Scientific employment in a tightening economy

A new survey shows salaries keeping up with inflation, shifts toward interdisciplinary work, but underrepresentation of women in higher paying positions.

Beverly Fearn Porter and Roman Czujko

Despite the tightening economic situation, most scientists working in physics and related areas are doing relatively well. The latest statistics on members of the nine scientific societies that constitute the American Institute of Physics show overall salaries keeping pace with inflation, and the unemployment rate remaining very low at 1%. However, the slow shift away from teaching as a principal work activity appears to have accelerated. Accordingly, university employment is declining vis-à-vis industrial employment. At the same time, members of the scientific societies are continuing their westward geographical shift, particularly to the sunbelt states and away from several northern regions, most notably the north central. Although the membership of the societies is gradually aging, new members are joining, frequently from backgrounds quite different from those of their predecessors. Vacuum science, high polymer physics, chemical physics and optics are four subfields that gained a larger number of new members during the past two years.

These are some of the major findings of a 1981 random-sample survey of over one-sixth of the approximately 50 000 US and Canadian society members. This survey, the third and largest in a series of annual AIP surveys, included a "longitudinal" sample—a smaller group of scientists followed since 1979—which gives a glimpse into the dynamics of society membership.

In this article we will focus on the employment situation of society members in 1981, but we will include some speculation as to how their situation will change in the future. More detailed data are available in the full membership profile[1] that came out of the survey. A report that will be available later this year on the 1982 employment situation of society members will benefit from a more extensive analysis of an enlarged longitudinal sample.

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Who are society members?

Society members are widely distributed throughout the United States. However, as figure 1 shows, they are most heavily concentrated in ten states and the District of Columbia. These areas contain one-third of the US population but nearly 60% of all the society members. Regional moves made by society members during 1981 produced a marked membership growth in the sunbelt states and an appreciable decline in the north central states. These net shifts in region of residence are general indicators of opportunities for scientific employment. They reflect the continued growth of high-tech industries in the sunbelt and the serious economic difficulties in many sectors of employment in the northern states.

The membership of the nine AIP Member Societies (which are listed on page 4) exhibits both cohesion and heterogeneity. As a whole, the membership has been trained in and is currently working in physics or related fields of science and engineering. Most members are male (94%), white (92%) and US citizens (90%). In the past two years we have seen slight increases in female and foreign society members; the percentages are up by one and two points, respectively. The preponderance of society members—nearly 70%—hold PhDs.

While the majority of members identify themselves professionally as physicists, there is a substantial representation of engineers (16%), chemists (10%) and astronomers (4%), in addition to a broad variety of other professionals. Although each of these other professional groups is small in terms of the overall membership, some do form a larger proportion of specific societies. Psychologists, for example, play an important role in the Acoustical Society of America, and a substantial number of materials scientists can be found in the American Vacuum Society. While professional self-identification is one of the slowest changing variables, it is clear that physicists represented a somewhat lower proportion of the society membership in 1981 than they did two years before; chemists and other scientists increased their proportion somewhat. In part, this reflects the different characteristics of new members, fewer than half of whom identify themselves as physicists, and in part it is due to dramatic changes in the career directions of a small group of society members.[1]

Society members are a relatively young group: a third were born after the second world war and 42% received their degrees after 1970. However, between 1979 and 1981, the total society member population, including student members, aged by about $1/5$ of a year, raising the median age to 41.8 years.

Despite this slow aging, 15% of the total 1981 membership of the nine AIP Member Societies joined for the first time during the previous two years. As might be expected, these new members are considerably younger than other society members. While part of this is due to the large student component among the new members (over $1/4$), other society members also join at an early stage in their careers. The median age of the nonstudent new members is 33.6 years, compared with 43.6 for the continuing members. New members are also somewhat more likely than continuing members to be women, and considerably more likely to be foreign citizens, 16% in contrast to 5%.

Fewer than half the new members identify themselves as physicists; most consider themselves engineers, chemists and other professionals. New members also have somewhat different employment patterns. Fully 40% are employed by industry, a pattern that partially explains the overall membership's continuing shift towards industrial employment, a phenomenon we

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will describe below. New members, thus, clearly present a vibrant picture of their own. While they do not in themselves account for all the ongoing change in the composition of society membership, they are central to any understanding of the underlying dynamics.

Employment. While universities, primarily the province of the PhD, remain the predominant employer of society members, the gap between university and industrial employment is closing. Universities employ 35% of the members, industry 31%. In fact, recent PhDs are considerably more likely than older ones to be employed by industry and less likely to be employed by universities, as figure 2 shows. Other academic employment—colleges and secondary schools—primarily involve PhDs at the four-year college level and master's-degree holders at the junior-college and secondary-school levels.

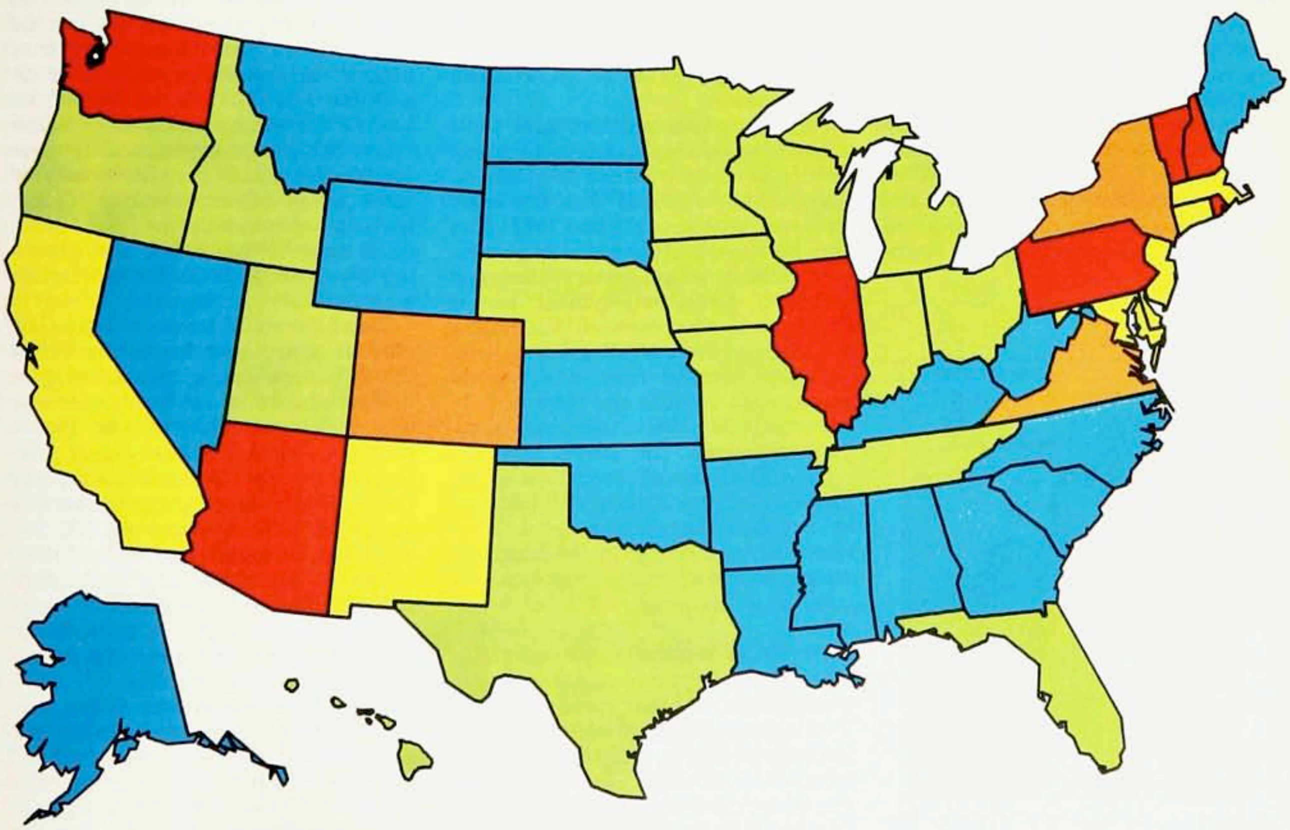
Although government, federally funded research and development centers, and nonprofit organizations employ society members at all degree levels, it is only in industry where one finds a full diversity of degrees. Industry is the major employer of people with bachelor's degrees, the central employer of those with master's and, after universities, the next largest employer of PhDs. During the past two years, industrial employment of society members has been on the increase, particularly among master's degree holders. Society members employed in industry tend to be concentrated in a relatively small number of large corporations. In 1981, 18 companies employed nearly one third of the members. The tail of the curve, however, was long, reflecting the many small companies that employ only a few society members each. These small companies are more likely than the larger ones to employ bachelor's and master's-degree holders and PhDs working in development, design and engineering.

While society members are involved in a broad range of work activities, nearly 70% are primarily engaged in basic research, teaching or applied research. In the past two years, the percentage involved in teaching declined by two points to 23%, while the percentage involved in applied research increased by a similar amount to 21%. This reflects the continuing basic shift in employer types mentioned earlier. For a given type of employer, the nature of a society member's work depends strongly on the member's highest degree. As figure 3 illustrates, industrially employed holders of bachelor's, master's and PhD degrees are generally involved in quite different work activities. Those with PhDs are much more likely to be involved in industry's applied research and its small amount of basic research. The difference between the work activities of those with master's degrees and those with bachelor's degrees is not as striking, but masters are more likely than bachelors to be doing some applied research while bachelors are somewhat more likely to be involved in design, engineering and other technical activities.

Where one is employed and what one is doing clearly has an effect upon salary. This should be kept in mind as we discuss salary structure in a changing economy.

Salaries

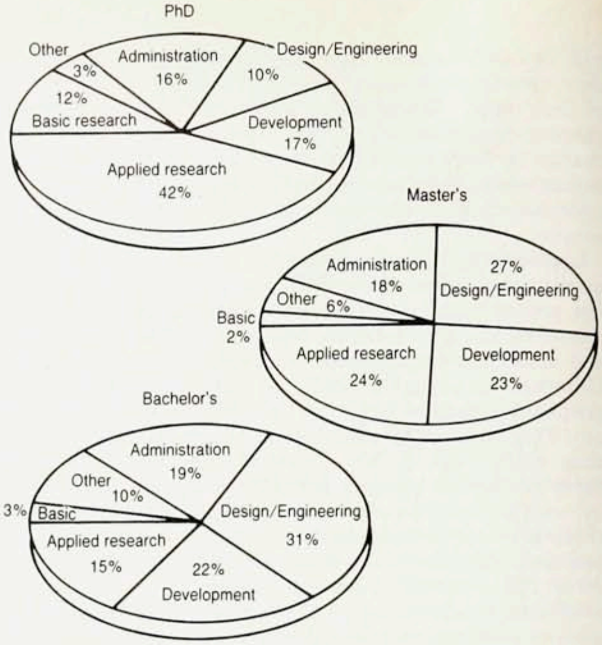
The year 1981 brought a tightening national economy, and although infla-



Geographic distribution of scientists. Colors correspond to the fraction of the general population belonging to any of the nine scientific societies that constitute the American Institute of Physics. Thus the map gives some indication of the degree to which each state's economy emphasizes scientific employment. In units of society members per 100 000 population, blue areas have 2–10; green, 10–18; red, 18–26; orange, 26–34; and yellow, more than 34. The national average is 22. Figure 1 tion was slowly being curbed, interest rates spiraled upward and budgets were cut. Unemployment, particularly in selected regions and industries, was severe; some companies, colleges and communities foundered. While 1982 finally saw some relief from the record-high interest rates, general unemployment rose to over 10%. Physicists, engineers and related scientists are hardly immune from such circumstances, but the effect on society members by mid-1981 was barely discernible, except in selected areas, which we will discuss. Although the effect of the generally deteriorating 1982 employment situation on society members remains to be seen, we expect some increase in the unemployment rate and a compression in the salary levels.

In 1981, the unemployment rate of society members hovered around 1% as it had two years earlier. While some increase in unemployment is expected for 1982, it is not likely to rise beyond 2%, with some regional variation. Science and engineering unemployment rates have, however, except in the very worst of times, been a poor indicator of the economic situation of scientists and engineers.

Salary levels are perhaps more relevant indicators. In 1981, the overall median salary for full-time employed society members was $35 000. Median salaries in the different academic sectors ranged from $22 000 to $30 000 depending upon the type of educational institution, while median salaries outside of academe were close to $40 000. These salary levels represented a 12% annual increment between 1979 and 1981, except in secondary schools and government. Secondary-school teachers received yearly increments of less than 8%. Thus, although all groups have not been dealt with equally in terms of salary changes, most society members kept pace with inflation between 1979 and 1981. While median salary increments between 1981 and 1982 are not expected to be as high, they are expected to be at or above inflation rates.



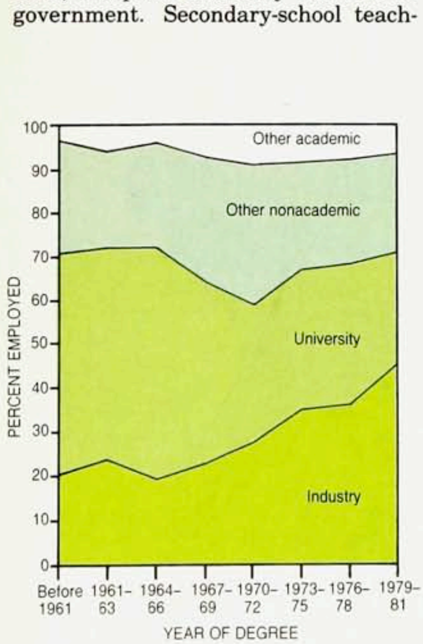
Work activity in industry as a function of employee's highest degree. Based on 1981 survey. Figure 3

Figure 4 presents salary data for a subset of the society members discussed above: members from our longitudinal sample who remained with the same employer between 1979 and 1981. The data for these individuals most accurately reflects actual salary increases within a given employment sector. (Individuals who changed employers, included in the overall gross figures, typically changed from one type of employer to another and were usually rewarded with substantial salary increments.[1]) Again, the lowest increase, both in absolute and percentage terms, can be found among those still teaching at the secondary-school level. The rather large increase in the nonprofit sector primarily reflects changes in salaries at university-affiliated hospitals.

Differences in salaries are associated with several factors in addition to or in combination with the type of employer. Two important factors are the level of the highest degree and the number of years of experience. The only type of employer for which there is a sufficient number of individuals for us to make statistically significant comparisons between all degree levels is industry. Society members with PhDs working in industry receive median salaries of $41 800, about $5000 higher than their colleagues with master's and bachelor's degrees. However, the age distribution is markedly different at each degree level, with bachelor's degree holders being the oldest. In terms of years from highest degree, the salary differential is even more pronounced, $10 000 or more at each level of experience. Median industrial PhD salaries range from $34 000 for society members with less than five years experience to over $50 000 for members with twenty or more years of experience. Median bachelor's degree salaries, on the other hand, range from $24 000 at the starting levels to $40 000 for individuals with extensive experience.

This differential between degree levels in industry, however, is dwarfed by the difference among master's degree holders who work in industry and those who work in secondary schools. Figure 5 underscores one of the central problems facing the scientific community today. While salary is hardly the sole reason for a society member's choice of employer, the large salary differentials between industrial and secondary-school employment for master's degree holders must be seen as a major factor affecting initial employer choice and later employment mobility.

Because three-quarters of the nonstudent society members who are employed full-time have PhDs, we will take a closer look at this group. The salaries of those with PhDs vary by work activity, employer and experience. As might be expected, those involved in teaching have the lowest median salaries, $29 000; those involved in administration have the high-



Type of employer by year of employee's PhD. Based on 1981 survey. Figure 2 est, $49 000. However, overall salaries show the greatest variation according to type of employer, with industry paying the most.

Salary variation for PhDs occurs not only between but within employer types. Figure 6 illustrates the large range of industrial salaries as indicated by the different median, quartile and decile salaries at each level of experience. Industrial salaries show the greatest range, particularly for employees many years from their degrees. This reflects both the varied career paths—research and engineering, or administrative—that are available in industry, and the broad diversity of companies that employ society members. Such experience curves present but one example of the rich and varied salary detail observed within each of the different employer types.[1]

Patterns of specialization

People who belong to the AIP member societies work in a broad variety of fields and subfields of science and engineering. In 1981, 65% were employed in physics and astronomy, over 15% in related fields of science, nearly 15% in engineering and 5% outside of science, typically in administration.

Within physics, the solid state remains the major research field of employment, followed by optics, which has shown a clear growth over the past two years. Plasma physics appears to have replaced nuclear physics as the third largest subfield of research work in physics. The following round out the ten largest employment subfields in 1981: elementary particles, chemical physics, acoustics, medical physics, atomic and molecular physics, and astrophysics. These subfields employ nearly 70% of those members conducting research in physics and astronomy. Although changes in smaller subfields are difficult to measure, it appears that employment has risen significantly over the past two years in fluid dynamics and vacuum science.

The major related fields of employment in science remain chemistry, materials science and computer science, with a notable increase over the last two years in the number of new society members working in chemistry. The primary engineering subfields in 1981, electronic and electrical engineering, were also the fastest growing during the past two years.

The fields and subfields in which members work are affected by a variety of factors. Certainly a central one is the level of highest degree. Two-thirds of the society members with PhDs are working in subfields of physics and astronomy, primarily the ten major research areas outlined earlier. However, physics education at the college level is also a major subfield. The employment distribution of PhDs in related fields of science and engineering closely resembles that of the overall membership.

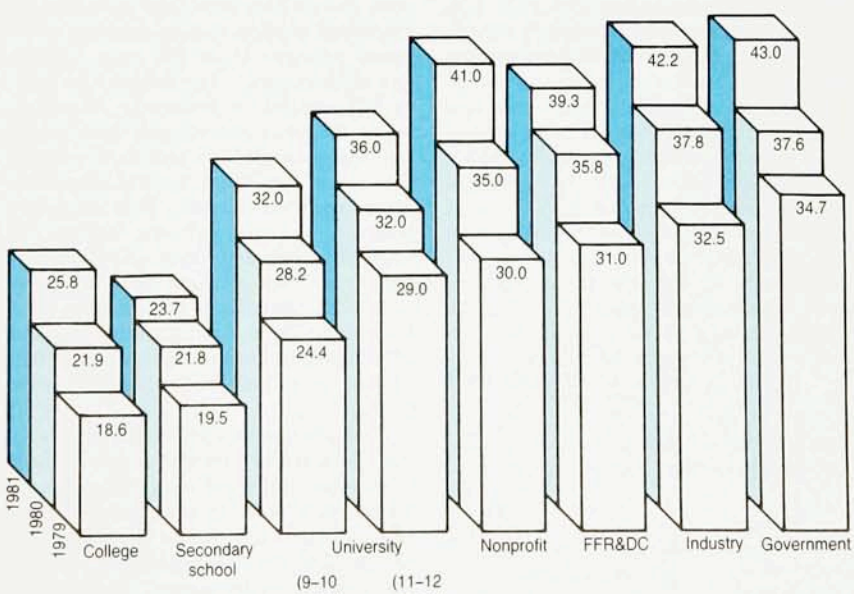
At the lower degree levels, physics subfield concentrations change. While many master's degree holders are working in physics education, it is more typically at the junior-college and secondary-school level. Outside of education, master's degree holders in physics are predominantly involved in optics, medical physics and acoustics. Among the bachelor's degree holders, involvement in physics education is less pronounced and is almost exclusively in the secondary schools. Those holding bachelor's degrees are primarily found in optics, acoustics and vacuum science. The mix of engineering and related science work fields is remarkably similar for the master's and bachelor's degree holders. Electronic engineering, general engineering, computer science, chemistry and materials science are the dominant areas of employment for holders of lower degrees who are working outside of physics.

When one examines the employment of society members in further detail, it becomes clear that there is a relationship between subfield of work and professional self-identification. All but a few of the individuals working in elementary particles, nuclear physics, low-temperature physics, plasma and solid-state physics consider themselves physicists. While most of the society members who are working in atomic and molecular physics and biophysics consider themselves physicists, some also consider themselves chemists, and in the case of biophysics, some also identify themselves as biologists.

Similarly, while the majority of those working in electromagnetism, electronics, optics and fluid dynamics consider themselves physicists, a notable number also consider themselves engineers. In many areas where society members are working, physics is not the primary field of identification. In acoustics and vacuum science there is a heavy mixture of engineers, as there is, of course, in the varied areas of engineering. In high-polymer physics, chemical physics and crystallography, we find a high proportion of individuals identifying themselves as chemists. The findings here highlight the interrelationships that exist among physics, engineering and related fields of science.

Secondary subfields. Approximately three-quarters of the members who note a primary subfield of work also indicate a secondary area of specialization. Based on this information, we have identified subfield constellations, that is, groups of interrelated areas of specialization. These constellations of subfields provide a more detailed picture of the type of work individuals are actually doing and also illustrate the natural clustering of related subfields. Figure 7 shows the most common patterns of interdependence among subfields. Working in multiple areas of specialization is particularly prevalent in industry and other nonacademic settings.

The examination of the nature of subfield constellations can help us understand the career paths of scientists. An individual's shift within a constellation of subfields may indicate typical

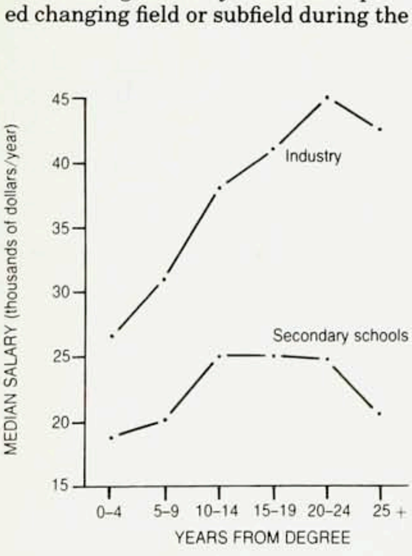


Median salaries as a function of employer, for the years 1979, 1980 and 1981. Based on individuals who remained with the same employer during those years. Numbers indicate annual salaries in thousands of dollars. Figure 4 career development, that is, a gradual shift in emphasis between related primary and secondary areas of specialization. In contrast, movement from one constellation of subfields to another may indicate a dramatic change in career direction. Future AIP studies will contain a more thorough analysis of the relationships within and between subfield constellations, with particular emphasis of the effect of specific changes on professional self-identification.

Despite the blurred edges between many fields and subfields of science, it is clear that there has been marked movement out of many of the traditional degree subfields of physics and into a number of the more applied and interdisciplinary areas of physics. Nuclear physics shows the greatest outmobility, with more than twice as many people having received degrees in nuclear physics as are currently working in that area. There has also been significant departure from the degree fields of low-temperature physics, elementary particles, solid state, and atomic and molecular physics.

On the other hand, there has been a marked influx of people into medical physics, acoustics, optics, geophysics and fluid dynamics. Apparently, the large subfields of physics with high outmobility provide versatile training and thus act as feeder fields for the more applied subfields of work. The mobility noted here, of course, is based on cross-sectional data and may have occurred at various points in time. However, our relatively small 1979–1981 longitudinal sample does provide a description of current changes in demand for scientists in the various subfields of employment.

One in eight society members reported changing field or subfield during the last two years. Figure 8 gives the areas of employment showing major net changes during the period. One should note that the median age of members reporting subfield shifts is 38, which suggests that subfield mobility may pervade a professional career.



Master's degree salaries in industry and secondary schools, plotted as a function of time from receipt of the degree. From 1981 survey. Figure 5

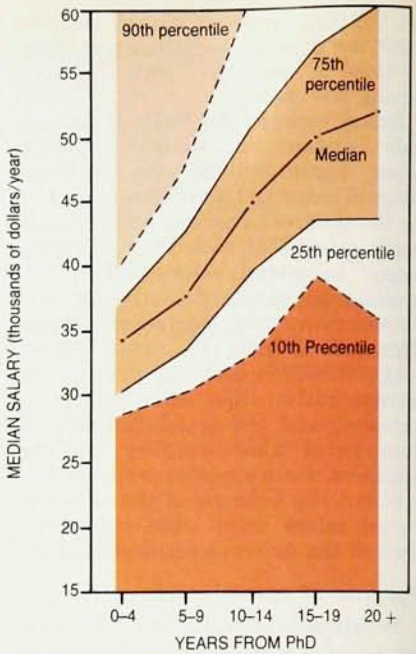
Women

The expanded 1981 survey has afforded a more detailed description of several small but vital subgroups. Here we will analyze the employment of female society members and give brief overviews of other groups: postdocs, the self-employed and Canadians.

Nearly 6% of all society members are women. This represents an increase in female society membership over the last two years. Women are less likely than men to work in industry, and more likely to work in the academic sector, with the largest difference appearing in secondary schools. Within industry, women are less likely than men to work in subfields of physics and more likely to work in the related sciences, most notably computer science. Women are also less likely than men to be engaged in developmental work. In both academe and industry, women are underrepresented in administrative positions.

Women in academe and industry, the two dominant sectors of employment, receive lower salaries than men. Although the number of women in our sample remains small, the data suggest that the factors affecting the salary discrepancies in industry are subtly different than the factors in academe. Within industry, the overall salary differences between women and men are especially pronounced. This is in part due to the fact that industrially employed women are an average of 11 years younger than the men. When age differences are controlled, the salary differential is reduced. However, while the youngest women earn just a few thousand dollars less than men of the same age, the income disparity grows with experience. This is in part because the two groups engage in different work activities. As we noted earlier, women are less likely to move into administration, the highest-paid positions. Thus, within industry, salary differences between women and men appear to reflect the available career paths.

Over the last two years, academically employed women received lower salary increases than their male colleagues—\$4000 vs. \$7000. In part, the differential increases are due to overrepresentation of women in secondary schools, the lowest paying sector. However, a related reason for the low salary increments is the type of academic positions held by women. Within each age group, women employed full-time in university and four-year college settings are typically held in lower-paying, entry-level positions such as assistant professor, research associate, lecturer and instructor. In contrast, men are more readily promoted into tenured, higher-paying, professional ranks. While those few women who do get promoted earn salaries comparable with those of their male counterparts, their median age is four years higher than that of the men. Clearly, it takes longer and is more difficult for a woman to be promoted than a man.



Salary structure in industry, as a function of the time since the employee received the PhD. From 1981 survey. Figure 6

Other groups. Approximately 6% of the PhDs in AIP member societies held postdoctoral positions in 1981. Three-quarters were working in universities while the remainder were employed in federally funded research and development centers, industry and government. Most postdocs appeared to be following the classical pattern of using the postdoctoral position to gain advanced research expertise or, at least, more time in their dissertation areas. In contrast, some appeared to be using their postdoctoral positions to develop new skills or to use their skills in new areas. Thus, postdocs in chemical physics, biophysics, biology and chemistry frequently had not earned their PhDs in those areas.

The self-employed make up a very small proportion of the society membership, slightly more than 2%. In contrast to the overall membership, less than half of the self-employed have PhDs and almost half are working outside of physics in related engineering, science and professional fields, where they are typically engaged in development, design, engineering and consulting. The self-employed are of special interest because the Bureau of Labor Statistics predicts that small scientific consulting firms will be the high-growth sector of employment in the 1980s.

Canada is the residence of about 2000 members of AIP societies, over 3% of all the members. The Canadian society members are somewhat younger than the US members; they also are more likely to have a PhD and to be employed in the more traditional areas of physics than their US counterparts. In fact, over half of the Canadian members are employed in universities compared with only 35% of the US members.

Scientific societies face change

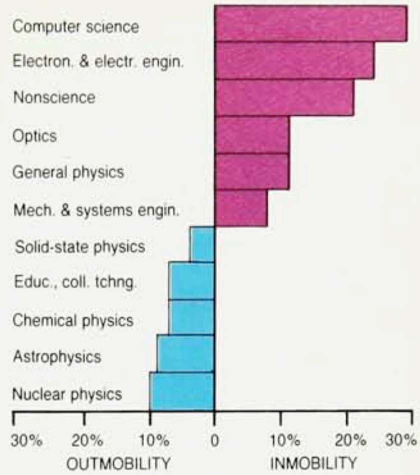
In highlighting the employment situation of society members, we noted, where feasible, changes that have taken place over the past two years. Although we saw some shifts, the overall structure remained relatively stable, as one might expect over such a short interval.

However, while net changes are seldom dramatic, the underlying dynamics of change may be considerably more volatile. New society members, graduate students on the verge of initial employment, and other society members considering major career shifts are dynamic elements of the membership. In each of these groups the representation of academic physicists is shrinking. At the same time, interdisciplinary industrial employment is growing, particularly among new society members.

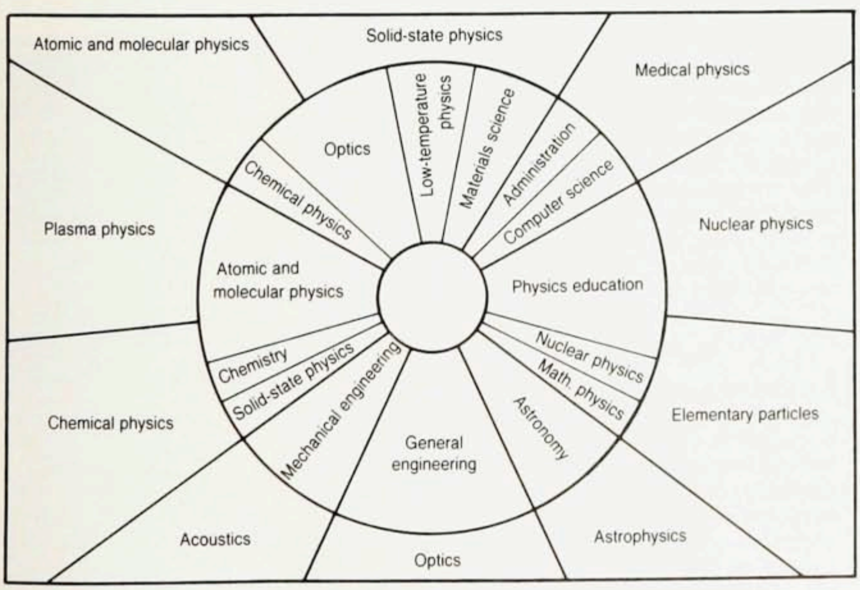
Attention to this shift in the professional emphasis of society members is important if scientific societies are to address the changing needs of their membership and stimulate continued membership growth. While the interests of the academic physics research community are always crucial, inattention to the broader, interdisciplinary concerns may produce a stationary, aging membership. As we will see, the nine AIP member societies have a rich interdisciplinary base.

Members of the nine societies have many common scientific and technological concerns, both in physics and in related disciplines; about one-fifth of the US and Canadian members belong to more than one of the AIP societies. With the exception of the Acoustical Society of America, all of the societies have a significant overlap in membership with the American Physical Society. The overlap between the American Association of Physics Teachers and the APS is particularly strong. In general, it is the university physicist who is most likely to hold joint membership with APS.

In addition to their common interest, however, each of the nine member societies has unique concerns and characteristics. Some societies, such as the American Association of Physicists in Medicine, the American Association of Physics Teachers, the American Physical Society and the American Astronomical Society have a strong base of academically employed physicists and astronomers. The AAPM has the highest proportion of members employed in nonprofit organizations, primarily hospitals. The AAPT is virtually the only society with a significant representation of high-school and junior-college teachers. The AAS, next to the AAPT, the most academically involved of the societies, is the major society where astronomers and physicists intermingle extensively. The APS, the largest of the nine societies, has a diverse but heavily research-oriented membership. The American Crystallographic Association, also academically based, has a very high proportion of chemists among its members.



Changes in field or subfield of employment during the two-year period 1979–1981. This figure shows the fields and subfields of major net change. Figure 8



Relationships between primary and secondary subfields of work. Primary subfields are in the outer portions of the figure. Secondary subfields, shown within the circle, reflect associated areas of specialization. Figure 7

In contrast, members of the American Vacuum Society and the Society of Rheology, two of the fastest growing societies, along with members of the larger Optical Society of America and the Acoustical Society of America, are predominantly employed by industry and include a relatively high proportion of engineers. While many members of these societies work directly in vacuum science, rheology, optics and acoustics, a significant number also work in a broad variety of related areas of physics, other science and engineering. The small overall shift toward industrial employment and the changing subfield mix mentioned earlier are in part a reflection of the growing predominance of these societies. To the extent that these societies continue to evidence high growth, they will affect the future composition of the total society membership.

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Reference

1. B. F. Porter, R. Czujko, *Society Membership 1981 Profile: An Expanded View*, publication number R-306, American Institute of Physics, New York (October 1982), available on request. Unpublished detail on individual societies is also available.