate is important because *people we admit to graduate*

*school now are going to receive PhD's in that period.* With the same assumptions as before, replacement and academic expansion could absorb about 4350 new physics PhD's, or 650 more than in the current period. This degree of increased use might, if expansion of nonteaching opportunities can be restored and maintained, be in approximate balance with present supply levels. If, as seems quite possible, supply were to contract spontaneously by some 200 to 300 PhD's per year, a sellers' market might conceivably recur by the late 1970's. Therefore, the possibility of overreaction is a real one. Here again we see the extreme importance of anticipation. Convulsive adoption at this time of those policies that would have been wise

four or five years ago will simply compound the error.

### Need and supply

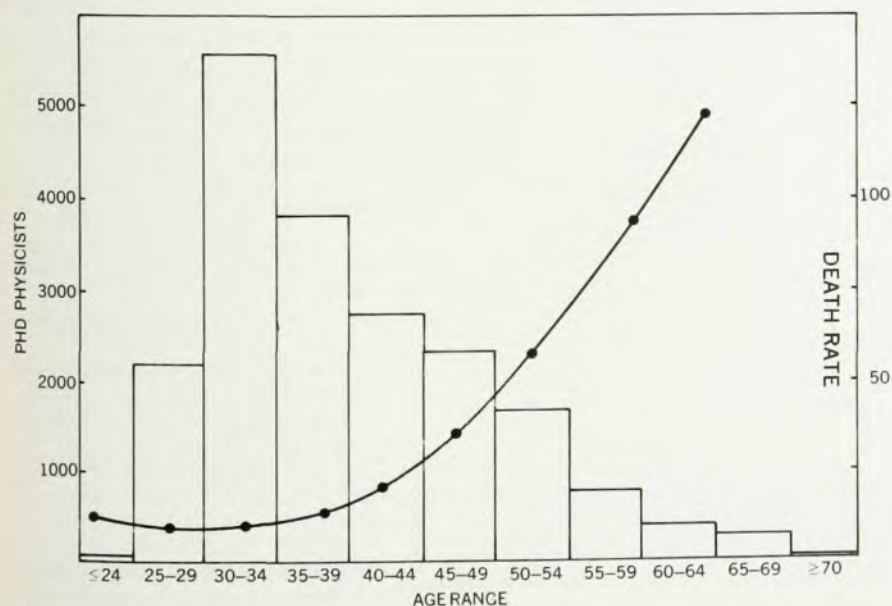
We have a challenge. It is difficult to escape the conclusion that in the five-year period 1968 to 1973 at least several hundred and possibly more than one thousand new physics PhD's will have to find employment that has no precedent either in traditional academic employment or in previous expansion rates of industrial and government employment. The duration and intensity of this situation depend upon both future "needs" and future supply.

Future supply is quite uncertain because it is difficult to predict either the behavior of students or the manner in which young people will make career decisions in the next few years. There appears to be evidence that some students at least are shying away from careers in the physical sciences. But because this effect, if it exists, is overlaid with artifacts of military selective service, it will be several years before we can estimate the underlying trend in physical-science enrollments.

Is there such a thing as true need? Need depends on what kinds of tasks you think require the attention of physics PhD's in your society, and this decision is clearly a matter of judgment. Physics PhD's are gifted people and very well trained, and I do not expect to see the day when there is an unemployed one. Rather, I expect to see physics PhD's in very unfamiliar kinds of employment. The great challenge facing us at this point is to define new roles for physicists in an imaginative way that is responsive to the current preoccupations of the society. It remains to be seen

Table 2. Age Distribution of US Physicists

| Age    | All<br>Physicists | Deaths<br>All<br>Physicists | PhD<br>Physicists | Deaths<br>PhD<br>Physicists | All<br>Physics<br>Teachers | PhD<br>Physics<br>Teachers | Deaths (and<br>Retirements)<br>Per 5000<br>Man-Years |
|--------|-------------------|-----------------------------|-------------------|-----------------------------|----------------------------|----------------------------|------------------------------------------------------|
| ≤24    | 564               | —                           | 6                 | —                           | 127                        | 2                          | 9.1                                                  |
| 25-29  | 7950              | 63.6                        | 1718              | 13.7                        | 1637                       | 574                        | 8.0                                                  |
| 30-34  | 7431              | 66.1                        | 3590              | 32.0                        | 2097                       | 1553                       | 8.9                                                  |
| 35-39  | 5329              | 69.8                        | 2848              | 37.3                        | 1562                       | 1242                       | 13.1                                                 |
| 40-44  | 4230              | 86.3                        | 2383              | 48.6                        | 1140                       | 927                        | 20.4                                                 |
| 45-49  | 2994              | 100.9                       | 1591              | 53.6                        | 814                        | 616                        | 33.7                                                 |
| 50-54  | 1615              | 88.5                        | 827               | 45.3                        | 429                        | 301                        | 54.8                                                 |
| 55-59  | 1070              | 92.2                        | 563               | 48.5                        | 342                        | 218                        | 86.2                                                 |
| 60-64  | 748               | 95.9                        | 440               | 56.4                        | 276                        | 166                        | 128.2                                                |
| 65-69  | 388               | 388.0                       | 246               | 246.0                       | 148                        | 101                        | 1000.0                                               |
| ≥70    | 91                | 91.0                        | 74                | 74.0                        | 31                         | 22                         | 1000.0                                               |
| Totals | 32 491            | 1142.0                      | 14 311            | 655.0                       | 8620                       | 5732                       |                                                      |



PROJECTED AGE DISTRIBUTION of PhD physicists in 1973. Superimposed curve shows age-specific death and retirement rate per 5000 man-years. We can use this distribution to estimate what the market for physicists will be in the five-year period from 1973 to 1978. —FIG. 4





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what skills and abilities trained physicists possess that are relevant to the "problems of society" about which we hear so much.

I think that the employment pressure on physics PhD's must be considered to have roots deeper than the current hesitation in federal obligations for research and development support. It involves such questions as: "How much expansion of higher education in physical science is purposeful at the undergraduate and graduate levels?" The answer again depends upon one's definition of the societal roles of trained physical scientists. That definition is one to which we must give enterprising and imaginative attention.

We could easily overreact, and the supply-versus-demand situation may be different in six or seven years. In the meantime, however, some substantial number of (mostly) young physicists will be caught in a temporary squeeze. At the risk of moralizing about the difficulties of others, I believe that they must adapt, and not panic and lose their nerve. I believe that physicists, being very gifted, should pride themselves upon their adaptability. Joshua Lederberg says in a different context that "adaptability is man's unique adaptation." (He made this statement in a discussion of eugenics and population engineering, so perhaps the context was not really all that different.) Each time a physicist demonstrates his effectiveness in a new role, he opens the way for others to follow him and enhances the public image of physics as a profession. Clearly everyone concerned must help and encourage young physicists to pioneer the necessary adaptations.

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