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SOME FACTORS INFLUENCING CAREER CHOICE IN PHYSICS*

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I. INTRODUCTION

This study examines the possible relationships which may exist between some objectively determinable characteristics of physics doctorate candidates at the time of their graduate level training and their subsequent choice of professional careers after receiving the degree.

II. DATA SOURCES

A substantial amount of data bearing on this subject is available in the National Doctorate Roster maintained by the National Academy of Sciences — National Research Council. These data were, however, not used in this study. We chose, rather, to employ a selected sample, which is the population of all Ph.D. physics graduates in the University of California at Berkeley and Stanford University, for the years 1956 through 1965. This sample numbers 540 and comprises approximately 10% of the total production of physics Ph.D.'s in the United States during the ten year period. The U.C.-Berkeley contribution comprised 73% of the sample.

Such a sample is obviously non-random with regard to the United States population of physics doctorates, and the probable existence of bias must be recognized if one attempts to extend our findings more generally. The geographical area represented is small and there is substantial and continuous contact between the two departments. Both are major producers of physics doctorates. In a rank ordered list of number of doctorates awarded by individual institutions, 1950 through 1959, the University of California ranked first and Stanford 17th of 82 universities listed.[1]

On the other hand, use of this sample offered substantial advantages for our study. Data in considerably greater depth than would otherwise be available, such as names of advisers and subject of dissertations, could be quite easily obtained by direct access to local sources. Most individuals in the sample were personally known, frequently still in close contact, to our local associates. This in particular made it rather easily possible to secure the critical data on present occupation for a very high percentage of the population.

Finally, with regard to the undergraduate background of Ph.D. physics graduates, comparative statistics indicate no substantial bias. It has been reported that liberal arts colleges provide undergraduate education to about one-fifth of all physics doctorates.[2] In our sample the proportion was 122 out of 540, or 22.6%.

The system of classification of present occupation which we selected is based on the type of institution in which the man is working rather than field of specialization, since we believe this to be the more generally useful statistic. Institutions within which the various persons in our sample are currently working were classified as follows:

1. Major university physics graduate schools.
2. Other universities and colleges.
3. Basic research, national laboratories.
4. Applied research, national laboratories.
5. Government operated laboratories.
6. Industrial laboratories, and private non-profit institutes.

The distinction between the two classes of educational institutions is quite arbitrary. There are currently 130 graduate schools in the United States which confer the Ph.D. degree in physics. A relatively small number of these, however, produce the majority of Ph.D.'s. One frequently encounters references to the "top 20", or occasionally the "top 25". Our criterion was somewhat more generous. In 1960 the number of schools granting doctor's degrees in physics numbered approximately 100. In the decade 1950 to 1959 the number of degrees granted by the "top 25" ranged from 69 to 426. The 50th in rank granted 25. Thereafter the number granted decreased rather rapidly, the 65th granting 10 and the 77th only one. It appeared to us that a reasonably appropriate division was the selection of the first 50 for the "major" classification. The criterion was production alone.

The concept of national laboratories was stretched a bit to include some institutions which, though corporations, are wholly engaged in support of the effort of governmental agencies, for example, Aerospace Corporation and the Rand Corporation. Private non-profit institutes were originally coded as a separate category. We found, however, that this provided a sample of only six, much too small to have significance. It was, therefore, grouped with industrial laboratories.

All regularly employed persons whose affiliation could be determined at all fell quite unambiguously into one of these six classifications with the exception of two persons engaged in government scientific administration. These two were included in the "Government Laboratory" class.

The primary source of location data was the current directory, dated June 1965, of the American Physical Society.[3] This served to locate approximately 75% of the persons in the sample. Address files of the two physics departments located about half of the remainder, and personal or telephoned inquiries directed to former associates and advisers located a substantial number of those remaining. At this point 505 of the total 540, or 93.5% of the total sample, were definitely located in one of these six classifications. Several recent graduates were known to be either in military service or not yet employed. It was not considered to be worth the further effort required to locate any of the small number remaining. A cursory examination of the characteristics of this residual group indicated that it was reasonably unbiased except for year of Ph.D. Over half were 1963 to 1965 graduates.

We believe that this method of classifying career choices is the only one likely to provide tangible clues to the ultimate choice. The rapidly growing trend towards one or two years of postdoctoral training makes the use of first employment after granting of the degree highly suspect as a useful statistic. Further, there is in many other cases a short period of high postdoctoral mobility, in which perhaps several moves from job to job may be made before the man finds himself in a satisfactory position. These considerations argue against the inclusion of data from the last year, or two years, at all. Against this, however, rapid changes in the entire field of physics, including career opportunities, argue for consideration of fairly recent data only. We believe that a sample comprised of the last ten years production of physics doctorates strikes about as even a balance as is currently possible.

III. STATISTICS

The set of statistical information included, besides current institutional affiliation, the following:

1. Indentification of each subset, by names of person, and source of doctorate, U.C.-Berkeley or Stanford.
2. Physics subfield of graduate level specialization.

3. Year of doctorate.
4. Year of bachelor's degree.
5. Source of bachelor's degree, classified as major or other by the same criterion as current affiliation.
6. Graduate adviser, (and title of dissertation).

Physics subfields were classified as follows:

1. Astrophysics, cosmic rays, space physics.
2. Atomic and molecular physics, quantum electronics.
3. Elementary particle physics.
4. Nuclear structure physics.
5. Plasma physics.
6. Solid state and condensed matter physics.
7. Classical physics, (acoustics, optics, mechanics, fluids, heat, electricity and magnetism, statistical mechanics).
8. Applied physics.

Theoretical work was identified as such but appropriately distributed in the above subfields.

Distribution tables have been made comparing current institutional affiliation with five variables, physics subfield, year of doctorate, years elapsed between BS and Ph.D., source of BS degree and, in a smaller sample, graduate adviser.

Table I was intended to shed some light on the recurring question of what effects different kinds of graduate training have on future careers, specifically training in what is too often called "Big Science" and "Little Science." It is obvious that no field is exclusively in one or the other of these categories. "Big Science" is, however, generally exemplified by elementary particle physics, which requires access to high energy accelerators for experimental work, and in which most experiments are done by large groups, often with highly fragmented individual responsibilities. Much work in atomic and molecular physics and solid state physics is done by small groups, sometimes an adviser and only a single graduate student, with relatively inexpensive apparatus and small budgets. Astrophysics, space physics, nuclear structure physics and plasma physics experiments may, on the other hand, range through space probes and high current intermediate energy accelerators to plasma jets and are clearly of neither one kind nor the other.

We find in Table I, that elementary particle physics, with 41% of all doctorates, provides almost exactly 50% of the contribution to major university physics departments, accounting for 37% of graduates trained in this subfield. Atomic and molecular physics, with 18% of all doctorates, contributes 21% of those in major university physics departments, accounting for 35% of graduates in the subfield. Solid state physics, with 8.5% of doctorates contributes 10% of those in major university physics departments, accounting for 37% of graduates in that subfield. These nearly identical proportions of graduates contributed from both ends of the "Big Science-Little Science" spectrum indicate that at least in this respect the kind of training has little influence.

In justification of our choice of "in major university physics departments" as an indicator, we may observe that in the demography of doctorates the most important reproductive element in the system lies here. If one prefers a physical analogy, these comprise most of the fissionable elements in the chain reaction.

The Table I comparisons provide largely negative evidence, and may thus help to quell arguments which might have been based on opinion.

The distributions in Table II were designed to secure any evidence of secular change. In three categories such change is obvious while in the others trend is

TABLE I

DISTRIBUTED BY INSTITUTIONAL AFFILIATION AND SUBFIELD OF GRADUATE STUDY

Physics Subfield	Not Identified	Major Universities	Other Schools	Basic Natl. Res. Labs.	Appl. Natl. Res. Labs.	Gov't. Labs.	Ind. and Private Labs.	Total	%
Astro physics, space, etc.	0	5	4	0	1	2	4	16	2.96
Atomic and molecular	8	35	14	5	5	6	26	99	18.33
Elementary particle	9	83	27	41	31	5	26	222	41.11
Nuclear structure	13	13	19	6	13	8	23	95	17.59
Plasma physics	1	2	0	2	4	1	4	14	2.59
Solid state physics	1	17	5	0	1	4	18	46	8.52
Classical physics	2	7	5	0	1	2	10	27	5.00
Applied physics	1	5	2	1	2	1	9	21	3.90
Total	35	167	76	55	58	29	120	540	100.00
%	6.48	30.93	14.07	10.19	10.74	5.37	22.22	100.00	

TABLE II

DISTRIBUTED BY INSTITUTIONAL AFFILIATION AND YEAR OF DOCTORATE

Year	Not Iden- tified	Major Univ.	Other Schools	Basic Natl. Res. Labs.	Appl. Natl. Res. Labs.	Gov't. Labs.	Ind. and Private Labs	Total
1956	6	9	2	6	9	1	14	47
1957	2	12	8	1	11	0	13	47
1958	2	12	4	1	3	3	10	35
1959	0	7	8	4	3	2	15	39
1960	5	16	9	4	5	3	22	64
1961	1	20	7	3	7	3	10	51
1962	1	25	6	7	9	7	8	63
1963	5	22	11	12	6	3	14	73
1964	8	21	7	7	3	5	9	60
1965	5	23	14	10	2	2	5	61
Total	35	167	76	55	58	29	120	540

absent or at least much less pronounced. The trend in both categories of educational institutions, "major" and "other" is to increasing numbers of recent graduates, while in industrial and private research laboratories it is just the opposite.

There are at least three hypothesis which might explain these trends, but our data sheds no light on any of them. First, the increasing numbers of recent graduates in educational institutions may reflect the increase in post doctoral training. Second it may reflect increases in number or size of physics departments. In the five years 1960 to 1964 the number of departments conferring doctorates increased from 100 to 130.

Lastly, it may reflect a delayed migration from education to industry, resulting from the compound effects of a number of causes which are easily imagined.

It is quite possible that all three of these causes have acted together to produce the observed effect. Any concrete evidence for any of these hypotheses will require the acquisition of a year by year history of movements of each of the individuals in the sample, but such an investigation is beyond the scope of this study.

Table III examines the distribution of years elapsed between the bachelors degree and the doctorate. Characteristically, all distributions are highly skewed. Since we are dealing with a rate process having a finite upper limit and an infinite lower limit an appropriate statistical measure of central tendency is the harmonic mean which is the reciprocal of the mean rate of progress to the doctorate.

The most interesting comparisons are between the distributions in the "major university" and "other" categories. It appears that normal entrance to the major university physics department is gained by a relatively uninterrupted attainment of the doctorate. The size of the extended tail on the "other" category leads to at least a suspicion that the distribution may be bimodal. Perhaps some portion of those who enter a teaching career in "other" institutions at the bachelors or masters degree level continue a long drawn out but eventually successful pursuit of the doctorate. Again, investigation of this possibility was beyond the scope of this study. We did however, draw a random sample of 20 doctorates in which we determined the actual number of equivalent full years of graduate study before achievement of the doctorate. The distribution was approximately normal with a mean of 4.7 years and a standard deviation of .8 years. It appears that more extended intervals of time between the BS and Ph.D. are almost invariably caused by interruptions or deferrals of graduate study, not by extended periods of study.

TABLE III

DISTRIBUTED BY INSTITUTIONAL AFFILIATION AND YEARS ELAPSED BETWEEN BS AND PH. D.

Years Elapsed	Not Identif.	Major Univ.	Other Schools	Basic Natl. Res. Labs.	Appl. Natl. Res. Labs	Gov't. Labs.	Ind. and Private Lab	Total
2	0	0	0	0	1	0	0	1
3	2	3	0	3	0	0	0	8
4	3	27	3	5	6	2	13	59
5	5	32	16	13	14	7	26	113
6	2	33	12	12	14	7	14	94
7	6	26	10	6	8	3	23	82
8	4	18	7	6	6	2	11	54
9	4	14	5	1	4	3	12	43
10	2	5	4	1	1	1	8	22
11	1	5	5	1	1	2	4	19
12	2	1	3	4	1	0	2	13
13	1	0	3	1	0	1	1	7
14	0	1	2	1	1	0	0	5
15	0	0	2	0	0	1	2	5
16	0	0	2	0	0	0	3	5
17	3	0	0	0	0	0	1	4
18 & over	0	2	2	1	1	0	0	6
Total	35	167	76	55	58	29	120	540
Harmonic Mean	6.56	5.88	7.14	6.64	5.89	6.44	6.49	6.25

TABLE IV

DISTRIBUTED BY PHYSICS SUBFIELD AND YEARS ELAPSED BETWEEN BS AND Ph.D.

Years elapsed	Astrophysics Space, etc.	Atomic & Molecular	Elementary Particle	Nuclear Structure	Plasma Physics	Solid States	Classical Physics	Applied Physics	Total
2			1						1
3		1	5	1		1			8
4	3	13	24	8	1	7	2	1	59
5	2	23	47	19	2	10	5	5	113
6	2	11	46	16	2	9	4	4	94
7	4	19	28	12	6	6	4	3	82
8	2	10	23	9	1	4	3	2	54
9		7	10	11	2	6	5	2	43
10	1	4	11	3		2	1		22
11	1	3	8	3		1	2	1	19
12		4	5	2				2	13
13		1	5	1					7
14			3	2					5
15	1		1	2				1	5
16		1	1	3					5
17		1	1	2					4
18 +		1	3	1			1		6
Total	16	99	222	95	14	46	27	21	540
Harmonic Mean	6.24	6.18	6.01	6.64	6.40	5.82	6.76	6.68	6.25

Table IV compares the distribution of years elapsed between BS and Ph.D. in different subfields of physics graduate study. The purpose of this comparison is to provide an answer to the question; does the mode of research, specifically the "Big Science" mode of elementary particle physics, result in significantly altering the average time required to produce a doctorate degree ? If, as before, we choose atomic and molecular physics, and solid state physics as characterizing the "Little Science" mode we note that the harmonic mean time for the doctorate in elementary particle physics falls quite exactly at the mean time of the two "Little Science" subfields. There is, in fact, no substantial indication that any subfield differs significantly from the others in this respect.

TABLE V

DISTRIBUTED BY INSTITUTIONAL AFFILIATION AND SOURCE OF BS DEGREE

Source of BS degree	Not Identified	Major Univ.	Other Schools	Basic Natl. Res. Labs.	Appl. Natl. Res. Labs.	Gov't. Labs.	Ind. and Private Labs.	Total
Major Univ	27	125	45	41	42	17	75	372
Other schools	8	42	31	14	16	12	45	168
Total	35	167	76	55	58	29	120	540

Table V compares the distribution of present location with the source of undergraduate training. The most obvious conclusion which may be drawn from this comparison is that undergraduate education in either class of institution somewhat predisposes a person to return to the same kind of environment in the event that he enters a teaching career after the doctorate. 33.6% of those whose bachelors degree was received in an institution classed as "major" are now in this class of institutions, compared to 25% whose BS was received from an "other" school. Conversely, 12.1% of those whose BS was received from a "major" school are now in "other" schools, compared to 18.5% whose BS was received from an "other" school.

When one combines this observation with the fact that the probability of receiving a doctorate at all is nearly five times as great for those whose undergraduate training was received in a major university as for those whose training was received in a four year college,[4] (73.6% of the "other" universities and colleges group), additional strength is given to our previous observation that the major reproductive element in the physics doctorate system is to be found in the major universities category.

Table VI, comparing the distribution of career choices and graduate advisers, was added, after the previous four comparisons had been made, in an effort to find some more clearly definable association. It is exceedingly difficult to quantify this comparison since none of the variables may be objectively valued. The implications of the comparison do, however, appear clear cut.

The entire sample of 540 doctorates listed the names of 91 advisers, many only once. Forty advisers were listed with 5 or more doctorates, comprising 426 or 79% of the total. From these 40 we selected the nine most productive, who accounted for 179 or 33% of the total. The distribution of this sample of 179 among the seven categories of current affiliation compares quite closely to the distribution of the total population of 540.

The distribution among these categories for each of the nine advisers is, however, clearly different. Whatever values one may wish to attach to any of these classifications it seems apparent that the major variable affecting career choice is the graduate adviser.

We tend increasingly to view all education as the rather impersonal process of teaching and being taught. It can even be done by machines. It seems an inescapable conclusion, however, that the graduate education of physics doctorates much more resembles the older and more intimate relationship of master and

TABLE VI

DISTRIBUTED BY INSTITUTIONAL AFFILIATION AND GRADUATE STUDY ADVISER

	Adviser and Subfield	Not Identified	Major Univ.	Other Schools	Basic Natl. Res. Labs.	Appl. Natl. Res. Labs.	Gov't. Labs.	Ind. and Priv. Labs.	Total
1	Elementary Particles	0	10	0	3	1	1	2	17
2	Elementary Particles	1	9	3	3	1	0	1	18
3	Elementary Particles	0	7	4	2	3	0	2	18
4	Elementary Particles	1	6	5	1	1	1	0	15
5	Elementary Particles	1	7	6	3	5	3	9	34
6	Atomic and Molecular	2	8	3	2	2	1	1	19
7	Atomic and Molecular	3	6	0	4	3	0	8	24
8	Nuclear Structure	2	2	5	1	6	0	6	22
9	Solid State	1	3	0	0	0	1	7	12
	Total	11	58	26	19	22	7	36	179
	%	6.15	32.40	14.52	10.61	12.29	3.91	20.11	100

apprentice. To some of us at least this is a pleasant view and a hopeful prognosis for the future of not only science but of man as well.

This study, and the rationale which we have applied to it, was suggested by Dr. W.K.H. Panofsky, of the Stanford Linear Accelerator Center. The writer is indebted to the academic authorities of both the University of California and Stanford University for providing us with access to the appropriate records. Staffs of both departments actively and graciously assisted in collecting the data. Any conclusions which have been drawn from the data are, however, solely the author's.

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