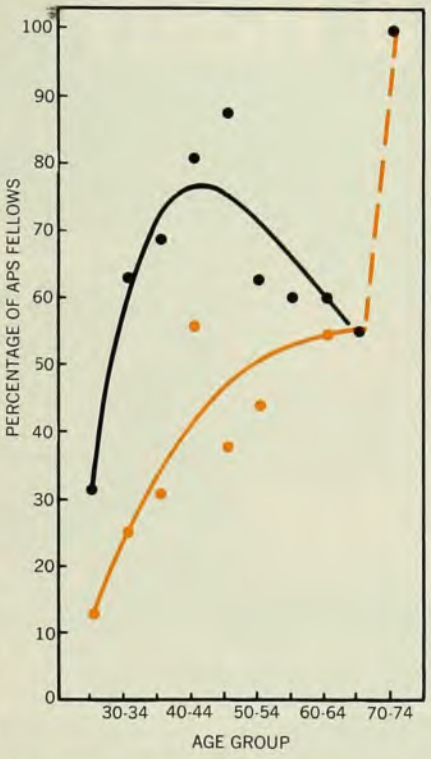
Do older physicists continue to achieve?

Scientists share with the rest of mankind the fate of growing older. Do we gain or lose by the experience? Do we achieve more or less as we grow in years? Do those of us who have been creative remain creative? To what extent are the answers to these questions a function of our environment and the attitudes and expectations of others? Two years ago I accepted an assignment—manager of education and personal development at the IBM Thomas J. Watson Research Center—based on the premise that scientific achievement and creativity can continue in individuals as they grow older, provided that their environment is suitably supportive and challenging. However, I also felt a strong compulsion to find out whether that premise was correct or not. Somewhat to my surprise I convinced myself that it was; I would like to share my experience with my fellow physicists.

My brief research into the variation of scientific achievement with age was based on easily accessible data: the *American Men of Science* biographies, publication counts *(Physics Abstracts)* and *Science Citation Indexes* of 1963, for Fellows of The American Physical Society with birth dates from 1884 to 1918. Admittedly, publication is not the only measure of achievement for scientists, but it is a particularly relevant one for the particular group sampled—Fellows of APS. Publication is a necessary and often sufficient measure of achievement to attain the rank of Fellow. Does the achievement continue into later years? To be fair it was necessary to remove from the sample those physicists who demonstrated other evidences of achievement that were clearly time-and-energy competitive with publication. Thus, those members of my sample who became chairmen of university departments, or achieved high managerial ranks in industry, were eliminated from the publication comparisons.

Statisticians will be disappointed in the small size of my sample. However, it was a total sample of the 1948 APS-Fellow populations of two well-known industrial research laboratories, plus the total sample of an alphabetically chosen set of APS Fellows of the same age group, all members of each group still APS Fellows in 1970. The three groups were approximately equally populated.



Percentage of APS Fellows as function of age who averaged more than two publications per year (colored dots) over five-year period and who averaged more than one publication per year over a five-year period (black dots).

I was particularly interested in the vitality or staying power of the top achievers. *They* are our most precious resource; if they show staying power, perhaps there is hope for the rest of us. Hence I examined particularly the records of those 23 individuals who exhibited at least one five-year span with two or more publications per year. Seven of these also rose to high managerial ranks, showing a satisfying correlation between scientific and executive achievement at least in the frame analysed. However, I had to eliminate these seven from my final statistics on publications because their managerial responsibility was competitive with their publications in later years.

The encouraging results of my analysis are shown in the accompanying figure. The ordinate is the percentage of the population in the age group indicated by the abscissa who, for that five-year span, achieved more than one publication per year (black dots). The colored dots show those who achieved more than two publications. That latter group shows a continuously increasing high publication percentage by age, statistically significant to age 64 (ten individuals) and perhaps to 69 (six individuals). Only two people are represented by the 100% point in the 70 to 75 bracket.

Taking the lesser measure of achievement, more than one publication per year, productivity peaks around age 50 (or 70); however, perhaps a more valid statement is that over 50% in each age group achieved a rate of at least one publication a year between the ages of 30 and 75. Variations in the achievement records between different individuals were much greater than the difference with age.

The major unanswered question is, how about the *creativity* or at least relevance of the publications of the older scientists? A partial and encouraging answer is that the *Science Citations* index of these older scientists is not only high (i.e., the frequency with which their peers reference them), but also contains over 50% references to their work in the latest decade (1961–71). *Their* work *is* timely! It was not unusual to observe some shifting of fields of activity among these scientists. For example, "gaseous electronics" of the twenties and thirties led to "plasma physics" of the sixties.

Thus on the whole I was encouraged by the positive implications of my research into the "technical vitality" of older scientists. So encouraged, I have returned from my stint in "education" to an active pursuit of technical subjects.

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Data on creative output versus age (August 1974, page 9) can be readily compiled. But interpretations of these data in terms of "creativity" versus age are fraught with hazard. One may be led to state conclusions with an apparent air of scientific authority, which

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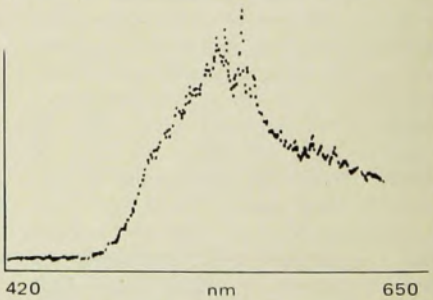

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may in fact be mere popular prejudices, or unconscious rationalizations of the status quo.

It is plain confusion to identify creative output, which may be readily defined in simple terms, with creativity, which is something quite different, and is at least as hard to define and measure as intelligence, emotional maturity, integrity, and other personality traits.

What is at issue is not a mere matter of verbal nicety, but the possibly erroneous inferences for social policy that may arise from the confusion. We refer, for example, to personnel policies of employers and to funding policies of agencies and foundations that support research.

If one assumes that the declining portion of the output curve is rooted in psychological limitations inherent in *homo sapiens*, one will draw one set of conclusions and will lean toward one set of policies; but if one surmises that the curve is merely the expression of a widely prevailing set of socially determined factors, one's policies and attitudes will almost certainly be more flexible, and one will deal with individuals as they should be dealt with according to law—that is, according to individual merit and not according to age.

There is probably some temptation to assume that the later stage of aging is a degenerative process, and that the downward trend of output in later years is an expression of that process. But there is a contrary view, which needs to be stated explicitly: Creative output is almost certainly facilitated by a fund of accurate, discriminatingly collected knowledge, proven judgment, success experience in a variety of undertakings and the corresponding increase of self-confidence, and these can only come with age. If the downward trend prevails in spite of these factors, there is an abundance of social factors to account for that trend, including the misinterpretation of output-versus-age curves, and career patterns that confine the individual to a narrow subject-matter range (job-equals-rut syndrome), or which channel the creativity of later years into non-scientific areas.

The role of reward and recognition systems may also be important in shaping the output curve. In this connection, it is interesting to compare the careers of Newton and Galileo.

Newton, showered with honors, terminated his scientific career in his early forties. But Galileo, under house arrest to the end of his years for his challenges to the "establishment," continued his remarkable scientific career into his seventies.

Proven creative talent is too scarce and valuable a social resource to allow it to become the victim of fatalistic policies and attitudes that have a dubious foundation in theory, or no foundation at all.

LAWRENCE CRANBERG
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Physicists die young?

In reading the obituaries in PHYSICS TODAY over the years, I have often been struck by the young age at which many prominent physicists die. I began to wonder if I had joined an especially hazardous profession.

So, one evening I sat down in front of the fire and checked the age at death for physical scientists whose obituaries were published in PHYSICS TODAY from August 1969 to January 1975. I found 192 deaths, with the mean (and median) age at death of 64 years. The standard deviation appeared to be about 15 years. The youngest physicist was 29, the oldest 102.

What conclusions can be drawn from this? I do not know. The human beings in the sample were mostly Caucasian male physicists. The cause of death was either accidental, natural, or not given. If you assume that the production rate of physicists between 1880 and 1940 was roughly constant, then you might say the life expectancy for the physicists you see around you is about 65. You might guess that half of the physicists you know will not live to collect their retirement benefits.

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Error in space science

I would like to point out a serious error in your reporting of the recommendations of the National Research Council's Space Science Board for FY 1976 (March, page 70). The Board did not, as you reported, recommend either or both the elimination of the Jupiter Uranus program or the delay of the Pioneer Jupiter orbit. Instead the Board merely concluded[1] that the ". . . fiscal constraints do not permit the early start of two large programs (Pioneer Jupiter Orbiter and Mariner Jupiter Uranus) for the exploration of the outer solar system . . .". In their report the Board identified slipping Pioneer Jupiter Orbiter or eliminating Mariner Jupiter Uranus as *separate* alternative ways for meeting the fiscal planning wedge of NASA's Office of Space Science. The Board did not, however, specifically recommend that one or the other of these alternatives be adopted. Instead they recommended that an immediate reexamination of the strategy for outer planets be undertaken by NASA.

In my view this was a wise decision by the Board, since both of these projects are of great scientific leverage and of