rocks. Though all surface water is probably ultimately of volcanic origin, much of the water released in any one volcanic eruption may have been recycled, even repeatedly. It is hoped that determination of the abundance of isotopes, especially of oxygen, may indicate how much volcanic water originates at depth and how much is of surface derivation.

One of the principal difficulties in the study of volcanic gases has been the reaction that takes place between the gases in the container after collection but before analysis. J. J. Naughton, of the University of Hawaii, is now developing a method by which the gases are separated by means of an absorption column in the field at the time of collection. It is hoped that this will make possible the determination of the actual composition and interrelationships of the gases at the time they arrive at the surface. From this determination, thermodynamic calculations will indicate something of the condition the gases, including water, must have been in under various earlier temperature-pressure relationships within the earth. Thus far, the results seem promising (*23*).

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High School Backgrounds of Science Doctorates

A survey reveals the influence of class size and region of origin, as well as ability, in Ph.D. production.

Lindsey R. Harmon

In the current resurgence of interest in the high school curriculum, major emphasis has been placed on the improvement of science teaching. An increasing concern has been felt for many years regarding the deficiencies of the high school courses of study pursued by most students, from the standpoint of preparation for possible pursuit of scientific studies in college and graduate school. The aim of the present article is to shed some light on this question through an examination of the high school backgrounds of a representative sample of recent science doctorates—specifically, the whole 1958 crop of doctorates from American universities.

This study was made possible by the existence of a file of third-level research degrees from all United States universities from 1936 to the present, maintained currently by the Office of Scientific Personnel of the National Academy of Sciences–National Research Council and supported by grants from the National Science Foundation and the U.S. Office of Education. This file includes doctorates in all fields; in the present study it will be useful to compare the findings on science doctorates with those on doctorate-holders in other fields. Currently, each candidate for a third-level degree fills out a simple one-page questionnaire as he approaches graduation; these completed questionnaires are collected by the deans of the graduate schools and forwarded to the Office of Scientific Personnel. One item on this questionnaire is the name and address of the high school from which the new doctorate-holder graduated. These high school addresses made the present study possible.

The initial use of these high school names was that made by Samuel Strauss, lately of the District of Columbia public school system, who had conducted a small-scale study on his own of the doctorate-level graduates of two nearby universities. He had had a good response from the high schools and sought a wider sample, based on the the Doctorate Records file of the Office of Scientific Personnel. His request for funds from the National Institutes of Health was supported by the Office of Scientific Personnel and backed up by a parallel request to the National Science Foundation from that office itself. Both requests were granted. Strauss undertook a study of the 1957 graduates, and the Office of Scientific Personnel made a study of the 1958 graduates, along practically identical lines. This article is based on the 1958 results.

Last spring, a questionnaire form was prepared for each holder of a 1958 doctorate, to be mailed to his former high school. All forms for a given high school were assembled and sent, together with a letter, to the principal, informing him of the relative standing of his high school in the state and nation with respect to the number of graduates in the 1958 doctorate "crop." For each of its graduates who held a

The author is director of research, Office of Scientific Personnel, National Academy of Sciences–National Research Council, Washington, D.C.

Table 1. Fields of the doctorate compared in terms of mean intelligence test score, rank in graduating class, and grade point average.

Field of doctorate	Intelligence test score*		"Normalized rank" scores†		Math.-sci. GPA	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Mathematics	138.2	17.0	130.2	14.1	82.55	9.71
Physics	140.3	16.4	131.4	16.7	82.20	10.74
Chemistry	131.5	16.3	125.8	16.8	78.15	12.68
Geology	133.1	14.7	120.4	16.7	73.10	14.82
Engineering	134.8	16.2	128.0	17.3	80.65	11.74
All physical sciences	134.7	16.6	127.4	16.9	79.55	12.41
Biological sciences	126.1	16.4	117.3	18.1	69.35	15.55
Social sciences	132.0	16.9	120.1	18.8	67.70	17.36
Arts and humanities	132.1	16.4	122.6	18.1	70.25	16.90
Education	123.3	16.2	115.9	17.9	66.35	16.32
Social sciences, arts, education	129.8	17.1	119.6	18.5	67.95	16.97
Natural sciences	131.7	17.0	123.9	18.0	75.80	14.46
Total	130.8	17.1	121.8	18.3	71.55	16.37

*Intelligence test scores converted to Army Standard Scale values, with a mean of 100 and standard deviation of 20. †Rank in class converted to Army Standard Scale (see text).

1958 doctorate, the school was given information on all degrees held and was asked to supply information from the school records, to be kept confidential and used for research purposes only.

The rate of response to this questionnaire by the high schools was most gratifying, particularly as it indicates that any bias in the results due to nonresponse is small indeed. In 1958 there were 8930 doctoral degrees awarded. Of this total, approximately 13.3 percent went to people who had graduated from foreign high schools. That leaves 7787 from U.S. high schools. We were able to identify the high schools of 7063 of these, or about 91 percent. For a variety of reasons, high school information was not available on the remaining 9 percent (some had gotten high school diplomas via General Educational Development tests). Of this 7063 for whom we established tentative high school identification, we received from the high schools replies for 6455, or 91.4 percent—an astonishingly high response rate, particularly in view of the fact that no follow-up was attempted for the nonresponders. The usable data were reduced somewhat, to 6259, because some schools which did reply could provide no information (the school had burned down, records had been discarded, and so on), or because their returns were received too late for processing. Of the 6259 usable responses, there were 2853 in the fields of science: 1797 in the physical sciences and 1056 in the biological sciences.

From these high school data we are able to derive two measures of general academic ability and one measure of scientific achievement, as well as specific grades in various courses. From the intelligence tests in the records we are able to get a measure of general academic aptitude, and from the rank in graduating class, a measure of general achievement in all high school subjects. This high school class rank is, of course, also useful as a measure of aptitude for further work in college. Each of these measures requires a word of explanation, as each must be converted for statistical handling and interpretation.

Intelligence Test Scores

In the case of test scores, an attempt was made to compensate for inequalities in the spread of the I.Q.'s for various tests. The known variances of these tests were employed to set up a standard score scale; where the variances were not known (this was true in the case of some of the less-used tests), the assumption was made that the I.Q.'s were comparable to those for the most-used tests—the Henmon-Nelson, Kuhlman-Anderson, and California Mental Maturity tests—which apparently have very similar means and variances of obtained I.Q.'s. The final, common scale employed for the standardized tests is necessarily an arbitrary one, to provide integrated results. For this scale we have adopted the Army Standard Scale, which assumes a mean score of 100 and a standard deviation of 20. This facilitates comparison of the results of the study under discussion with results of other studies where explicit statements are made regarding the mean and standard deviation of the test scores. It is the scale adopted by Wolfle in his *America's Resources of Specialized Talent* (Harper, New York, 1954). Comparison with the older Stanford Binet scale, which has a standard deviation of the I.Q. of about 16 or 17 (varying with age), gives the following results: a Binet I.Q. of 125 equals Army Standard Scale 130, and Binet 140 equals Army Standard Scale 158, rounded to the nearest whole number.

Rank in Graduating Class

High school class rank, in its original percentile form, is unsatisfactory for computational purposes because the centile rank is not a constant unit of measurement. Hence, we have transmuted these centiles to standard scores, assuming a normal distribution of class ranks, and have termed them "normalized rank scores." This scale has a mean of 100 and standard deviation of 20, to match as nearly as possible the interpretative significance of the intelligence test scores. However, a one-for-one comparison is not justifiable, as these normalized rank scores are of course based on high school graduates only, whereas the intelligence scores are based on the whole population. Because of selection on the basis of academic ability throughout the school years, high school graduates are of course superior to the general population, and the standard provided by this norm group is distinctly more rigorous than that provided by the intelligence tests.

It is well to remember, however, in interpreting these normalized high school rank scores, that if one seeks to compare any two individuals, he makes the assumption that the high schools from which the two students came are equal in their academic standards. Taking all schools together, we know that this is not the case, of course. The norms are local only. This deviation from the standardized test scores is significant for our purposes, particularly when we make comparisons between schools of different sizes and different regions. Whatever educational handicaps a student may suffer by coming from an inferior educational environment is compensated for in the class rank score—he is compared with his peers in this score, and not with all students across the nation. Further, in field-to-field comparisons these interschool differences tend to cancel out, so that the normalized high school rank may be considered to be unbiased by differences in schools when we compare one field with another. Individuals from schools of all levels of excellence are found in all doctorate fields.

Mathematics-Science Grade Point Average

These two indices provide two measures of general academic ability at the high school level. For a study of scientists-in-the-making we are interested in particular in a third measure, based specifically on the grades in mathematics and science earned in high school. Accordingly, there was computed for each student a mathematics-science grade point average (GPA) in which a grade of C is equal to 50, a grade of B is equal to 70, and a grade of A is equal to 90. While not directly comparable to the intelligence or high school rank scales, this grade point average did yield a score readily handled statistically.

The data from all of these measures are perhaps best appreciated if seen graphically. Figure 1 provides a graph of the intelligence test scores of the doctorate population as a whole in comparison with the spread of scores for the general population of the country, as calibrated by the Army General Classification Test, or AGCT scale. The smooth dotted curve depicts the spread of scores found in a standard cross section of the whole population, while the solid polygon represents the distribution of the doctorate population. The two groups are, of course, not equal in size but are here depicted proportionally. A single year's section of the U.S. general population of the approximate age of the average 1958 Ph.D. includes 2.4 million people, while the doctorate group from U.S. high schools numbers only 7787. Accordingly, the scale of comparison of the two groups is 3100:1, as only one person in 3100 attains the doctorate. The frequency scale for the general population is shown at left in Fig. 1. The doctorate population distribution scale adjoins it, giving the actual number of Ph.D.'s found at each 10-unit level of the Army General Classification Test scale. On the right in Fig. 1 is another kind of scale, showing the relative proportion of Ph.D.'s in the population at each level of ability. The curve at the far right utilizes this scale to express the proportion of doctorates at each intelligence level. At the level of average intelligence (AGCT 100), the figure is practically zero. To the right, the curve rises to about 12 per 1000 at AGCT 130, which is just about the average ability level for all Ph.D.'s. From here on the curve rises more steeply, to about 60 per 1000 at the cut-off point that Terman used in his original studies of "genius" (AGCT 158), and to about 190 per thousand at the highest level tabulated, AGCT 175. Thus, even at the highest ability level, only one person in five attains the doctoral degree. There is thus a substantial reservoir of underdeveloped ability, regardless of the level of ability one assumes to be requisite for Ph.D.-level training, and even when we grant that not everybody at the highest ability levels needs a doctorate to complete his education.

Rank, by Doctoral Field

Table 1 shows the means and standard deviations for the several fields of the physical sciences, and for other groups, on the intelligence measures, normalized rank-in-class scores, and mathematics-science grade point average, all derived from the high school records. The leading position of the physical science group is apparent on all three of these indices. It is of interest to note that the arts and humanities group ranks second on all

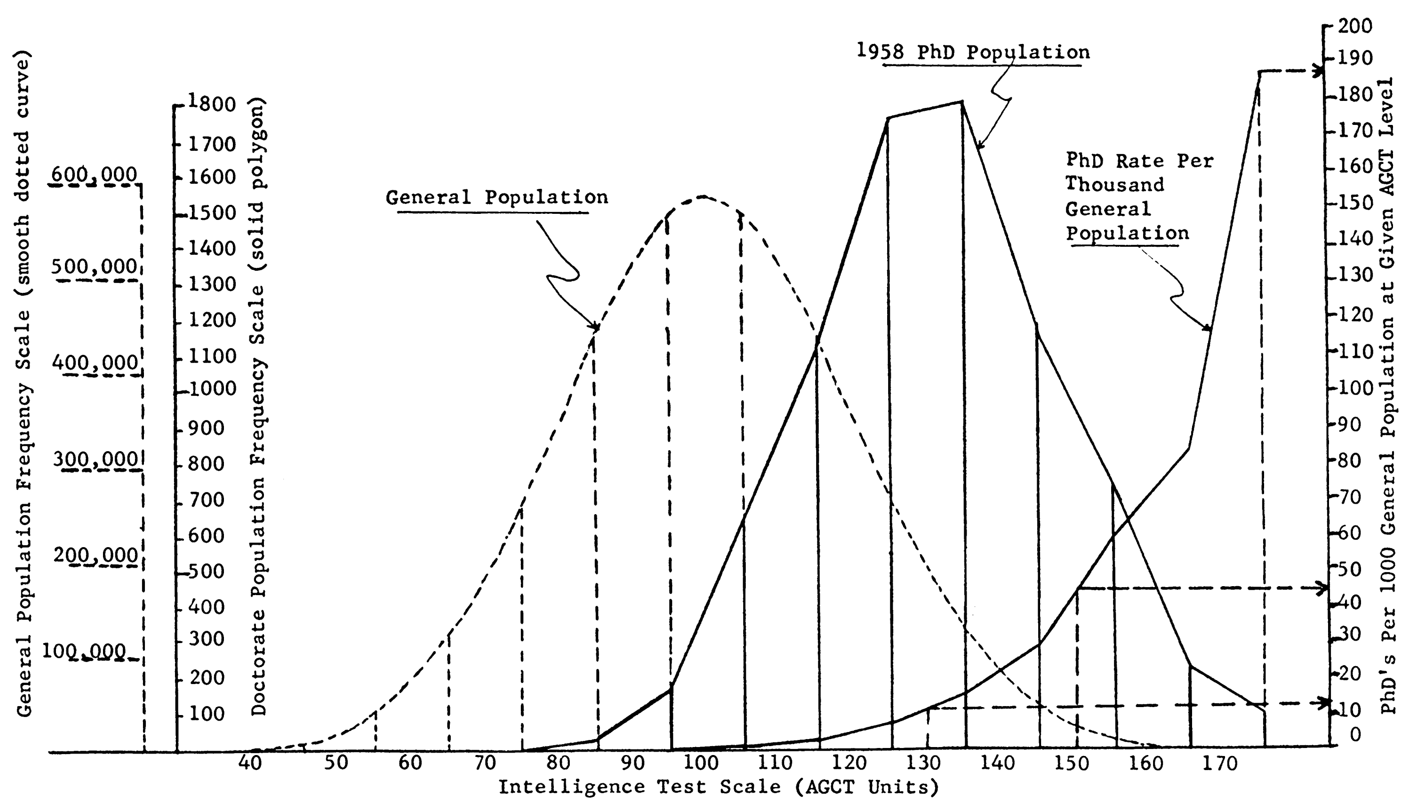

Fig. 1. Distribution of general intelligence test scores from high school records of 1958 doctorate population as compared with distribution of scores for the general population (scores are expressed in terms of Army General Classification Test units).

Table 2. Distribution of intelligence test scores for five general fields of the doctorate and for the total doctorate population.

Army Standard Scale dist.*	Approx. gen. population age 32, 1958†	Doctorates (N)					
		All fields	Phys. sciences	Biol. sciences	Social sciences	Arts, human.	Education
170 and up	530	46	20	1	15	7	3
160–169	2,670	101	46	11	27	14	3
150–159	12,150	337	153	37	93	35	19
140–149	39,250	530	246	67	112	74	31
130–139	108,000	826	298	150	179	116	83
120–129	218,200	806	243	153	214	89	107
110–119	361,800	520	140	119	106	65	90
100–109	457,400	298	64	79	67	28	60
90–99	457,400	81	19	19	12	8	23
80–89	361,800	15	3	4	2		6
70–79	218,200	7	1	5		1	
Below 70	162,600						
Total	2,400,000	3567	1233	645	827	437	425
100 (mean)		130.8	134.7	126.1	132.3	132.1	123.3
No inform.‡		4220	931	676	924	771	918

*The Army Standard Scale has a mean of 100 and standard deviation of 20. †Approximate mean age at attainment of the doctorate is 32; the number of individuals of age 32 is therefore the base population from which these doctorate holders were drawn. ‡U.S. high school graduates for whom no intelligence test scores could be obtained.

Table 3. Distribution of converted rank-in-class scores for doctorates in five general fields and the total doctorate population.

Normalized rank score categories	1944 High school grad. population	Doctorates (N)					
		All fields	Phys. sciences	Biol. sciences	Social sciences	Arts, human.	Education
160–169	1,377	55	27	4	13	8	3
150–159	4,947	195	100	19	40	25	11
140–149	16,881	547	244	70	106	87	40
130–139	44,931	819	325	120	170	115	89
120–129	93,687	1132	391	171	231	180	159
110–119	152,898	820	230	166	178	106	140
100–109	195,279	697	155	158	177	87	120
90–99	195,279	387	65	92	104	49	77
80–89	152,898	139	18	35	36	21	29
70–79	93,687	53	5	12	12	7	17
60–69	44,931	19	2	5	5	2	5
Below 60	23,205						
Total	1,020,000	4863	1562	852	1072	687	690
Mean		120.8	126.4	116.3	119.1	121.6	114.9
S.D.		18.3	16.9	18.1	18.8	18.1	17.9
No inform.		2924	602	469	679	521	653

Table 4. Distribution of mathematics-science grade point averages for doctorates in five general fields and for the total doctorate population.

Math.-sci. letter grade	GPA numerical grade	Doctorates (N)					
		All fields	Phys. sciences	Biol. sciences	Social sciences	Arts, humanities	Education
A	90	617	326	79	90	78	44
A−	85–89	837	414	106	135	98	84
	80–84	841	301	124	158	128	130
B+	75–79	625	204	96	138	95	92
B	70–74	665	153	122	155	109	126
B−	65–69	422	89	90	92	57	94
	60–64	508	84	110	122	73	119
C+	55–59	381	48	87	98	61	87
C	50–54	383	51	77	102	59	94
C−	45–49	230	26	43	77	30	54
	40–44	198	15	36	65	29	53
D+	35–39	109	7	21	31	21	29
D	30–34	70	4	15	21	13	17
D− or E	Below 30	52	1	3	23	12	13
Total		5938	1723	1009	1307	863	1036
No grades		321	74	47	69	56	75
Mean GPA		71.55	79.55	69.35	67.70	70.25	66.35
S.D.		16.37	12.41	15.55	17.36	16.90	16.32

three indices, surpassing the biological sciences even on the mathematics-science grade point average. The social sciences, with a rank almost identical to that of the arts and humanities on the intelligence index, clearly comes third in class rank and trails in fourth position on the grade point average. The pattern is quite clear—the social science group is composed of relatively bright individuals whose achievement in mathematics and science is distinctly out of line with their general high aptitudes. Whether this is a reflection of differential aptitude, or whether the relatively poor achievement in mathematics and science is important in determining these people's choice of field in college and graduate school cannot be ascertained from these data alone. Another feature of Table 1 that is quite striking is the marked difference in rank between the physical sciences and the biological sciences on all measures of ability; this difference is, in fact, somewhat greater for the indices based on local norms than for the intelligence tests which employ national norms. The trailing position of doctorates in education is apparent on all three measures. This group includes both Ph.D.'s in education and Ed.D.'s; the differences in findings for holders of these two degrees were very minor.

Within the physical science field, the subgroups that stand out on all measures are the mathematics and physics majors. The differences between these two groups are small, the physicists leading in measured intelligence and class rank, the mathematicians in mathematics-science grade point average. In Table 1, the means for the subgroups of the physical sciences are higher, on all three measures, than the means for any other group, with the exception of the mean for the chemistry group on the intelligence index, which is a half point below the corresponding means for the social sciences and the arts and humanities groups.

The group means shown in Table 1 give only a partial picture. Although the standard deviations enlarge this picture somewhat, consideration of the whole range of scores is necessary for a true comparison of scores in each field with corresponding scores for the general population and for other doctorate groups. Table 2 provides distributions of intelligence test scores, in terms of the Army General Classification Test, for the five major fields of the doctorate, for the doctorate group

Table 5. Number of doctorates per 1000 individuals in the general population, by field of specialization and ability level.

Intel. scale (AGCT units)	Doctorates (*N*) per 1000 general population						Non-Ph.D.'s per 1000 general population
	Phys. sciences	Biol. sciences	Social sciences	Arts, human.	Edu- cation	All fields	
170+	36.20	7.66	27.10	17.74	6.23	189.40	810.60
160–169						82.60	917.40
150–159	22.10	6.24	15.81	7.79	5.20	60.55	939.45
140–149	11.00	3.49	5.89	5.10	2.63	29.50	970.50
130–139	4.84	2.84	3.42	2.90	2.56	16.70	983.30
120–129	1.95	1.44	2.03	1.10	1.63	8.06	991.94
110–119	0.68	0.67	0.61	0.49	0.83	3.14	996.86
100–109	0.25	0.35	0.30	0.17	0.44	1.42	998.58
90–99						0.39	999.61
80–89	0.034	0.048	0.024	0.02	0.08	0.09	999.91
Below 80						0.07	999.93

as a whole, and for the general population. It shows, also, the number of individuals within each general field for whom these scores are available, and the number of individuals for whom no intelligence test data were available. Throughout the computations which follow, the assumption is made that data on distribution of intelligence test scores (and data on distribution of class ranks and grade point averages, also) are unbiased—that is, that the data are reported on a representative sample of the whole group. Although there is no way to check this assumption, by the same token there is no way to compute the degree or the direction of any bias that may exist. This assumption should nevertheless be borne in mind, for future developments might make it possible to define this situation more precisely, and perhaps might provide usable bias estimates.

The distributions of normalized rank-in-class scores are provided in Table 3, and the distributions of mathematics-science grade point averages, in Table 4. It may be noted that it is possible to provide a theoretical distribution of rank-in-class scores (but not of grade point averages) for the whole high school population simply by applying normal curve frequencies to the known total of high school graduates. The year 1944 was chosen as most representative for the 1958 doctorate group; actually, these people graduated from high school over a period of several years, the year of graduation being, on the average, most recent for the physical science group and earliest for the education group.

Correction for Inequalities

Because the various fields of specialization are unequal in "popularity" or in number of people entering them, it is necessary to make some corrections in the raw frequency distributions of Tables 2, 3, and 4 in order to obtain the most meaningful comparisons. This has been accomplished in the next set of tables through a series of corrective coefficients, to correct for differences by field in the proportion of individuals for whom data were provided by the high schools, to correct for relative field size, and then to express the results in terms of an index number which facilitates field-to-field and level-to-level comparisons. In Table 5, the number of doctorates at each intelligence level in each field is compared with the number of people in the general population at that intelligence level. The figures given in the table have been corrected for unreported scores, but differences in field size remain. The vertical comparisons—that is, comparisons between ability levels for any given field—are thus justified, but the interfield comparisons are subject to error. The column for all fields combined (column 7) reflects all ability levels, whereas breakdowns by field are not given for the extremes of the distributions because of the unreliability of the small numbers at these levels. The entries in this "all fields combined" column are plotted in Fig. 1, together with the frequency distributions of the general population and of Ph.D.'s. It should be noted, in studying the figures in column 7, that they are not the simple sum of the entries under the various field headings; this is because of variations in field size and in score distributions within each field. Column 8 shows the number of non-Ph.D.'s in the population at each ability level—in effect, the untapped reservoir at any level of intelligence.

Field-to-Field Comparisons

Table 6 provides indices which may be used to compare the fields with each other at each level—a procedure not justifiable in Table 5. For Table 6, the data for each field were first corrected for field size and then divided by the Ph.D.-attainment rate for all fields combined at AGCT level 130. For this index base, any productivity rate might have been chosen; the rate for people of "mean doctorate ability level" appears to be a useful reference point. To interpret the resulting figures, look at the first entry in column 2—1053 for physical sciences at AGCT level 160 and above. This means that this ability stratum of the population produced doctorates in physical science at a rate 10.53 higher than the productivity rate for doctorates in general of the ability stratum AGCT 130. In column 2 it may be seen that this same ability stratum produced biological scientists at only 3.65 times the base rate. In column 3, the figure 999 means that social scientists were produced by this highest-ability stratum at 10 times the base rate. The figure for doctorates from this stratum in the

Table 6. Doctorate productivity indices for the several fields and ability levels.*

Intel. scale (AGCT units)	Productivity index						
	Phys. sciences	Biol. sciences	Social sciences	Arts, human.	Edu- cation	All fields	
170+	1053	365	999	945	278	1531	811
160–169						668	
150–159	643	297	583	415	232	490	
140–149	320	166	217	272	117	239	
130–139	141	135	126	154	114	135	
120–129	57	69	75	59	73	65	
110–119	20	32	23	26	37	25	
100–109	7	17	11	9	19	12	
90–99						3	
80–89	1	2	1	1	4	0.7	1.5
Below 80						0.6	

*These indices give a means of comparing Ph.D. productivity at each ability level and in each field (corrected for field size) with Ph.D. productivity at AGCT 130 (mean, all fields combined).

arts and humanities is about 9½ times the base rate, and for doctorates in education, slightly under 3 times the base rate. The over-all productivity of this intelligence stratum, shown by the figure 811 in column 8, is over 8 times the base rate. The number of doctorates represented by this combined category is adequate to warrant a breakdown into productivity rates for AGCT levels 160 to 169 and for 170 and above. The resulting figures are shown in column 7 as 668 and 1531, respectively—the latter indicating a productivity rate for doctorates for the highest intelligence level of over 15 times the rate for AGCT 130.

Figure 2 shows graphically the data of Table 6. Here each field is represented by a distinctive pattern, and the combined data for all fields are shown as an open box surrounding the separate fields, forming a frame of reference for the various fields as well as providing a general index for comparison of intelligence levels. It is apparent from Fig. 2, as from Table 6, that the physical sciences and social sciences are the outstanding fields at the higher ability levels, followed closely by the arts and humanities, with the biological sciences and education lagging far behind at AGCT levels of 140 and up. Whatever the reasons for these differences, it is apparent that the fields of biology and education have not been able to attract their proportionate share of individuals of highest intelligence, as intelligence is judged from high school intelligence test scores. As the problems in these fields are certainly inherently as challenging as those in the physical sciences or social sciences, it might be inferred that there is a failure somewhere, probably at the high school level or even earlier, to present these challenges adequately to the bright young people who eventually attain doctoral degrees.

Table 7. Number of doctorates per 1000 high school graduates, by field of specialization and rank in high school class.

Normalized* high school rank scores	Percentile ranks included	Doctorates (*N*) per 1000 graduates						Non-Ph.D.'s per 1000 graduates
		Phys. sciences	Biol. sciences	Social sciences	Arts, human.	Education	All fields	
160 and up	99.85+	27.8	5.7	13.4	9.0	4.5	64.0	936.0
150–159	99.3–99.8						63.1	936.9
140–149	98–99.2	20.0	6.4	10.0	8.9	4.9	51.9	948.1
130–139	93–97	10.0	4.1	6.0	4.4	4.1	29.2	970.8
120–129	83–92	5.8	2.8	3.9	3.3	3.5	19.3	980.7
110–119	68–82	2.1	1.7	1.9	1.2	1.9	8.6	991.4
100–109	49–67	1.1	1.3	1.4	0.8	1.3	5.7	994.3
90–99	28–48	0.5	0.7	0.9	0.4	0.8	3.2	996.8
80–89	15–27						1.5	998.5
70–79	6–14	0.1	0.3	0.3	0.2	0.3	0.9	999.1
Below 70	Below 6						0.5	999.5

*Normalized rank gives a scale with a relatively constant unit of measurement, whereas percentile ranks are of varying value, as shown by the percentile ranges in column 2.

Table 8. Doctorate productivity indices for the several fields and for normalized rank in high school class*.

Normalized rank scores	Productivity index						
	Phys. sciences	Biol. sciences	Social sciences	Arts, human.	Education	All fields	
160 and up	633	211	385	374	158	405	402
150–159						400	
140–149	456	240	289	370	169	328	
130–139	228	154	174	184	141	185	
120–129	132	106	113	138	121	122	
110–119	47	63	53	50	66	54	
100–109	25	47	41	32	44	36	
90–99	10	27	25	18	28	20	
80–89						9	
70–79	3	10	8	7	11	6	7
Below 70						3	

*The index here is based on 100 for the productivity rate (all fields combined) at normalized rank 121.8, which is the average for all doctorates.

Table 9. Percentage frequency and cumulative frequency distributions of mathematics-science grade point average, by field of doctorate.

Math.-sci. GPA scale	General field of doctorate											
	Phys. sci.		Biol. sci.		Social sci.		Arts, human.		Education		Total	
	At GPA	Below GPA	At GPA	Below GPA	At GPA	Below GPA	At GPA	Below GPA	At GPA	Below GPA	At GPA	Below GPA
90+	18.9	81.1	7.8	92.2	6.9	93.1	9.0	91.0	4.3	95.8	10.4	89.6
85–89	24.0	57.1	10.5	81.7	10.3	82.8	11.4	79.6	8.1	87.6	14.1	75.5
80–84	17.5	39.6	12.3	69.4	12.1	70.7	14.8	64.8	12.6	75.1	14.2	61.4
75–79	11.9	27.7	9.5	59.9	10.6	60.1	11.0	53.8	8.9	66.2	10.5	50.8
70–74	8.9	18.9	12.1	47.8	11.9	48.3	12.6	41.1	12.2	54.1	11.2	39.6
65–69	5.1	14.0	8.9	38.9	7.0	41.2	6.6	34.5	9.1	45.0	7.1	32.5
60–64	4.9	8.8	10.9	28.0	9.3	31.9	8.5	26.1	11.5	33.5	8.6	24.0
55–59	2.8	6.0	8.6	19.3	7.5	24.4	7.1	19.0	8.4	25.1	6.4	17.6
50–54	3.0	3.1	7.6	11.7	7.8	16.6	6.8	12.2	9.1	16.0	6.5	11.1
45–49	1.5	1.6	4.3	7.4	5.9	10.7	3.5	8.7	5.2	10.8	3.9	7.2
40–44	0.87	0.70	3.6	3.9	5.0	5.7	3.4	5.3	5.1	5.7	3.3	3.9
35–39	0.41	0.29	2.1	1.8	2.4	3.4	2.4	2.9	2.8	2.9	1.8	2.1
30–34	0.23	0.06	1.5	0.30	1.6	1.8	1.5	1.4	1.6	1.3	1.2	0.88
		0.06		0.30		1.8		1.4		1.3		0.88
10–14	0.06	0	0.30	0	1.8	0	1.4	0	1.3	0	0.88	0

High School Class Comparisons

Table 7 presents data for normalized rank-in-class corresponding to data in Table 5 for intelligence test scores—that is, number of doctorates per 1000. The base population here, however, is the total high school graduating class for 1944, not the general population. Table 8 presents data for normalized rank-in-class that correspond to the index figures for intelligence given in Table 6. The range of index figures is much more restricted for class rank than for intelligence test scores, the highest category for class rank out-producing the average by only 4:1, as compared with 8:1 for the top intelligence-test category. Apparently there are factors quite unrelated to later attainment of the doctorate that are more heavily involved in rank in high school class than they are in intelligence-test performance. This is particularly apparent in the social science field.

The data for mathematics-science grade point average do not lend themselves to a normative treatment in the way that intelligence-test scores and class ranks do, for we have no norm base from which to compute the performance of the nondoctorate population. Table 9 gives the percentage for each field at each grade-point-average level, and the cumulative frequencies by field. The letter-grade equivalents for each numerical grade point average are given in Table 10 for convenience in interpreting the data. In Table 9, the first column within each field gives the percentage of all cases within the field at each given grade-point-average level. The second column for each field gives the cumulative percentages from the bottom, or the percentile rank with respect to the lowest score, in each grade-point-average category. To take the highest category, 90+ or "straight A," it may be seen that 18.9 percent of the physical science group score a straight A in high school math and science courses. Another 24 percent fall just barely short of a straight A, so that only 57 percent in this first field fall below the A− category. By comparison, about 82 percent of the biological scientists, 83 percent of the social scientists, 80 percent of the arts and humanities group, and 88 percent of the education group fall below this point. Similar comparisons may be made at each grade-point-average level.

To obtain a somewhat different view of the same data, the doctorate-holders achieving each specified grade-point-average level were divided by field, and the percentages assigned to the respective fields are tabulated in Table 10. Thus we see that of all doctorate-holders achieving straight A in high school math and science, almost 53 percent majored in physical sciences, 13 percent majored in biological sciences, 15 percent in social sciences, 13 percent in arts and humanities, and 7 percent in education (each entry is rounded to the nearest whole number). At the grade B level, the fields are more nearly equal, while at C and lower levels the social sciences and education are most prominent. These results are of course quite consistent with the findings on mathematics-science grade point average and with the means for the various fields, presented in Table 1.

Geographic Region

Up to this point we have been concerned with ability measures derived from the individual's high school records. It is also possible to apply to the data for each individual the ranking of his high school on indices of geographic location, size of graduating class, and so on, obtained in a manner similar to that used for obtaining intelligence and class-rank measures. The normative

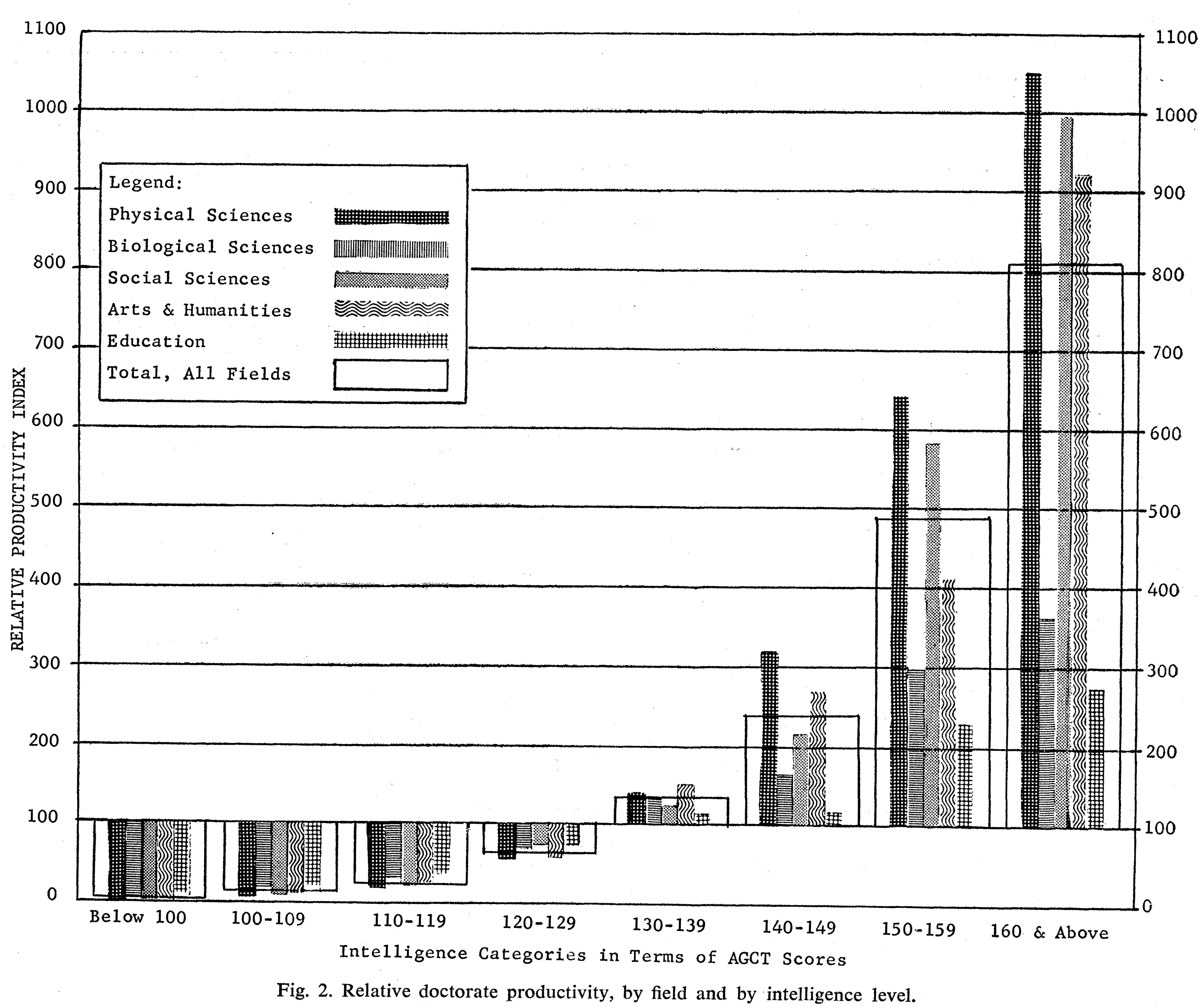

Fig. 2. Relative doctorate productivity, by field and by intelligence level.

Table 10. Relative concentration of the several fields of the doctorate for various mathematics-science grade point average.

GPA level	General field of doctorate: Phys. sciences (%)	Biol. sciences (%)	Social sciences (%)	Arts, humanities (%)	Education (%)	Letter grade equivalent
90+	52.84	12.80	14.59	12.64	7.13	A
85–89	49.46	12.66	16.13	11.71	10.04	A−
80–84	35.79	14.74	18.79	15.22	15.46	
75–79	32.64	15.36	22.08	15.20	14.72	B+
70–74	23.01	18.35	23.30	16.39	18.95	B
65–69	21.09	21.33	21.80	13.51	22.27	B−
60–64	16.54	21.64	24.02	14.37	23.43	
55–59	12.60	22.83	25.72	16.00	22.83	C+
50–54	13.32	20.10	26.64	15.40	24.54	C
45–49	11.30	18.70	33.48	13.04	23.48	C−
40–44	7.58	18.18	32.82	14.65	26.77	
35 and below	5.19	16.88	32.47	19.91	21.21	

Table 11. Number of doctorates in the several fields per 1000 high school graduates, by region of the United States.

Region	High school graduates, 1944 (*N*)	General field of doctorate: Phys. sciences	Biol. sciences	Social sciences	Arts, human.	Education	All fields
New England	59,800	2.97	2.13	2.68	1.75	1.71	11.23
Middle Atlantic	198,175	3.50	1.58	2.77	1.57	1.71	11.11
East North Central	213,260	2.07	1.23	1.51	1.06	1.30	7.17
West North Central	116,685	1.75	1.09	1.65	1.18	1.74	7.43
South Atlantic	96,150	1.75	1.47	1.34	1.28	1.26	7.08
East South Central	99,425	0.60	0.41	0.56	0.53	0.74	2.84
West South Central	97,895	1.51	0.95	0.99	0.96	1.31	5.73
Mountain	40,600	2.01	2.03	1.42	1.11	1.59	8.17
Pacific	98,010	1.93	1.38	1.49	0.89	1.07	6.74

Table 12. Doctorate productivity indices for the nine regions of the United States.

Region	General field of doctorate: Phys. sciences	Biol. sciences	Social sciences	Arts, humanities	Education	All fields
New England	140	164	161	151	124	147
Middle Atlantic	164	122	165	136	124	146
East North Central	97	95	90	91	94	94
West North Central	83	85	99	102	126	97
South Atlantic	83	113	80	110	91	93
East South Central	28	32	34	46	53	37
West South Central	71	74	59	83	95	75
Mountain	94	156	85	96	115	107
Pacific	91	106	89	77	77	88

Table 13. Number of doctorates in the several fields per 1000 high school graduates, by class size.

Class size categories	High school graduates, 1944 (*N*)	General field of doctorate: Phys. sciences	Biol. sciences	Social sciences	Arts, humanities	Education	All fields
1–9 10–19	17,200 72,700	0.69	0.76	0.64	0.61	1.08	3.28 3.73
20–39	154,000	1.08	0.94	0.89	0.85	1.52	5.10
40–59	102,000	1.41	1.07	1.08	0.79	1.45	5.70
60–99	139,500	1.80	0.95	1.17	1.04	1.23	6.16
100–199	180,800	2.27	1.50	1.73	1.42	1.45	8.36
200–399	204,200	2.78	1.49	2.09	1.30	1.23	9.01
400–599	92,200	3.19	1.74	2.95	1.39	1.61	11.00
600–799	36,400	3.23	1.67	2.82	1.73	1.45	11.03
800+	21,000	7.30	3.32	6.00	2.76	2.23	22.18

data needed for this purpose were derived from the U.S. Office of Education's *Directory of Secondary Day Schools, 1951–52*, which gives for each high school in the country the number of students graduated in 1952. The geographic region is of course derived directly from the address. For the purposes of this article, the United States is divided into nine regions, as follows. (i) New England: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut; (ii) Middle Atlantic: New York, New Jersey, Pennsylvania; (iii) East North Central: Ohio, Indiana, Illinois, Michigan, Wisconsin; (iv) West North Central: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas; (v) South Atlantic: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida; (vi) East South Central: Kentucky, Tennessee, Alabama, Mississippi; (vii) West South Central: Arkansas, Louisiana, Oklahoma, Texas; (viii) Mountain: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada; and (ix) Pacific: Washington, Oregon, California, Alaska, Hawaii.

The U.S. Office of Education's *Directory* gives the total number of students graduating in each state in 1952. Regional totals were derived by summing, and these regional totals were adjusted to the 1944 base on the assumption that the proportion of students graduating in each region in 1944 was the same as in 1952. Although this assumption cannot be directly checked (if it could be, the actual figures would be used), it provides a constant figure, 1.02 million graduates, as a base for all comparisons with the 1958 doctorate population.

For each region, the number of doctorates per 1000 high school graduates was computed, by fields and for the total of all fields. These figures are given in Table 11. To derive an index which compares both fields and regions equitably, these data were corrected for variations in field size and then divided by the over-all figure for productivity of doctorates per 1000 high school graduates—7787/1,020,000, or 7.63. This produces the indices shown in Table 12, which are analogous, for the regions, to indices given in Table 6 for intelligence measures and in Table 8 for rank in class. The data of Table 12 are shown graphically in Fig. 3. The detail provided by this graph has some interesting aspects which suggest, if they do not

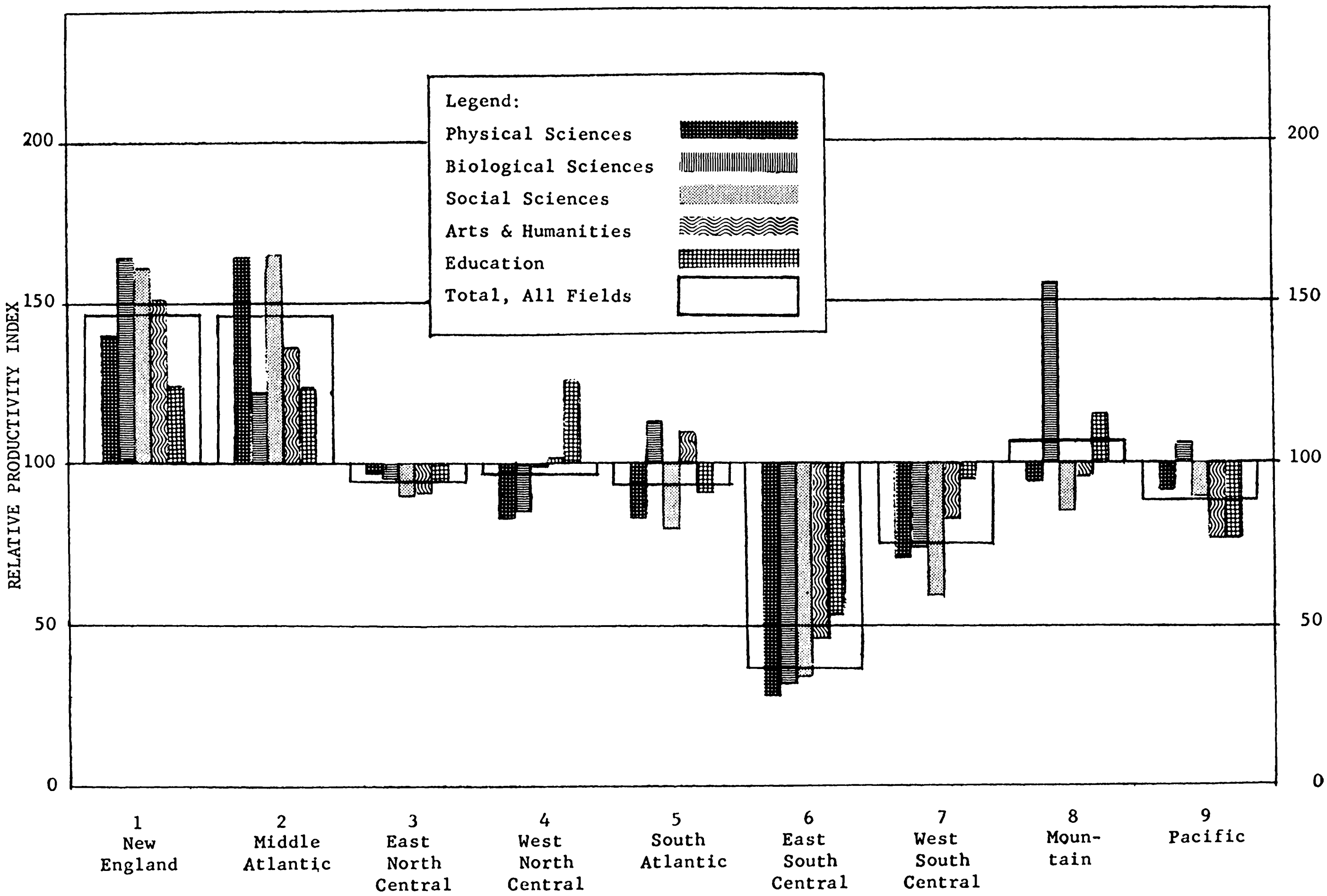

Fig. 3. Relative doctorate productivity, by field and by region of the United States.

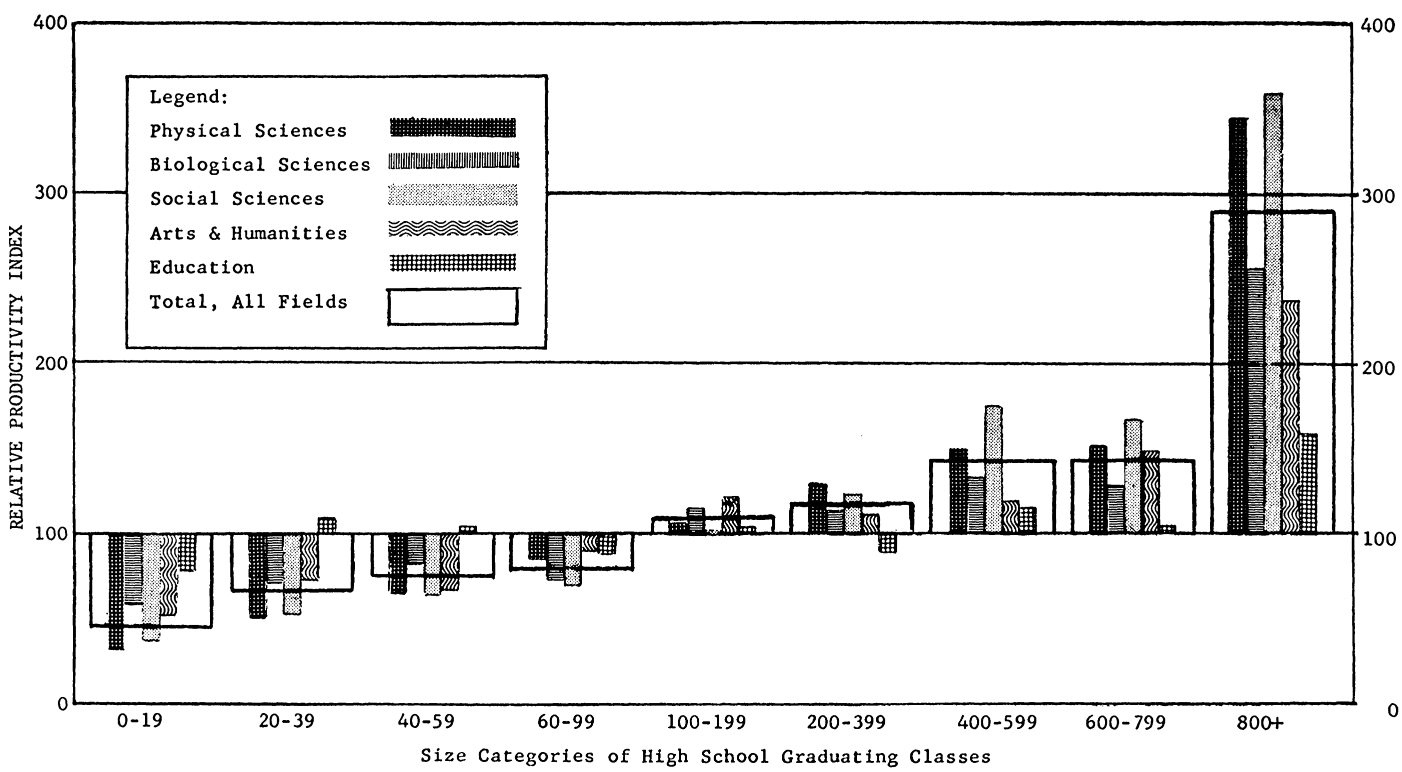

Fig. 4. Relative doctorate productivity, by size of high school graduating class.

demonstrate, some of the factors that determine choice of field.

It may be noted that the northeastern states, as a whole, outproduce the rest of the country by almost 50 percent, when all fields are considered together. In the Middle Atlantic states, where the dominant demographic feature is the huge urban complex extending from New York City to Philadelphia, the productivity index for the biological sciences is only 25 percent above the national norm, while for all fields combined, it is almost 50 percent above the national average. The obvious hypothesis is that this pattern is a function of the reduced contact with life forms in the urban areas. This hypothesis is further strengthened by the exceptionally high productivity index in the biological sciences for the Mountain states—over 50 percent above the national norm, although the indices for the other fields are unexceptional. In spite of these rather spectacular variations for the biological sciences, the field which deviates most from the norm is social sciences, with physical sciences in third place. In the case of these latter two groups, the deviations from the national norm are more often in line with the variations for all fields considered together and are thus not as conspicuous as deviations for the biological sciences. Education shows the least regional variation in productivity rate in the five general fields.

Table 14. Doctorate productivity indices, for various categories of class size.

Class size cate-gories	General field of doctorate					
	Phys. sciences	Biol. sciences	Social sciences	Arts, humanities	Edu-cation	All fields
1–9 10–19	32	59	38	53	78	43 49
20–39	51	72	53	74	110	67
40–59	67	83	65	68	105	75
60–99	85	73	70	90	89	81
100–199	107	116	103	122	105	110
200–399	131	115	125	112	89	118
400–599	151	135	176	120	116	144
600–799	153	129	169	150	105	145
800+	344	257	359	239	161	291

Size of Graduating Class

The influence of size of high school graduating class is of particular interest at this point, both because of the recommendations of the Conant report and because of a prior finding of the Office of Scientific Personnel, reported in *Science* [**130**, 1473 (27 Nov. 1959)]. In this prior report it was shown that size of high school graduating class is positively related to the *proportion* of graduates going into the physical and behavioral sciences, and negatively related to the proportion going into the biological sciences. At that time, no normative frame of reference was available; it was possible only to make comparisons within the doctorate population. From figures on high school graduating class size given in the U.S. Office of Education's *Directory of Secondary Day Schools,* referred to above, it was possible, in the present study, to determine how many of the total number of graduates came from classes of a given size, as tabulated in Table 13. These numbers were scaled down, as were those in Table 11, on the basis of the 1.02 million graduates of 1944. Then, by the processes described for other measures, relative productivity measures were derived for each class size for each field of doctorate. These indices are shown in Table 14 and displayed graphically in Fig. 4. Both the over-all trend, which shows a positive relationship, and the variation in these indices by field of doctorate are of considerable interest.

The field of physical sciences appears to be the most sensitive to class size, with the social sciences a close second. The reasons for these variations cannot be determined directly from the data, but some rather obvious hypotheses may be constructed. The smaller schools are, in general, deficient in both the laboratory equipment and the personnel necessary for extensive pursuit of the physical sciences. The larger schools, in general, are better equipped and offer more mathematics and science courses, taught by teachers with more highly specialized training. In the case of the social sciences, it seems much more likely (especially in view of the poor showing of this group on the mathematics-science grade point average) that urban concentration itself, with the multiplicity of social problems that it presents, is a strong factor in the decision of students in large urban schools to enter the social sciences. The biological sciences group, it may be noted, is positively affected by class size, but not so strongly as are the physical and social sciences. In order to examine this question further, the doctorates in the agriculture-related sciences were studied separately. Here a true negative relationship was found: the smaller classes produced more agricultural scientists per 1000 graduates than did the larger schools. The reason here seems quite obvious: these people come predominantly from farm backgrounds, and rural schools make up the bulk of the smaller-class-size categories.

In the arts and humanities group a relationship between size of high school class and production of doctorates is found, but it is not particularly marked. In the case of education, the relationship is almost nonexistent. When data for all fields are combined, two findings are outstanding. One of these is the remarkable productivity of the largest-class-size category—three times the national norm. The other is the finding that schools with less than 100 graduates per class are all below the national norm, while those with more than 100 are all above the national norm. This provides dramatic confirmation of the minimum standard that was proposed by Conant in his well-known study.