The Growth of Medical Research 1941-1953 and the Role of Public Health Service Research Grants

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Since the beginning of World War II, there has been considerable expansion of medical research in the United States. This expansion has been made possible by the diligent toil of many scientists, the vision and cooperation of hundreds of research institutions, and the generosity and enlightened self-interest of the millions of citizens who have borne the cost through gifts or taxes.

Realizing that many persons would share our interest in the magnitude, cost, and results of this expansion as well as in the role played by the Public Health Service research grants program, we wish to present here some aspects of the development.

Total Expenditures for Medical Research in the United States

Some measure of the magnitude of medical research is reflected in cost figures. Though precise cost figures are not available, it has been estimated (*1*) that the total expenditure for medical research in the United States increased from an annual rate of $18,000,000 in 1941, to $115,000,000 in 1946, and to $181,000,000 in 1951. Thus, the total annual expenditures, uncorrected for inflation, increased tenfold in a decade. It is important to note (Fig. 1) that the sources of the funds also changed to a marked degree. The Federal Government, a very minor contributor in 1941, provided $28,000,000 in 1946 and $76,000,000 in 1951. Industry provided $55,000,000 in 1946 and $60,000,000 in 1951. Contributions from all other sources, including foundations, were $32,000,000 in 1946 and $45,000,000 in 1951.

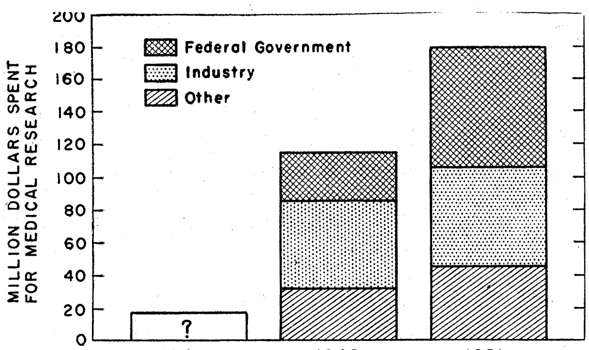

Fig. 1. Increase in total expenditure for medical research in the U. S., 1941–1951.

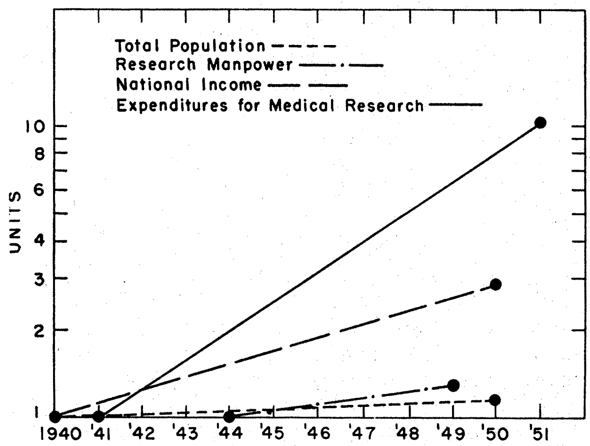

Fig. 2. Growth rate of population and the national income in the U. S. in comparison with trends in expenditures for medical research and trained medical research manpower, 1940–1951.

Medical Research Manpower

The total trained manpower for medical research in the United States has never been determined, but considerable information can be obtained by the study of various listings and rosters, such as *American Men of Science* (*2*). In the 1944 edition, 5665 non-Federal, nonindustrial medical scientists were listed. The number had increased 29.66% to 7345 in the 1949 edition. Of these 7345 scientists, 5391 were associated with medical schools and 1954 had various other affiliations. In addition, there were 825 listed in Federal Government services and 838 in industry, making a total of 9008.

The rate of increase of trained research manpower is probably considerably greater than these figures indicate because of the delay between completion of training and the achievement of sufficient scientific stature to be listed in *American Men of Science*.

Medical Research as a National Effort

In Fig. 2, on semilogarithmic scale, there is shown the crude growth rate of the population and the national income in comparison with trends in expenditures and trained manpower in medical research. It is evident that medical research manpower has increased more rapidly than the general population, and that expenditures for medical research have increased at a greater rate than national income.

Our estimates indicate that 0.024 per cent of the national income was spent for medical research in 1940, with an increase by 1950 to 0.074 per cent. By extrapolation over the same time period, the percentage of the population holding senior medical research positions increased from 0.0035 per cent in 1940 to 0.0051 per cent in 1950. The national medical research effort, in spite of an accelerated expansion over the past decade, still absorbs only a minute fraction of the national income and the national manpower pool.

The expansion continues, however, without perceptible slackening, and the demand appears far from being satisfied. The availability of research money attracts young men who become trained and in turn create more demand for research money. Educational institutions and hospitals that never before participated in research are beginning to appoint research-minded staff members who attract research money, train young men, and so forth. This self-catalyzing process has continued in the face of a national emergency, and despite the drafting of young men for military service. Fund-granting agencies receive ever more numerous requests for the support of worthwhile research. It thus would appear that the limiting factor in the current expansion has been money rather than manpower.

Trends in Volume and Types of Research, Sources of Published Papers, and Sources of Support

We have found it most difficult to obtain accurate information on research work in progress. The excellent paper by Deignan and Miller (*3*) gives valuable data on perhaps a 20 per cent segment of the work in progress, but contains no information on research supported within the given institution. Thus, there are no data on work in industry and in Government laboratories, or on work supported by hospitals, universities, or local donors.

TABLE 1

Sources of Publications in Medical Science

Source	1948		1951		Change between 1948 and 1951	
	No.	%	No.	%	No.	%
Universities and colleges	2929	65.71	3750	66.92	+821	+28.03
Research foundations	242	5.43	289	5.16	+ 47	+19.42
Hospitals	410	9.19	448	8.00	+ 38	+ 9.27
Commercial laboratories	220	4.93	197	3.51	− 23	−10.45
Government laboratories	393	8.82	588	10.50	+195	+49.62
Other	264	5.92	331	5.91	+ 67	+25.38

TABLE 2

Acknowledged Financial Support of Medical Publications Originating in Universities and Colleges

Source of support	No. of papers 1948	No. of papers 1951
U. S. Public Health Service	369	935
Other Federal agencies	309	368
Foundations and voluntary agencies	725	799
Commercial	197	148
Other	21	62
No acknowledgment	1308	1437
Total	2929	3729

In order to obtain a broader sample of the total effort, we have analyzed the publications in 36 leading research journals for the years 1948 and 1951. In 1948 there were 4458 articles, and in 1951 the number had increased 20.45 per cent to 5604. Each journal published more articles in 1951 than in 1948, and most journals showed a greater backlog in 1951 (as judged by the interval between receipt of manuscript and publication). This indicates a greater volume of research in all the basic sciences as well as in most clinical fields.

The changing pattern of distribution of research effort is indicated in Table 1. Educational institutions are increasing their lead in volume of publications, and Government laboratories appear to be moving into second place at a rapid rate. Papers from commercial laboratories have decreased in number whereas from all other sources papers have increased.

Colleges and universities receive a considerable but unknown portion of the financial support of their research through grants and contracts. We therefore recorded the acknowledgments of grant or contract support mentioned in those papers coming from colleges and universities (Table 2). This study confirms the growing importance to universities of Federal support in medical research. The absence of acknowledgment of grant or contract support may, in some cases, be an oversight; but since it is true that grants and contracts usually provide only partial support of a project, it seems clear that universities and colleges continue to provide substantial support of medical research from their own funds. Foundations and voluntary agencies appear to have supported more work in 1951 than in 1948. Only the commercially supported studies show a decrease in number.

Trends in Geographical Distribution of Research Manpower and Publications

The concentration of medical research in a few centers has long been recognized and the undesirable consequences of such concentration have been pointed out by many writers. We have therefore examined the geographical distribution trends with particular in-

TABLE 3

GEOGRAPHICAL DISTRIBUTION OF NON-FEDERAL NONINDUSTRIAL MEDICAL SCIENTISTS BASED ON *American Men of Science* LISTINGS

Area	States	1944 Edition		1949 Edition		Increase	
		No.	%	No.	%	No.	%
New England	Me., Vt., N. H., Mass., R. I., Conn.	651	11.49	774	10.54	123	18.89
Middle Atlantic	N. Y., Pa., N. J.	1556	27.47	1942	26.43	386	24.81
South Atlantic	Del., Md., D. C., Fla., Va., W. Va., N. C., S. C., Ga.	712	12.56	841	11.45	129	18.12
East North Central	O., Ind., Ill., Mich., Wis.	1109	19.57	1451	19.76	342	30.84
East South Central	Ky., Tenn., Miss., Ala.	196	3.46	207	2.82	11	5.61
West North Central	Minn., Ia., Mo., N. D., S. D., Neb., Kan.	610	10.77	828	11.27	218	35.74
West South Central	Ark., La., Okla., Tex.	266	4.70	351	4.78	85	31.95
Mountain	Mont., Ida., Wyo., Nev., Utah, Colo., Ariz., N. Mex.	117	2.07	181	2.46	64	54.70
Pacific	Wash., Oreg. Calif.	448	7.91	770	10.49	322	71.88
Total		5665	100.00	7345	100.00	1680	29.66

terest. From the standpoint of scientific manpower we find that the most rapid rates of increase are not in the old well-established institutions of the East, but rather in other institutions and areas (Table 3). To what extent the redistribution of manpower may be due to local interest or to policies of large granting agencies remains unknown, but it seems likely that local initiative has been an important factor. Not all geographic areas have been equally successful in attracting scientific manpower. Some appear to have the desire but to lack the funds, and vice versa. In this connection, it is interesting to compare the distribution of population and per capita income (Table 4) with the distribution of research manpower. One sees a tendency toward proportionality, but there are exceptions even on the basis of large geographical areas. If one examines the record, state by state, one finds even greater disproportions, so that some rather populous states with better than average per capita income have almost no trained medical research manpower as we have measured it.

TABLE 4

COMPARISON OF MEDICAL RESEARCH MANPOWER WITH POPULATION AND PER CAPITA INCOME BY GEOGRAPHICAL AREA

Area	AMS listings, 1949 (%)	Population, 1950 (%)	Thousand population per AMS listing	Per capita income
New England	10.54	6.18	12.03	$1554
Middle Atlantic	26.43	20.01	15.53	1717
South Atlantic	11.45	14.06	21.16	1137
East North Central	19.76	20.17	20.95	1603
East South Central	2.82	7.62	55.45	865
West North Central	11.27	9.33	16.98	1387
West South Central	4.78	9.65	41.29	1144
Mountain	2.46	3.37	28.04	1358
Pacific	10.49	9.61	18.81	1709
Averages			20.42	$1436

This maldistribution may possibly be due to an error in measurement, but we have considerable confidence in the general reliability of this manpower sampling method because the results show a high degree of correlation (0.92–0.98) with other analyses we have made on rosters maintained by the Office of Education and the Office of Defense Mobilization. There are obvious reasons, of course, why one must not assume that all medical scientists listed in *American Men of Science* are equally productive in research. The men listed may be assumed to meet certain minimum standards since the listings are developed with the guidance of the national professional scientific societies and are based on educational background, publications, academic position, and scientific reputation.

It is well known, however, that even though the Ph.D. candidate must demonstrate some research ability in his thesis work, he may lose interest in research or may have so many other duties that he is unable to continue his research in an academic or other position. The M.D. with his training directed primarily toward the practice of medicine rather than research is not always trained in research, even though he may be a renowned professor.

One should therefore take into account such factors as research ability, research interest, research opportunity, and research facilities. These factors cannot readily be measured directly, but inasmuch as they play an important role in determining whether a man publishes research papers, they can be measured indirectly by enumeration of scientific publications. We realize that when such a measurement is applied to a single investigator it means little, for one man may write much and contribute little of importance, whereas another man may write but one paper and yet make a major contribution. As the number of scientists involved increases, however, the importance of this individual variation diminishes, so that, for a large geographical area with many scientists, the number of papers written in a given period becomes quite significant. It is believed that the accuracy of the method is further increased by limiting the enumeration to the highly reputable national scientific periodicals which screen papers carefully before accepting them for publication. Accordingly, 53 such periodicals were analyzed and the 13,911 articles were tabulated according to the institution of origin. The results are summarized in Table 5, which shows the comparative percentages in 1940 and 1950.

TABLE 5

GEOGRAPHICAL ORIGIN OF ARTICLES APPEARING IN LEADING MEDICAL SCIENTIFIC PERIODICALS

Area	Articles appearing in 50 periodicals, 1940 (%)	Articles appearing in 53 periodicals, 1950 (%)
New England	13.54	13.29
Middle Atlantic	31.28	27.80
South Atlantic	10.31	10.52
East North Central	19.88	21.18
East South Central	3.29	2.37
West North Central	9.43	8.61
West South Central	3.93	4.52
Mountain	1.20	2.01
Pacific	7.10	9.69

When the distribution of sources of publications is compared with the distribution of scientific manpower, it is noted that some areas appear more productive, man for man, than others. The ratio between percentage of publications and percentage of men in 1950 varies from 0.82 in the Mountain States to 1.26 in the New England States. When the ratio is determined for individual universities the variation is much more striking—0.14 for the lowest and 1.71 for the highest. Anyone familiar with the great variation from one school to another in amount of research activity will not be surprised at this twelvefold difference.

RESEARCH POTENTIAL

In view of these major differences in productivity it is obviously necessary to adjust manpower figures if one wishes to consider research potential. Reynolds and Price (*4*) developed a useful index of research potential based on manpower, publications, advanced degrees, approved residencies, and other factors. They subsequently found that essentially the same index could be obtained by considering only manpower and publications. The index is obtained by the formula:

$$\%\ \text{Research Potential} = \frac{\%\ \text{AMS Listings} + \%\ \text{Publications}}{2}$$

Using this formula, we have calculated the distribution of research potential for the years 1940 and 1950 (Table 6).

TABLE 6

MEDICAL RESEARCH POTENTIAL IN NON-FEDERAL INSTITUTIONS BY GEOGRAPHICAL AREA

Area	R. P. 1940–44 (%)	R. P. 1949–50 (%)
New England	12.51	11.92
Middle Atlantic	29.37	27.12
South Atlantic	11.44	10.99
East North Central	19.73	20.47
East South Central	3.38	2.60
West North Central	10.10	9.94
West South Central	4.32	4.65
Mountain	1.64	2.23
Pacific	7.51	10.08

These figures demonstrate that some redistribution of research potential has occurred, but the striking changes are obscured by the fact that all these geographic areas contain institutions that are growing in research potential at widely different rates. If one considers individual medical schools, the changes are more striking. Reynolds and Price (*4*) arranged the medical schools in descending order of research potential and recorded the results in groups of ten. We have used their same grouping and brought the re-

TABLE 7

CHANGES IN RELATIVE MEDICAL RESEARCH POTENTIAL IN INSTITUTIONS HAVING MEDICAL SCHOOLS

Group	R. P. 1940–44 (%)	R. P. 1949–50 (%)	Increase (%)
1st ten	27.91	28.22	1
2nd ten	14.38	15.94	11
3rd ten	7.63	7.72	1
4th ten	5.52	6.56	19
5th ten	4.04	4.25	5
6th ten	2.99	3.70	24
7th ten	2.03	3.39	67
Last eight	0.98	1.75	79
Total	65.48	71.53	

TABLE 8

MEDICAL SCHOOLS MOVING UP MOST RAPIDLY IN RESEARCH POTENTIAL RANK ORDER BETWEEN 1944 AND 1950

School	Increase in rank order
Univ. Utah	43
Univ. Washington	27
Syracuse Univ.	24
New York Medical College	19
Southwestern Medical School	18
College Medical Evangelists	17
Emory Univ.	16
Univ. Indiana	14
Boston Univ.	13
Tufts College	11
Bowman-Gray	11
Univ. Alabama	10
Univ. So. Calif.	9
Univ. Texas	8

sults up to date in Table 7, which shows that schools toward the bottom of the Reynolds-Price list had the most rapid increase in research potential. Increases at some schools have occurred at such a rapid rate that if a new list based on the more recent rating is made, it is found that eleven schools have moved up more than ten places. The University of Utah, for example, moved up 43 places; the University of Washington, 27 places; and Syracuse University, 24 places. The schools showing the greatest increases are listed in Table 8.

Comments on the General Picture

From the evidence presented in the preceding sections, it seems justifiable to conclude that in the decade from 1940 to 1950 medical research made rapid strides in the United States. Expenditures increased about tenfold; the Federal Government emerged as a major source of financial support; the pool of trained manpower increased considerably as did also the rate of scientific publications. Powerful new foci of research appeared, and the tendency to concentrate medical research in perhaps a dozen large centers was reversed as research activity increased across the land.

Many factors have worked to bring about these changes, such as unprecedented prosperity, military necessity, and education of the general public to the value of research. With growing public understanding has come growing public support both through voluntary agencies, such as the American Cancer Society, and through tax-supported agencies, such as the Public Health Service.

Development of the Public Health Service Research Grant Programs

Although the Public Health Service awarded a few grants for cancer research every year from 1937 on, the broad program began in 1946 with the transfer of 50 projects from the Office of Scientific Research and Development when that agency was dissolved. The new program had as its objective the improvement of the nation's health through the acquisition of new knowledge in all the sciences related to health. In the sense that the new knowledge is sought for the purpose of improving health this program is one of applied research, but many of the grantees consider their projects basic. Those who established the program believed that maximum progress can be achieved only if the scientists enjoy freedom to experiment without direction or interference, and they drew up policies and procedures accordingly. The decision as to which applications are approved rests with committees of non-Government scientists, who serve also to develop policies designed to meet changing needs. The investigator works on problems of his own choosing and is not obliged to adhere to a preconceived plan. He is free to publish as he sees fit and to change his research without clearance if he finds new and more promising leads. He has almost complete budget freedom as long as he uses the funds for research purposes and expends them in accordance with local institutional rules. Progress reports are required only once a year and are used chiefly as the tool for evaluation of renewal applications. Title to equipment purchased with grant funds is vested in the grantee institution and remains with that institution upon termination of the grant. Once a grant is made, there is no direction or interference on the part of Government.

Some control of the subject matter distribution of research, however, is implicit in a competitive project system since there are always more applications than there are funds, and by choosing which projects are to be supported, one sets the general pattern to some extent. In addition, Congress imposes a degree of control and direction when it appropriates funds earmarked for research on a designated disease or a specific organ. The extent to which funds have been earmarked is shown in Table 9. Here it is seen that in 1953 about 80 per cent is earmarked. In actual practice, however, it has been possible to provide reasonably equal opportunity for scientists regardless of their specialty in the health field, since the earmarked areas are broad and overlap to a considerable degree, especially with regard to the basic medical sciences.

In the eight years since the program began, more than 14,000 applications have been received covering

TABLE 9

NIH* Research Grants Appropriations by Fiscal Year

Field	1945	1946	1947	1948	1949	1950	1951	1952	1953
Cancer	85,030	76,900	515,000	2,599,635	3,300,000	2,600,000	3,129,079	3,100,000	4,920,000
General		703,258	2,922,280	5,901,163	7,025,492	5,570,000	5,108,645	4,305,000	4,255,000
Mental health				373,665	546,000	794,000	1,198,628	1,663,000	1,662,000
Heart						3,820,000	4,327,479	4,809,000	5,150,000
Dental						200,000	218,400	221,000	221,000
Arthritis and metabolic diseases							695,395	1,345,000	1,345,000
Neurological diseases and blindness							342,708	1,015,000	965,000
Microbiology							1,353,794	1,950,000	1,950,000
Total	85,030	780,158	3,437,280	8,874,463	10,871,492	12,984,000	16,374,128	18,408,000	20,468,000

* National Institutes of Health—the Bureau of the Public Health Service responsible for the administration of the research grants program.

every major scientific area related to health (Fig. 3). More than 7000 grants have been awarded, totaling nearly $100,000,000. The amount of support in specific scientific fields has been reported elsewhere and need not be repeated here. Suffice it to say that, in general, the distribution pattern of the grants corresponds closely with that of the applications and covers every active area of health research.

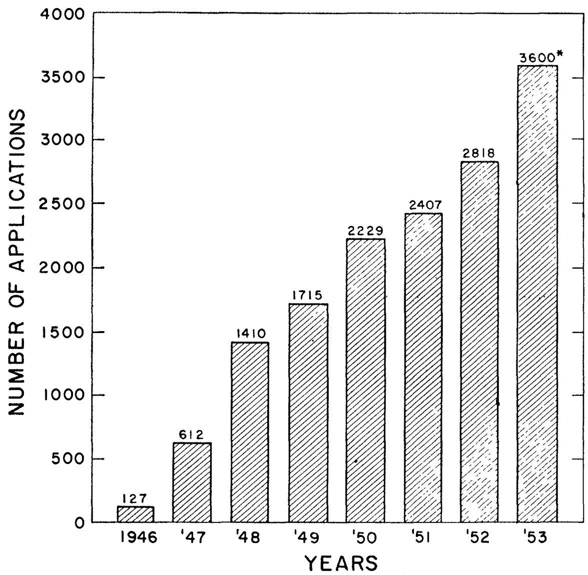

FIG. 3. Increase in applications for Public Health Service Research Grants received during 1946–1953. * Estimated on basis of receipts to date.

Geographical Distribution of Public Health Service Research Grants

Since this program seeks better health through research, it has been assumed that the geographical location of the scientist is of minor importance compared with the originality of his proposal and his ability as an investigator. Decisions on projects to be supported have therefore been made on the basis of individual merit. Other things being equal, one would predict that the aggregate result would be a grant distribution pattern similar to that of research potential. Reynolds and Price found this to be true from 1946 to 1949. The results from 1949 to 1952 are similar (Fig. 4). Only the New England States depart significantly from the expected pattern: they receive about 16 per cent of the funds and possess about 13 per cent of the research potential. All other areas are within 2 per cent of the expected pattern.

When funds requested are compared with funds granted (Fig. 5), the correlation is excellent. Thus it appears that the selection system is free of geographical bias. As research potential has shifted, the distribution of funds has shifted accordingly. Much has been written regarding the tendency of all granting agencies to concentrate their awards in the large well-established universities. Figure 6 indicates that the

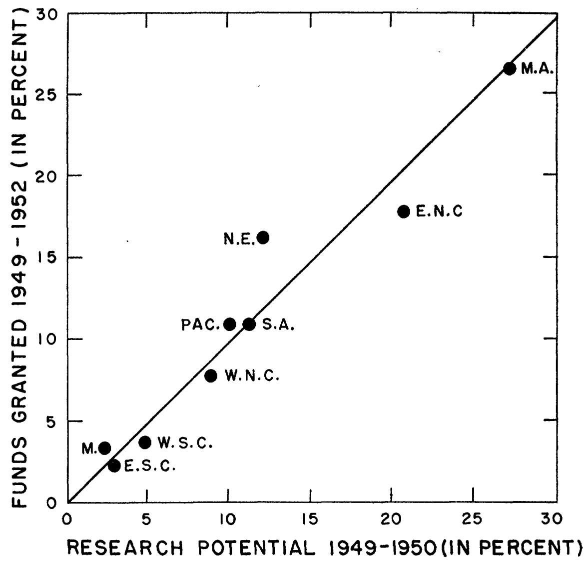

FIG. 4. Geographic distribution of Public Health Service Research Grant Funds awarded, 1949–1952, in comparison with geographic distribution of research potential, 1949–1950.

Public Health Service program shows this tendency to a slight degree. Thus 35 per cent of the funds went to the top ten schools which have, according to our calculations, 29 per cent of the research potential.

Role of Public Health Service Research Grants in the Country's Medical Research

One can only speculate as to what the developments might have been if the Public Health Service research grants program had not been established, but it seems obvious that a rapid expansion of effort in medical

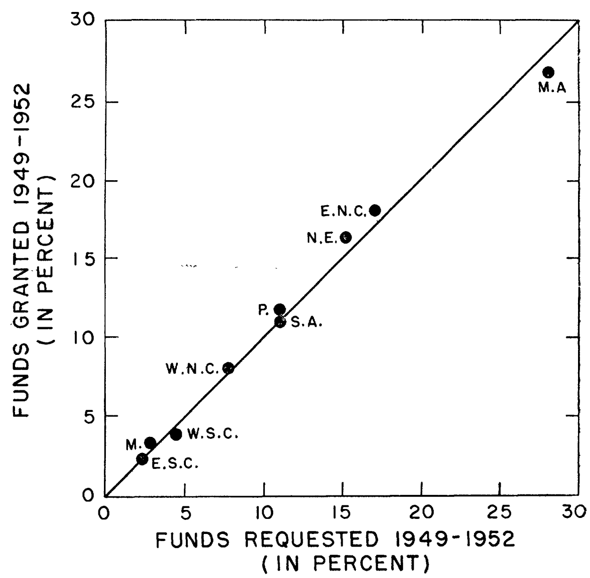

FIG. 5. Geographic distribution of Public Health Service Research Grant Funds requested, in comparison with distribution of funds granted, 1949–1952.

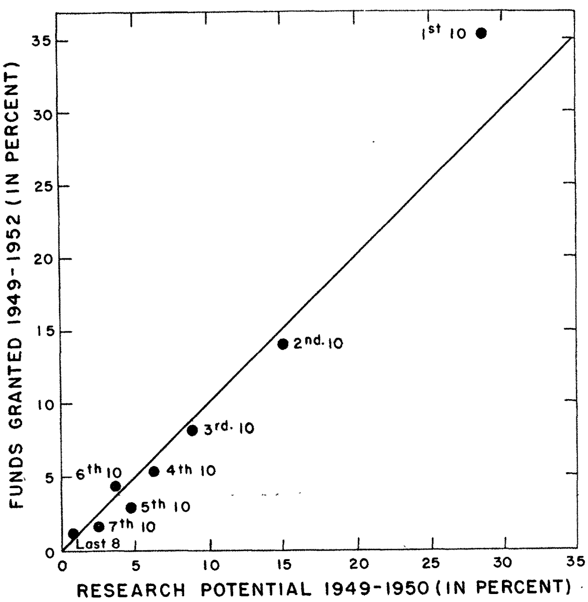

FIG. 6. Comparison of Public Health Service Research Grant Funds awarded, 1949–1953, with research potential, 1949–1950, in schools ranked according to descending order of research potential.

research was inevitable at the end of the World War II. Military necessity had required the initiation of the expansion and had set into motion the buildup of manpower, facilities, and the interest of the academic scientists. The general public, deeply impressed by the success of atomic research, manifested its desire to support medical research by establishing and giving generously to a number of voluntary associations.

In this expanding framework the Public Health Service program has served as only one of many sources of support. Thus, Deignan (*3*) reports that in 1951 the national foundations, voluntary agencies, and the Federal Government provided $32,893,609 in grants and contracts for medical research. Of this amount, about $22,000,000 came from Government, of which Public Health Service grants were $16,000,000. The remaining $11,000,000 came from private sources. In that same year, grants and contracts actually constituted only 18 per cent of the total expenditures for medical research ($181,000,000), so that the Public Health Service research grant program constituted only 8.8 per cent of the total support.

Despite the fact that, by percentage, the program was only 8.8 per cent, its effects were considerable. For example, of the medical research publications originating in universities and colleges in 1951, nearly 25 per cent acknowledged partial support by Public Health Service research grants. It is important to note that in most instances PHS support was only partial. The grants have averaged less than $9000 and have usually provided salaries for an assistant or two along with some equipment and supplies. Only rarely (less than 1.6 per cent of the funds) has a grant provided salary of the principal investigator and in no instance has a grant provided the total cost of a project. Thus the program has been of greatest assistance to those institutions that were willing and able to employ and provide basic facilities for competent scientists. By supplementing local support in this way the Public Health Service research grant program has served to make possible the increased usefulness of existing manpower and facilities.

In addition to utilizing existing manpower, the program has contributed to the training of many new scientists who received training while they were employed on grant funds. The magnitude of this training aspect can be inferred from the fact that 35 per cent of the funds, or nearly $35,000,000, was spent by grantees to employ professional assistants between 1946 and 1953. Many of these former assistants are now grantees themselves.

Another major effect of the program has been to help stimulate research in neglected fields—particularly research on some of the chronic diseases. From the over-all standpoint, however, perhaps the most important function of the program is that of a balance wheel. It serves at a national level to provide research opportunity on an individual basis to a large segment of the trained manpower pool for the work which the scientist himself wants most to do.

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