

MIRROR TO PHYSIOLOGY

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A Self-Survey of Physiological Science

R. W. GERARD, M.D., PH.D., Sc.D.

Professor of Neurophysiology in Psychiatry and Physiology
Member Mental Health Research Institute
University of Michigan, Ann Arbor

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PREFACE

This is a motley document, the product of many, presented for what it is. Fondly conceived as another Flexner report, it lacked a Flexner to produce it. The excitement of planning by varied committees was not always maintained through execution; communication, necessarily difficult, was strained by important changes in operating staff; questions were forgotten by the time answers became available; too much was undertaken with inadequate experience and funds (large though the support seemed); multiple purposes and distributed responsibility caused confusion and delay; the inevitable and evitable hazards of an extended undertaking exacted their full toll. As a result, the report is seriously late in appearing, and it lacks important portions of the anticipated perspectives along time and across disciplines.

But high devotion and hard labor have been poured into the mold, and the finished creation is not without merit. The Survey did pioneer in formulating a study of a profession, and its struggles have supplied both guidance and warning to many followers. It did amass great chunks of new data, collate older information, and make interpretations of the whole which have been put to use long before this report was completed. And it did catalyze much other successful activity, especially in the area of education, by the American Physiological Society and its sister organizations and by agents of other interests, from mathematics to medical schools.

Now that the experiences and findings of the Survey are public¹ we can only hope that their impact will be considerably greater—on investigators, teachers, administrators, editors, grantors; in short, on those groups who are and who channel physiology, now and in the future.

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Full sets of punched cards and codes are on file with the American Physiological Society and the Survey Research Center, Ann Arbor, Michigan, and are available under appropriate arrangements.

The National Science Foundation has supported the study financially, far beyond initial expectations of cost, has given those concerned with it entire freedom in all aspects, and has been patient with the delays in completion. The Foundation's interest and support are gratefully acknowledged. Particular thanks are also expressed to Dr. Louis Levin, Deputy Assistant Director, Biological and Medical Sciences, National Science Foundation, for his continued interest and help.

So many have helped, with or without official connection to the Survey, that it would be a hopeless effort to name all; and naming some carries an unwished neglect of others as its obverse. Yet how can I fail to thank Orr Reynolds, who helped initiate the project and directed it through its first infancy? Or Matt Bach, who carried the brunt of the study for sixteen months in Washington and then continued, on a volunteer basis and over an extended period, to prepare an exhaustive first draft of the report? Bill Land, an early member of the staff, later accepted the assignment of condensing and combining the material in the first draft—most tables of data are pretty much as he built or selected them, except that I have rounded figures freely—and of preparing a second draft of the descriptive text and adding some comparative material; and I could not fail to state this pleasant indebtedness. To Land is also due a careful check of data for consistency and validity. (Appendix G will aid the reader in judging the degree of significance of number and percentage differences presented in tables and text; but comparisons of small groups and subgroups or projections from respondents to total populations or from percentages to numerical equivalents, except as presented in the text, must be made with great care.) Wallace Fenn, co-chairman of the Central Committee, gave freely of his strength and dependability; Bob Galambos prepared an outstanding analysis of the personnel material; Ladd Prosser brought much wisdom concerning the college and general physiology; Ed Adolph gave generous attention to the second draft; Burr Steinbach, Maurice Visscher, and many others, gave assistance beyond the call of duty. Mrs. Thomas Law skillfully executed the illustrations; my wife meticulously checked manuscript.

I thank them all; I share with them the praise and blame due the Survey. For three things only must I accept individual responsibility—heavy editing for form of the final version of the report and addition of a few tables and calculations, including an appendix, insertion of occasional raisins of opinion in the textual dough of facts, and the chapter summaries and summary chapter.

October, 1957

R. W. GERARD

FOREWORD

This Survey was made at a time of tremendous flux in the socio-economic background of science in this country. The changes which have occurred are probably greater in the United States than in many of the older countries in Europe. The most significant change in recent years has been a great increase in the amount of Government support for scientific research. The purpose of the Survey was in part to discover the effect of this important infusion of dollars upon the status of physiology and of physiologists.

In looking back on the Survey it seems evident that its pace was too great. There were too many individuals contributing raw ideas and not enough time to sift out the good ones. The Director was expected to implement so far as possible the ideas supplied by the Committee, often after an inadequate period of incubation. Many of these ideas were good enough in themselves but it was unrealistic to expect a definite answer by any conceivable procedure. The necessity to start something quickly before the money ran out led inevitably to some hasty decisions. Everyone connected with the Survey did his best to make the study a real contribution to physiology but experience in this type of effort was lacking. We view this, the final result, with due humility and the firm conviction that we could do much better at a second attempt. Nevertheless the Survey has collected an impressive array of data, the final value of which is hard to predict. It may well turn out to be much greater than now appears.

The results of the Survey are informative and to some extent reassuring as to the status of physiologists. The present members of the profession seem to be reasonably well satisfied with their status and offered no excessive complaints, or as Pope wrote in his essay on Man—"The starving chemist, in his view, supremely blest." The numbers of physiologists have risen in proportion to the money available for their support and most of them find adequate opportunities to carry on their work in accordance with their own best judgment. Physiologists in general are as well off and as much respected as men of comparable experience in other branches of science. Almost everyone of course would like to be in a higher bracket in both prestige and salary, but it is only in a planned social order that salary can be made generally to exceed the level of public demand for the product.

Since the arrival of the Sputniks the public demand for more study of science in our educational system has been heard repeatedly. The need is

equally great for more study of physiological science. Indeed one of the distressing results of the Survey was the evidence that in the minds of the general public there is so little awareness of what physiology is. To be sure, there is a tremendous improvement over the situation in our schools 50 years or more ago. Even now, however, there is little enough physiology and too much of it comes to the public through the TV advertisements. Every physiologist knows how incredibly uncritical and deceptive the statements are. The level of physiological understanding is perhaps best illustrated by the widespread conviction that anything acid is bad and anything alkaline is therefore good. The Survey has showed us that we have a long way to go before the public will understand the full absurdity of that bit of advertiser's nonsense. And when that does happen, we shall probably have founded a new culture.

If there is any serious deficiency in physiology at present, it is probably in the recruitment of personnel of high competence. Here physiology competes not only with other sciences, particularly other medical sciences, but also with the professional practice of medicine and with private industry, which offers salaries to Bachelors of Science which are often equal to those given to Doctors of Science in Physiology. This is not, of course, a problem confined to physiology but it is certainly one which ought to receive the attention of those who are interested in the future of physiology or indeed in the future of science as a whole. The Survey represents an effort by the American Physiological Society to appraise this problem by first acquiring a better understanding of the present status of our own profession.

The work of the Survey has stimulated much thought on the status of physiology and this has already had an important influence on decisions taken in various academic institutions throughout the country. The data on the most desirable kinds of jobs are most revealing in the emphasis which is placed on individual freedom in research. This may well have a definite effect upon the treatment of physiologists in the future, particularly those in government or industrial laboratories where research is much more likely to be under rather drastic supervision from above. Perhaps the findings will help to raise the level of academic salaries so that universities will more successfully compete with industry for the best intellects. Perhaps, on the other hand, it will help the recruitment problem by showing that after all it is possible to make a reasonably comfortable living in teaching or research. Finally, the Survey will contribute much to the broad definition of physiology, which is not so much a restricted field of knowledge as it is a type of approach to biological problems.

Our definition of a physiologist for the purposes of the Survey was so broad that it may well have aroused some feelings of resentment in the minds of many who refused to admit that they belonged in this category. To them the Committee offers its apologies and disclaims any attempt to place physi-

ology as a discipline in any superior position relative to biochemistry or pathology or any other field of specialization. The usual definition of a *department* of physiology is much narrower. The broader definition was used only for purposes of the Survey. When attention has been drawn to the extensive contributions of physiology we use the term in this broader sense and realize that in many cases it might have been more accurate to have given the credit to biochemistry or some other sister department.

In part we set out to discover "What is physiology" but this was only a rhetorical question. In framing an answer we hoped not to describe sharp frontiers but simply to show how hazy the frontiers really are, how widely they extend, and how thoroughly they infiltrate into other disciplines. Biology is a continuum and all subdivisions are arbitrary. The definition of physiology, therefore, has no real importance in itself and is, furthermore, a completely hopeless and meaningless task. Our study of the problem has perhaps helped to demonstrate that under the general term, physiology or physiological science, there is opportunity for a valuable and satisfying career, and one which is also basic to progress in both medicine and agriculture. The real problem is not to define physiology but to learn how to improve and stimulate that scientific discipline until it has solved its ultimate problem—the nature of life itself. Various means of improving physiology to this end have been brought out in this Survey.

The suggestion for this Survey came from Ralph W. Gerard, the author of this volume. He also served as Chairman of the Committee which guided the work and he has taken chief responsibility for the final version of the report. The task proved to be far more formidable than anyone anticipated. Without the firm conviction of the Chairman that the Survey should, could, and at all costs of time and effort would be done, this final volume would not exist.

Throughout the preparatory work Dr. Gerard labored closely with the Office of the Director of the Survey in spite of the usual heavy professional demands upon his time, not to mention serious personal difficulties. During the preparation of the final manuscript he devoted a substantial fraction of his time to the work. Other members of the Committee were unable to contribute much of their time and provided only general advice and guidance. Almost all of the manual work of the Survey was of course carried out by the Office Staff, to whom the Chairman has made due acknowledgment in his preface. Chief credit for the overall accomplishment must, however, go to Dr. Gerard. It is my pleasure to acknowledge this on behalf of the Committee.

December, 1957

WALLACE O. FENN

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I

THE SURVEY IN BRIEF

PHYSIOLOGY AND PHYSIOLOGISTS

What Is Physiology?

The Survey of Physiological Science presents a composite picture of a scientific profession. 'What is physiology?' and 'Who are physiologists?' are two recurring questions. In spirit, physiology is not a science or a profession but a point of view; yet it is also institutionalized as both, so answers must be given. Briefly, and in an elementary way, here are some provided by the Survey.

All fields of knowledge and human interest are embraced by classifications, such as the librarian's decimal system, or the average college catalog of courses. Within such an all-embracing system it is customary to distinguish the natural sciences as comprising about one-tenth of the categories. Within the sciences, the custom today is to distinguish all those ways of studying living or once-living things as constituting biology. Within biology, the study of the dynamic or the active events in living beings is the subject matter of physiology. The same subject matter is often given other names; the term physiology is also used to include various other dimly related subject matters.

Physiology is, and is more than, the study of the physical and chemical processes in living units. This is, in essence, a paraphrase of one definition by a founder of modern physiology, Claude Bernard, as, 'the science whose object it is to study the phenomena of living things and to determine the material conditions in which they appear.' As such, physiology pervades the life sciences; it is a way of looking at life processes and understanding them. Physiology has also been called the science concerned with the organization of energy and matter in living systems and their likenesses to and differences from non-living systems.

Physiologists therefore study the physical and chemical processes in all living matter—from the single bacterium to flowering plants, from amoeba to caterpillar, shark, eagle, mouse, and man. Although most people regard physiology as a science primarily ancillary to medicine, this is not so. To be sure, much of its activity today is in the medical field because human physiology is not only the oldest branch of physiological science, but is also the one of most

immediate concern to humanity and therefore best supported. The real scope is as broad as all living beings, plant and animal.

Physiology is thus functional biology—using the word function in its scientific rather than in its pragmatic connotation. To those seeking to learn how organisms function, how life goes on, physiological science provides an approach which cuts across the lines of traditional biological disciplines. Generations of schoolteachers, abetted by the public press, have taught physiology only as it relates to human health, as practically synonymous with anatomy and as immutably 'tied to the tail of the medical disease kite.' Yet as functional biology, physiological science seeks a broader and more basic understanding of all life processes. Until this fundamental nature of the science of physiology is made widely clear by the agents of mass communication, physiology will remain in the public mind and to the public pocketbook merely as 'having something to do with the body.' Why the public knows what little it does about physiology and physiological science is told in Chapter XI.

Who Are Physiologists?

How the Survey operated to define physiology and to enumerate those scientists who considered themselves to be physiologists—some 5750 in the United States and Canada—is the subject of Chapter IV. A questionnaire was sent to some 7000 individuals and usable replies received from 4571 who regard themselves as physiologists, either primarily or secondarily. These respondents were estimated to be 79.5% of the total number. The exact figures depend, of course, on how 'physiologist' was identified.

There are about 1900 'central' or primary physiologists; that is, scientists who identify themselves with some branch of physiology (animal, plant, or bacteria) before they identify themselves with any other discipline. About double this number, 3850, are 'peripheral' physiologists, in that they first identify themselves with some other field of biology and only secondarily with physiology. This is the first survey of the physiological profession which has considered the important peripheral members.

Using categories which cut across both these groups, there are close to 3660 animal physiologists, 1230 plant physiologists and 700 bacterial physiologists, and an additional 160 in unspecified fields. These figures are detailed in Tables IV-1 and IV-2 and illustrated by Figure 1.

Physiologists are characteristically dispersed through many branches of biological science. The extent to which this permeation affects the thinking and methods of other disciplines, the Survey hoped to find out; but further investigation would be needed for the answer. The extent of potential interaction, however, is indicated by the considerable number of peripheral physiologists with primary interests in other fields, and of central physiologists

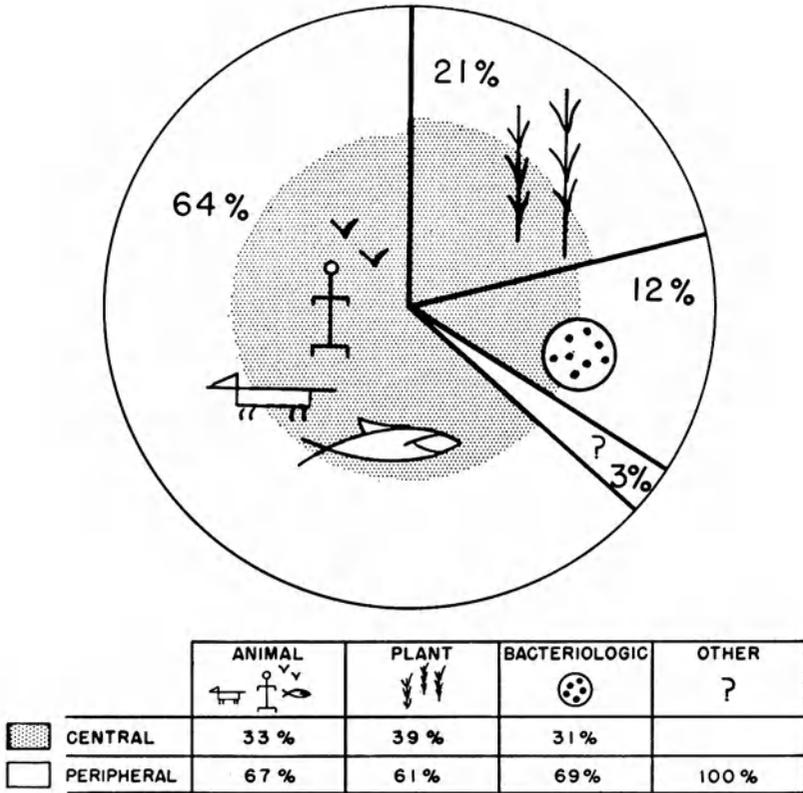


FIG. 1

secondarily identified with varied disciplines. These figures are in Tables IV-3 and IV-4, and the relationships are exhibited by Figure 2.

Most physiologists have the Ph.D. (or Sc.D.) degree, and some, mainly animal physiologists, have the M.D. degree, alone or in addition to the Ph.D. In the forty years, 1915 to 1954 inclusive, 1704 doctoral degrees in physiology have been granted by universities and colleges in the United States. This, however, is not a true measure of the growth of physiology, since physiologists obtain their doctorates in a wide variety of fields, such as: biochemistry, zoology, bacteriology, botany, biology, psychology, physics, chemistry, and agriculture and its related fields. Actually, only 32% of the Survey respondents, about the proportion of central physiologists, had taken their doctorates in physiology (Table X-13). A comparison of the number of doctorates in physiology and in all the biological sciences, for the period 1936-1950, is presented in Figure 3. The status of professional training and recruitment is considered in Chapter X.

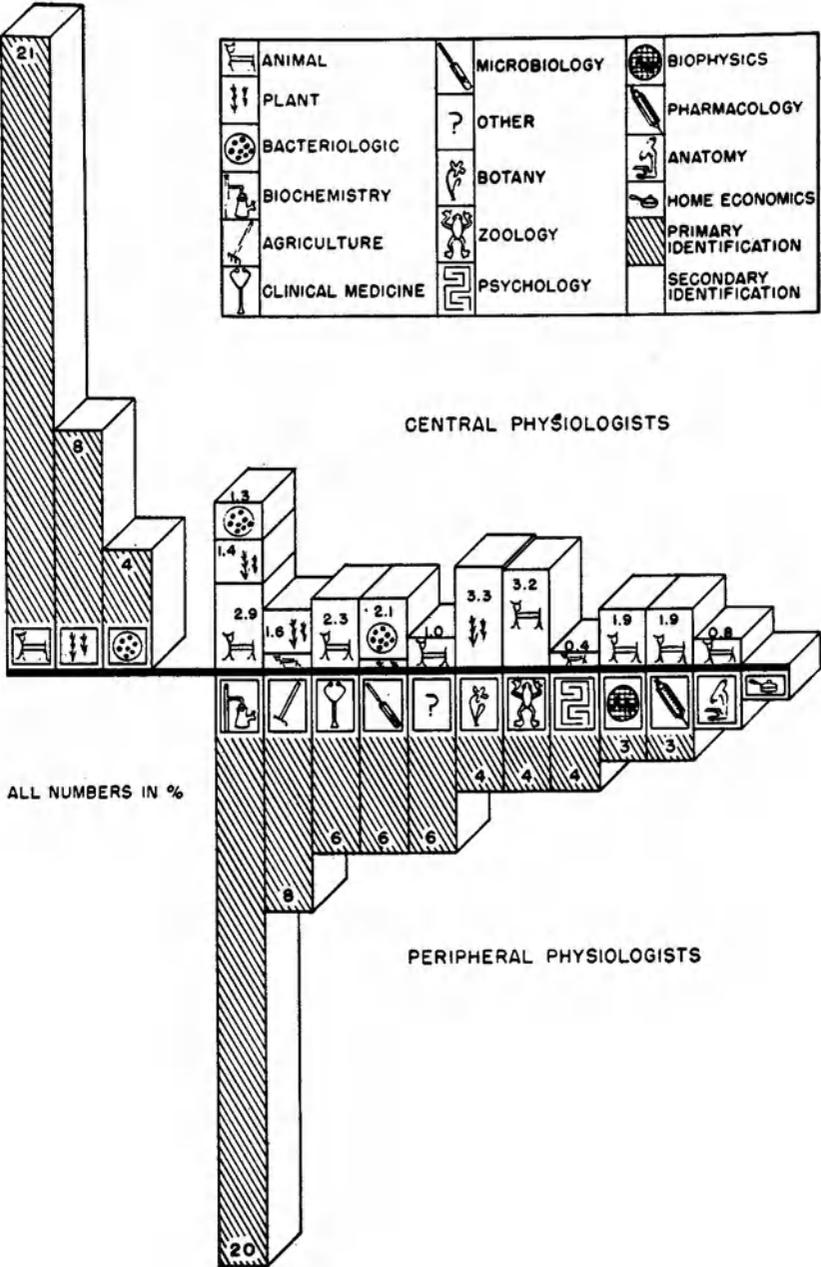


FIG. 2

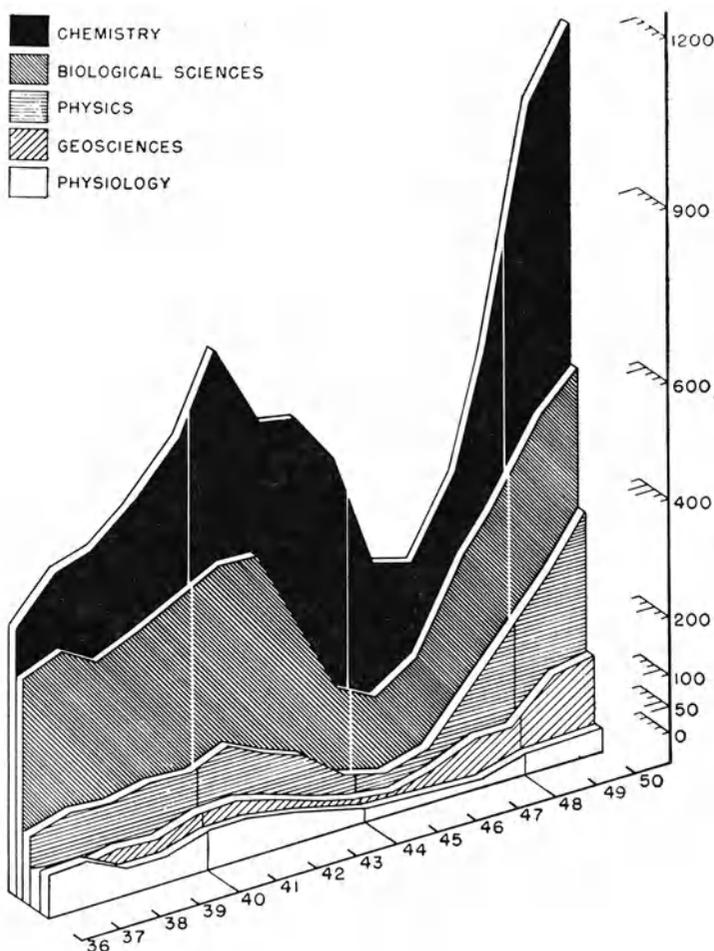


FIG. 3

What Do Physiologists Do?

The major functional activities of scientists are research, teaching, and administration. From a study of the distribution of time spent by physiologists in each of these functions, the Survey calculates that approximately 54% of physiologists' professional effort is used in research, 26% in teaching, 17% in administration, and 3% in such other activities as consulting. A comparison with other scientific professions is shown in Figure 4.

Two-thirds of the physiological profession are employed whole or part-time in academic institutions, one-seventh in government, one-tenth in industry, and a twentieth in clinical, private, or other employment (Table V-5). (In-

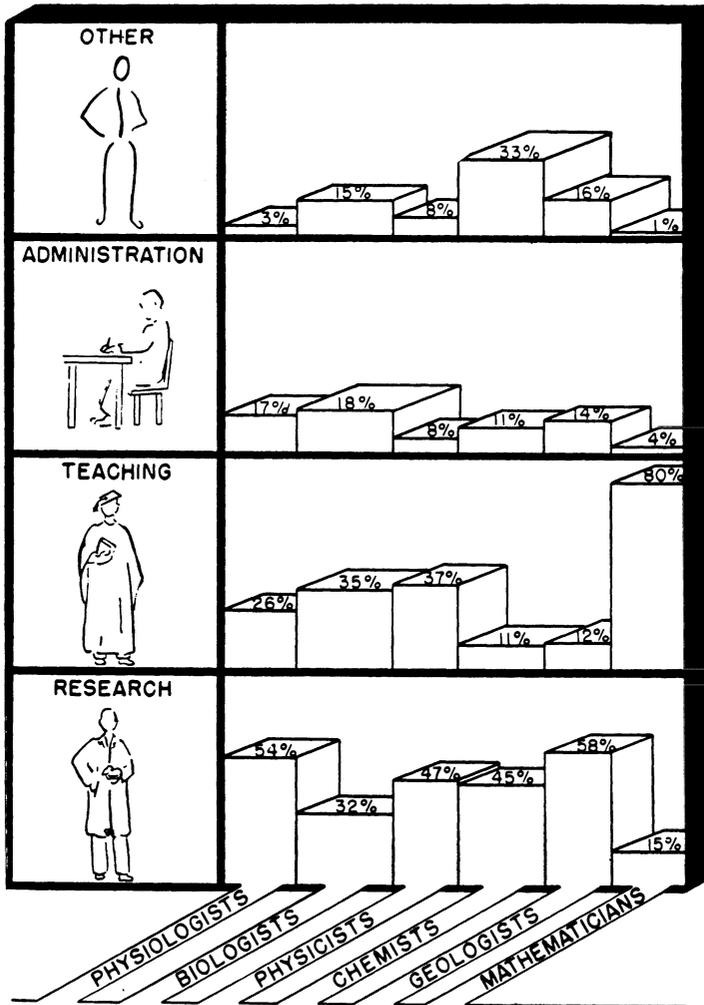


FIG. 4

cluding multiple employment, seven-tenths have academic positions; Table V-7.) Of those in academic positions, three-fourths have some professorial rank (Table V-8); but only one-fifth of the physiologists active in teaching—and practically all of these animal physiologists—hold teaching appointments in Departments of Physiology. Even among central animal physiologists only 60% hold teaching appointments in Departments of Physiology; and for peripheral physiologists the figure drops to 8%. This suggests that the teaching of physiology is both tightly compartmented and also diffused

through many academic departments. The departments in which physiology is taught are shown in Table V-10 and Figure 5.

Physiologists, like other scientists, are generally engaged in those research activities which seem most important to them. Only a few hundred physiologists are not doing some research, about 12% of all employed physiologists do nothing else but research, and another third give more than 60% of their time to research (Table VII-1). There is evidence that eminent research scientists are likely to possess certain personality traits (Chapter VI), and it may be that eminence in teaching and administration results from different trait combinations. The Survey made a statistical study of eminent physiologists and a less eminent control group without finding significant differences. The data obtained may well serve as impetus to further investigation, however, especially with more stringent criteria of eminence.

How Do They Like What They Do?

Of utmost importance to two-thirds of employed physiologists is the freedom and authority to carry out their own ideas (Table VI-1). Eighty percent

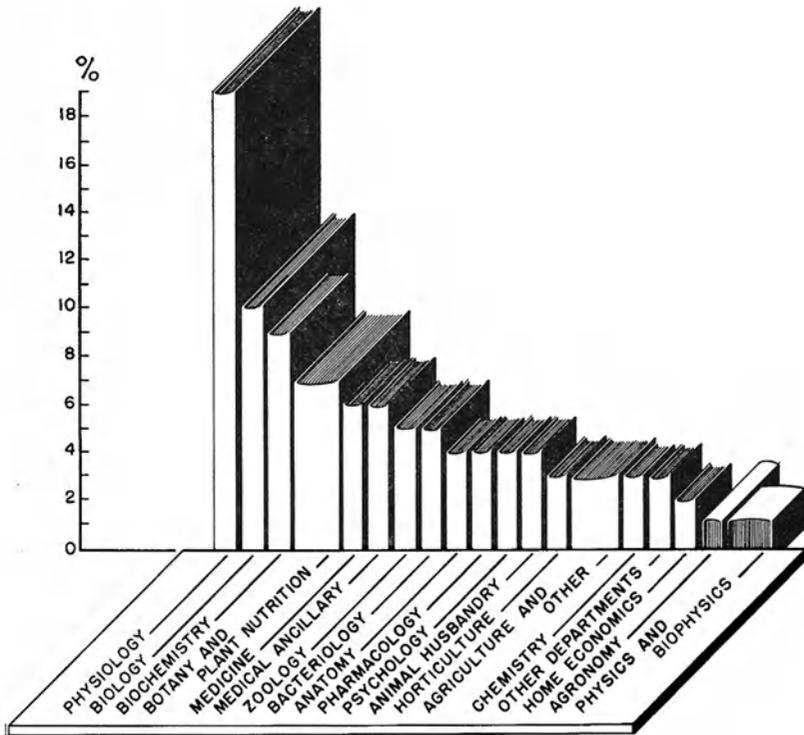


FIG. 5

of research physiologists have complete or great freedom in the choice of their research problems (Table VII-5), and about this fraction of all employed physiologists would prefer to work in academic institutions, where freedom and independence of thought and action find their most congenial setting. Five-sixths of all physiologists are very or fairly well satisfied in their present jobs; and the proportion is similar for those whose major activity is research (84% satisfied), teaching (82%), or administration (84%). The proportion of those who are 'very satisfied' is, however, somewhat lower for teachers than for either of the other groups (Chapter VI).

The factors leading to promotion in academic work, as judged by Survey respondents, are, in rank order: quality of research done, number of research papers published, other job offers, teaching abilities, and length of service. For promotion in industry and in government, they are: quality of research, administrative abilities, and length of service (Table VI-15).

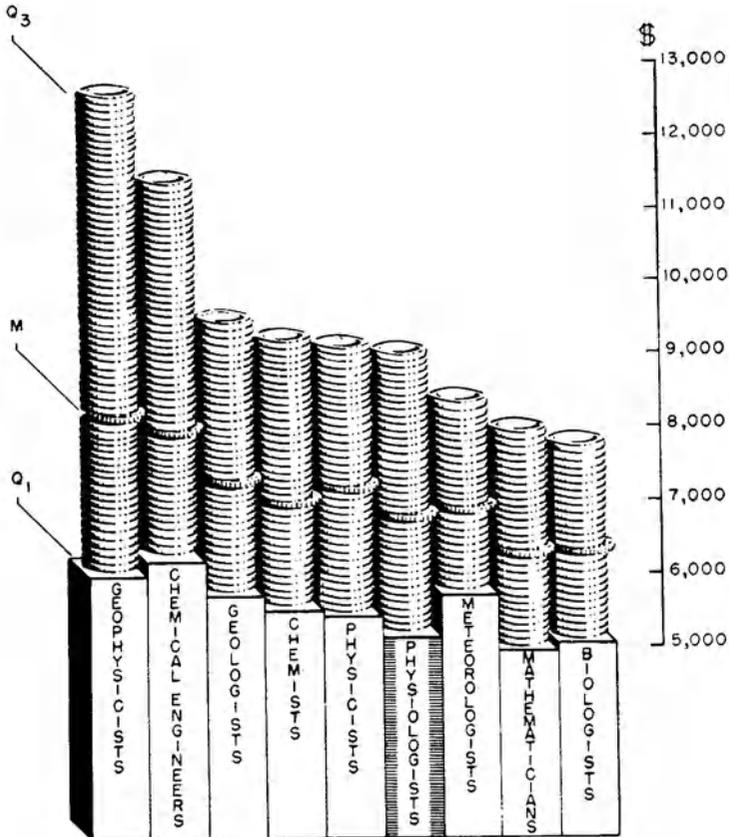


FIG. 6

How Much Do Physiologists Earn?

The median income of physiologists in 1952 was \$6700, with the lower quartile point about at \$5200 and the upper quartile at \$9000. These incomes are compared with those of other scientific professions at the Ph.D. level in Table V-19 and Figure 6. Animal physiologists have a median of \$7600; plant physiologists, of \$6300; and bacterial physiologists, of \$6600. These medians are lower in academic than in either government or industrial institutions (Table V-21). Apparently physiologists, indeed all scientists and scholars, who strongly prefer academic positions, subordinate material rewards to intellectual freedom and independence of action. The highest median incomes are received by physiologists in their fifties; \$8500 in academic institutions, \$8800 in government, and \$12,800 in industry (Table V-22). More detail about the income of physiologists is also presented in Chapter V.

Where Are Physiologists Located?

The geographical distribution of employed physiologists is given numerically and proportionally in Tables V-11 and V-12, and is illustrated by Figure 7. Over the past fifty years these proportions have not greatly changed,

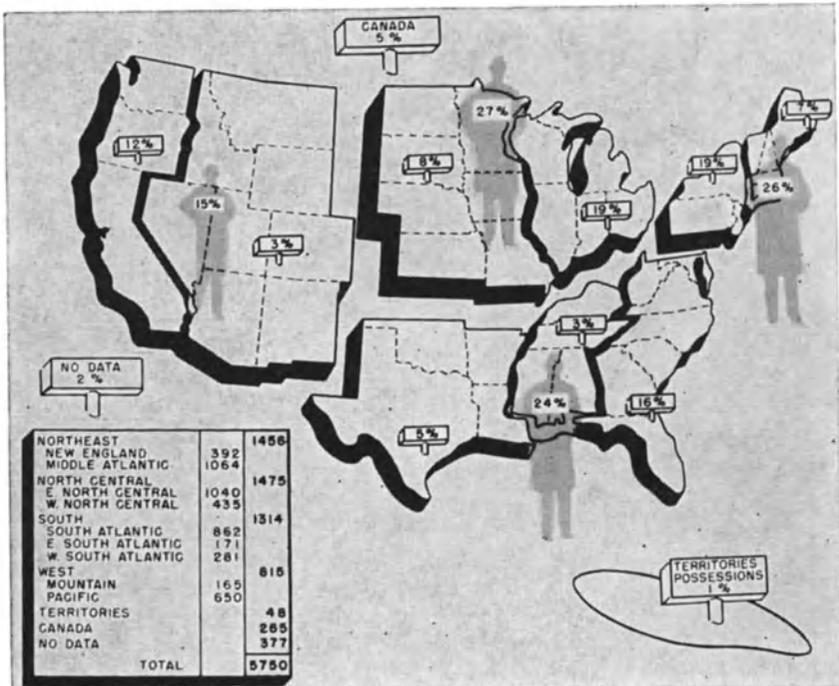


FIG. 7

although there seems to be a gradual decline in the New England and Middle Atlantic regions, and a gradual rise in the South Atlantic and Pacific regions (Table V-14). Physiologists working in Delaware, Maryland, and the District of Columbia—the Washington-Bethesda area of concentrated government research groups—constitute nearly half of those in the South Atlantic region. This proportion of teaching physiologists is slightly higher in the Middle Atlantic and West North Central regions and considerably so in the West South Central region and—if the research group in the Washington-Bethesda area is disregarded—in the South Atlantic region (Table V-16).

Like other people, physiologists move around the country in quest of the desired kind of job or salary or training (Table IV-17). The typical physiologist might have been born in almost any part of the country (although more likely in the Middle Atlantic or East North Central Region), of a higher than average socio-economic background and probably into the professional or managerial class (Chapter IV). Thus, educational opportunity and parental stimulus help arouse that interest in subject matter which is the starting point for most physiologists.

Where Do Physiologists Get Their Training?

The Survey found that four-fifths of the coursework of a physiological nature, broadly defined, is offered by liberal arts colleges and universities, particularly those having professional schools. Figure 8 locates the institu-

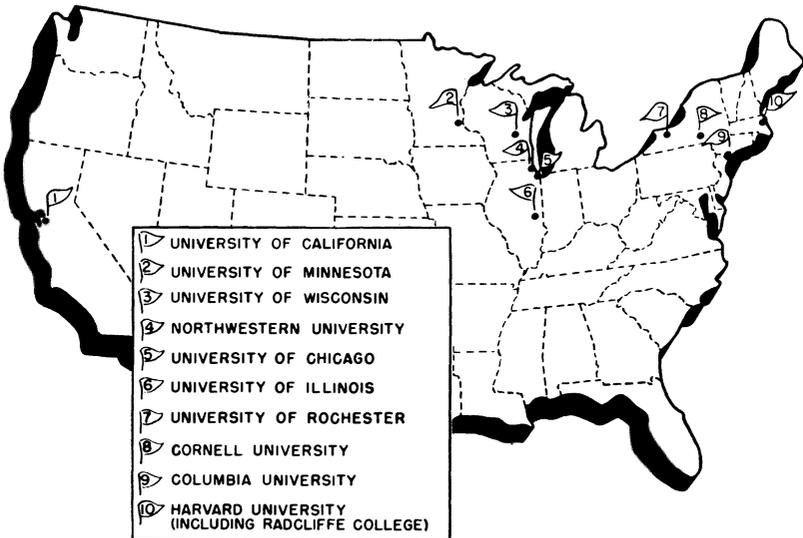


FIG. 8

tions which have consistently granted the most Ph.D. degrees, in physiology or in other departments for Ph.D. theses of a physiological nature (Table X-16). These are also the outstanding academic centers of physiological research. To test the influence of individual teachers and departments on the subsequent professional achievement of the student, the Survey gathered material on the professional genealogies of physiologists. The findings, not complete enough to report in detail, may serve as a starting point for some scholarly investigation of the history of scientific education in this country and for the impact of various types of personality. The problems of improving public awareness of physiology as a scientific discipline and of recruiting students of promise are discussed in Chapter X.

What Are the Characteristics of Physiological Research?

The Survey made statistical analyses of the changes over a period of years in various characteristics of physiological investigations. The study included: the experimental variables introduced, the structural level of the material used, the types of organisms selected, the types of functional response observed, and the sophistication exhibited in the measurements and in the application of basic scientific concepts. These are discussed in Chapter VII. The gradual increase in the level of sophistication of concepts and precision of method reflect the changing character of physiology over the years, including the advances in biochemistry in the past and in biophysics in the present, which tend to split these disciplines from the parent stream of physiological research. The bulk of physiological research is oriented toward medicine, partially because most physiologists are animal physiologists and partially because support is most readily available and the demand great for medical research. But physiologists regard much of this medical research as basically scientific rather than applied. Methods for analyzing research problems in the life sciences, to establish the relationship of basic to applied and developmental orientations, need standardization. The results may well bear on the relative importance or urgency of different problems and thus on the amount of support which is or should be afforded. Research activities and programs are discussed in Chapter VII.

How Is Physiological Research Supported?

Besides the moral support of freedom of thought and independence of action characteristic of academic work, physiologists require adequate space, equipment, and experimental material to maintain satisfaction in their work. Nearly two-fifths of research physiologists depend on money allocations from their own institutions for research support; one-fifth, on contracts or grants from other agencies or institutions; and the remainder, on both. Of those

investigators using extramural funds, two-fifths are supplied by non-military government funds, one-fourth by foundation grants, one-fifth by industrial or commercial funds, and one-sixth by government military funds (Table VIII-7). While considerable data were made available on medically-oriented research, none could be obtained by the Survey on governmental support of physiological research in agriculture. Despite this important unknown, it appears that physiological research as a whole is adequately underwritten; whether this is true for each subarea (and whether funds channel research) was not determinable from the Survey data. This important question for all fields of physiological and biological science requires thorough and precise investigation.

What Next?

This study has defined the populations of concern and amassed much information about the science and profession of physiology. The animal and plant areas are widely divided, perhaps too far to bridge, and core animal physiology is concentrated in the neural and circulation specialties. Analysis of present and future needs for men of industry, academia, and government, and of expected supplies indicate a satisfactory balance of biologists at the lower training levels, a serious deficit in Ph.D.'s. In physiological science 200 will be produced a year to 700 needed; in physiology 100 produced to 200 needed.

Money is not now the critical factor so much as is space; but each dollar invested in research returns a 100% yield a year for a quarter century and so multiplies the need for more men and money along an exponential curve. Growth seems about to slacken and the curve become sigmoid. At present, one investigator requires perhaps \$25,000 a year for his program and salary, receives an average grant of half this, and one research paper is the outcome of the turmoil.

With able men at a premium, improved teaching, at least down to high school, is essential to recruit and train them. Dynamic teaching of dynamic biology will be enhanced as high school and college teachers (and their students) have contact with and are made welcome by professional physiologists. Active investigators can be helped in productivity by technical assistants and services, wise administrative arrangements, more information service, and a congenial social climate.

A number of specific recommendations deal with research, education, public relations and recruitment, further studies, and the use of this Survey Report (Chapter XII).

II

ORIGIN AND OBJECTIVES OF THE SURVEY

Most physiologists have thought from time to time about the same problems that concerned the Survey of Physiological Sciences. In casual meetings with colleagues, in organized discussions such as those sponsored by the American Physiological Society, in formal recommendations to administrators and others concerned with policy, and with increasing frequency in professional journals, physiologists have pondered the relationship between the many facets of their science and our even more complex social environment. Mostly, only individual opinions, not all in agreement, supplied answers; but gradually more formal and concerted attention was marshaled.

The American Physiological Society has always been a leader in facing the sociology of its profession. It was one of the first biological groups to create a central office with an executive secretary who could give proper and full-time attention to publications, meetings, personnel, education, and the like, as well as to research and the reporting of experimental results; and a series of committees has grappled with one or another phase of the external or internal relations of physiology. When the National Science Foundation came into being, with a mandate to concern itself with such questions and with funds to support appropriate studies, some sort of systematic examination of physiology was almost inevitable. Indeed, when this Survey was initiated the first decision was to include all phases of physiology (full cooperation of the plant and microbiology groups was forthcoming); and it was hardly under way before other disciplines, such as psychology and mathematics, proposed surveys of their own. Necessarily, also, the characterization and delimitation of 'physiology' or 'physiological science' became a central problem. In relation to subject matter and methodology, to courses given and men employed, to administrative organization and public image, it was necessary to decide, 'What is physiology?'

In part, the question was answered in 1938, the semicentennial year of the Society, in *The History of the American Physiological Society*, which reviewed many phases of the historical growth of physiological science. But this history did not attempt to assess contemporary status nor to predict future trends; debate continued and, toward the end of World War II, the first of three formal studies was begun. In May, 1945, the Council of the American Physi-

ological Society appointed a fact-finding group (the 'Adolph Committee') composed of E. F. Adolph, T. E. Boyd, J. H. Comroe, Jr., and Philip Dow. Their study(1) consisted largely of an analysis of some thousand questionnaire returns from 54% of the physiologists solicited. This was later enriched by a summary of actual opinions of Society members presented to the Society in July, 1946, by Dow. The Committee reported that separatist tendencies within the profession 'have left the broad field of biological function with very little clearly focused evidence of its community of scientific interest' (ref. 1, p. 422).

Remedial suggestions offered were aptly summarized by Adolph at a meeting of the Society Council in March, 1946. He urged: *a*) national aptitude tests to disclose talent and aid to promising young students interested in physiology; *b*) adequate technical assistance for men primarily engaged in research; *c*) an aggressive campaign for higher salaries; *d*) a personal approach to appropriate administrators and teachers in an effort to spread physiology into industry, research, and undergraduate and secondary education; *e*) improved means of integrating the results of physiological research and of presenting them to the public which ultimately pays for the work.

The educational concerns were foremost, and it was subsequently voted "that a committee be appointed under the chairmanship of Ralph W. Gerard to organize a symposium on the training of physiologists . . . and to explore the extension of physiological instruction into wider areas." In October, 1946, the 'Gerard Committee' was organized as follows: R. W. Gerard; W. O. Fenn and M. B. Visscher, ex-officio; Paul Weiss, biology; Laurence Irving, military and environmental physiology; and Eugene Landis, medical physiology. In addition, K. S. Cole and A. C. Ivy participated in committee meetings and represented education, medicine, and governmental interests as well as their own fields of biophysics and mammalian physiology, respectively. The Gerard Committee was asked to take cognizance both of the report of the Adolph Committee and of its specific recommendations, and to report its own further recommendations.

In further clarifying the exact functions of the Committee—what field to cover, whether to seek new facts or analyze existing data, what specific objectives to work towards—Secretary Visscher wrote, "I am sure . . . the Council would be in favor of defining physiology in the broad way . . .," and President Fenn added, ". . . We [the Council] do not wish to drop the matter brought up by the [Adolph] Committee without taking further steps and it is not yet clear just what further steps ought to be taken. . . . Training of physiologists . . . [is] broad enough so that the Committee could consider any problems listed by the previous report. . . . I am sure the Council would welcome suggestions for definite action." And Gerard proposed that, "The American Physiological Society should undertake a thorough study of

the teaching of physiology. This study should define the relationship of a core of fundamental principles (cellular and mammalian) to the manifold fields of application . . . and recommend methods for obtaining the best possible balance. It should also seek for ways to extend and improve the teaching of human physiology in schools and colleges, not only as an advanced subject in biology and preparation for specialized research, but also as a part of non-scientists' general cultural education. It should formulate recommendations as to the optimal coverage of the medical physiology course and training which should precede it. This is a big job but its need is widely felt and a positive start should be made on it. . . . The group undertaking it should be very broadly representative of different fields, ages and interests."

In November, 1946, the Gerard Committee considered for two days the role which the American Physiological Society, and other professional groups, might play in promoting the recommendations of the Adolph Committee. But opinions varied as to what constitutes physiology and what provinces of content, application, and interest properly belong to the science; and the Committee emphasis shifted from the training of future physiologists to the fundamental problem of defining the field and its relation to the ancillary sciences and to society in general. Moreover, it soon became apparent that the available resources and facilities were inadequate for effective action on the Adolph proposals; private foundations had declined support of a study on the teaching of physiology, as proposed by Dow.

A symposium on 'Perspectives in Physiological Education,' held for the Society in May, 1947, was the basis of the Gerard Committee Report (14). Each Committee member interpreted physiology in the context of his special field of interest, and a brief questionnaire was circulated. In summarizing the data from the questionnaire, Gerard stated: "It is noteworthy that both members and non-members are more strongly in favor of the APS concerning itself with the wider problems of physiology than they are in the case of any other general item. The desire seems clear; the means, financial and organizational, must be explored by the Council and the Society. Decisions on these points will help determine the future of the American Physiological Society. Any action of the Society, in turn, cannot but influence American physiology." Despite this strong group opinion, and the recommendation for vigorous action by both committees, nearly five years elapsed before outside support enabled the Society to undertake these activities.

In the summer of 1951, while participating in a five-day conference called by the American Psychiatric Association at Ithaca, N.Y., to consider broadly the position of psychiatry in medicine, Gerard conceived the notion of a similar conference on the state of physiological science, to focus attention of the profession on rewarding areas for scientific progress and national service. Other members of the American Physiological Society—among them Orr E.

Reynolds, R. G. Grennell, and Milton O. Lee—were exploring members' attitudes regarding Society activities in relation to the widening and fragmenting circle of physiological scientists. By November, 1951, it was appropriate to hold an informal discussion about a possible survey, in order to provide definitive factual data on which to base discussion at a symposium of delegated physiologists. (A similar plan was later followed in the successful Teaching Institutes of the Association of American Medical Colleges.) Participants were: Gerard, then President of the Society; John Field II, then Assistant Director for Biology of the National Science Foundation; E. Piori, then Chief Scientist for the Office of Naval Research; and Reynolds, then Director of the Division of Biological Sciences in the Office of Naval Research. Progress justified formulation of more detailed plans for the Survey and of delineation of the respective interests and objectives of the Society and the Foundation (correspondence, Field and Gerard; e.g. Nov. 14 letter). Finally, at a meeting on February 22, 1952—where the Society was represented by R. W. Gerard, President; D. B. Dill, Past-President; E. M. Landis, President-Elect; M. O. Lee, Executive Secretary; M. B. Visscher; and O. E. Reynolds; and the Foundation, by J. Field; W. F. Harwood, Assistant Director for Administration; C. G. Grant, Study Director for Government Research Program Analysis; W. V. Consolazio, Program Director for Molecular Biology; and J. T. Wilson, then Program Director for Psychobiology—the proposal for this Survey was put into final form (Appendix A). It was fully expected that the study would prove valuable to the Foundation, by clarifying the problems of and providing detailed data on a major scientific group whose interests cut through many segmented disciplines in the total field of biology. However, it was agreed that the Survey was to be carried out for and by the Society in accord with the objectives formulated in its proposal.

The proposal was formally approved March 15, 1952 and the Survey of Physiological Sciences became a reality. The persons on committees and staff who were mainly responsible for planning and executing it, are presented in Appendix B. Contract NSF-C3, effective April 1, 1952, provided for a Pilot Phase of nine months, followed by a Definitive Phase of eighteen months. As events developed, there was also a Report Phase of approximately three years during which voluminous material from the various studies of the Survey was reorganized by L. M. N. Bach and distributed to Committee members and others. In 1956, the basic data of the Survey were condensed and reworked by W. D. Land, and a semifinal version of the document circulated for criticism and supplementation. By the Fall of 1957 this Report was completed.

The Pilot Phase had three main goals: to formulate the objectives and plan of action so that meaningful data, permitting significant conclusions, would be obtained; to collect existing materials; and to prepare the instruments, such

as questionnaires, and to organize the special projects to yield the necessary data. The Central Committee first delimited and divided the area of the Survey and set up subcommittees on Personnel, Research, Teaching and Communication, Applications and Consequences and—at a later date—Trends and Perspectives. Within each area the pertinent subcommittee formulated questions and procedures, from the most general to the most specific problems facing physiology and physiologists. The individual and collective interests of physiologists came to the forefront; so the objectives of the Survey were really those which concern every professional physiologist: to improve each aspect of the profession.

At certain stages in the planning the need for hypotheses was emphasized, since a simple descriptive approach could lead to uninteresting or uninterpretable information; but the danger of limiting the number and types of variables to be studied was also recognized. The general hope, consonant with the original concept of the Survey, was to establish broad objectives to guide the gathering of specific data, and to develop from these testable hypotheses. The nature of the findings to be expected was much discussed, and the distinction between interpretations derived solely from analyses of factual data and those based on evaluation and judgment was held constantly in view. Those problems judged during the planning stage to be most significant and most feasible to analyze were to guide the collection of factual material during the intensive definitive stage of the Survey; and evaluations and suggestions inferred from this corpus would be generated in the course of preparing the Report.

The objectives developed from these deliberations were at times frozen, to permit constant studies; yet they were mostly, especially in the early stages, kept flexible to accommodate the data which might appear. Factors which modified these objectives in the course of time were: considerations of cost and the pressure of time; making usable the data from earlier studies, with different questions and objectives, along with Survey material; the problem of confusing materials obtained on a time axis by historical methods, with materials more readily obtained by analyses of factual data or by questionnaires or personal letters or interviews—such as the judgments of eminent and experienced scholars and the clarification of factual findings by practicing physiologists. More attention and emphasis were given the Survey questionnaire for physiologists, relative to interviews, to other groups, to longitudinal studies, than had originally been intended. Despite these difficulties, the various Survey subcommittees formulated, during the first phase, many highly desirable objectives, perhaps so numerous and varied that they became operationally overwhelming. In any event, the Central Committee was impelled to establish priorities among the many questions proposed; and this rank order of objectives became the basis upon which data were gathered and analyzed, modified only by practical realities as the study proceeded.

Objectives given top priority included determination of: the sources of funds; the extent and nature of courses with physiological content and the influence on these of pre-professional or occupational requirements, and the number and kinds of students receiving instruction in physiology, particularly at the graduate level in basic science, in medicine and medical ancillary fields, and in agriculture and engineering or industrial management; the educational backgrounds and interests of teachers, and how these influenced course content at the undergraduate level and training of graduate and professional students; the number of physiologists and the extent of physiological teaching in fields not called physiology; the utilization of physiologists in teaching, research and other capacities, with particular attention to the kinds of jobs available or desired; and the conditions of research, including freedom of choice of research and time and facilities available for research.

Other objectives, only slightly less important, were mostly related to the subjects already mentioned and included: the use of research funds, the availability of apparatus and living material; the extent of and changes in presentation of physiology at all educational levels; the qualifications of teachers at those levels; the problems of communication, through research publication and scientific meetings; the availability of publications and abstracts; and a personnel inventory of the physiological profession. Many other topics were essentially corollaries to these.

In practice, particularly as the Survey questionnaire became the prime instrument for obtaining data, the objectives took order more on the feasibility and limitations of the total operation than on the priorities assigned by the Committee and the Survey staff for purposes of operational guidance. Yet, as a whole, the information particularized in many lists of desiderata was obtained during the course of the Survey program.

III

THE SURVEY IN OPERATION

A gleaning from records of committee meetings, working papers, and the like may give some sense of the development of the program, as well as give aid to those planning such studies. These papers are on deposit in the American Physiological Society. The first formal actions of the Survey were taken at a meeting of the Central Committee in Washington in late March, 1952, at which the functions of the Pilot Phase were set forth; it was decided to limit the geographical coverage of the Survey to the United States and Canada; and the major decision was reached that, for defining the scope of the Survey, physiology is 'the study of functional processes in living organisms,' and that General and Comparative Physiology and Plant Physiology were explicitly to be included.

The formal requirements of the Pilot Phase were: formulation of pertinent questions; collection, evaluation, and completion of existing data; and development of operating methods for collecting and analyzing data and, in general, creating the basic instruments of the Survey. Besides these procedural duties, the Pilot Phase was to formulate the problems clearly, determine the critical questions to ask and present them so that meaningful answers would result, reconcile proposed research procedures with utilization of existing materials, and collect and collate studies in related fields. The Survey was planned to stand on three methodological legs: a longitudinal analysis of physiological literature, mainly journal articles, to obtain chronological depth and to project trends, if possible, into the future; a cross-sectional analysis of recent public information on physiology and other disciplines and professions, to obtain comparative breadth and a frame of reference for the new findings; and penetrating study by questionnaires and interviews, to obtain the fuller understanding of conditions available through the collective attitudes and judgments of physiologists.

Dr. Orr E. Reynolds, active in and informed on the Survey from its inception, accepted the responsibility of Executive Director, but was available on an almost full-time basis only during this early period. On May 1, 1952, the Central Office began operations in space adjacent to the office of the American Physiological Society, then in the Dupont Circle Building; and rented from the National Academy of Sciences. The Academy library, card-punching and

sorting services, and its mailing, message, and telephone facilities were available; and it also helped with insurance and similar business arrangements. The Society made available reference sources, mailing lists, auditing and purchasing facilities, and placement records, and the Survey enjoyed the valuable cooperation of the staff of the Society and Federation, especially of Dr. Lee. The Washington locale also proved a happy choice because of the location of data files, the ease of conferring with officers of other scientific groups, the availability of part-time employees, and the frequent presence of members of the Survey committees.

The existence, and significance, of the Survey was first presented in a press release issued by the National Science Foundation, later in a statement in *Science*; and Gerard's past-presidential address to the American Physiological Society at its Fall Meeting in September, 1952, was largely devoted to hopes and plans for this study(28). To further interest Society members, a Survey exhibit was prepared for this Fall Meeting. The exhibit showed the geographical distribution of grants for physiological research, and also the distribution with respect to location and society membership of physiologists cited in eight relevant *Annual Review* series. This exhibit, also shown at the September meeting of the American Institute of Biological Sciences, helped to alert scientists who would later receive Survey questionnaires.

By mid-July, 1952, the subcommittees had been organized and the entire group met at New London, Connecticut (see Appendix B). Each subcommittee defined its area of investigation and, within it, proposed questions, suggested ways of obtaining valid answers, and indicated methods of operation. Individuals were also asked to assume specific duties in evaluating and presenting Survey results. The subcommittee reports prepared at this time became a basis for over-all decisions on objectives and, to some extent, on procedures to be used in amassing and analyzing data. As an instructive example of work flow, the plans of some subcommittees and the responses reported a year later by the Survey staff are given in Appendix J.

During the summer and fall of 1952, the activities of the Central Office were intentionally of an exploratory nature, and several Survey projects arose from ideas and services volunteered by many persons interested in the Survey. Actually, most of the projects listed in Appendix C were initiated during the Pilot Phase, although many special aspects developed at a later period.

At the third Central Committee meeting, held in Chicago in mid-October, 1952, it was decided to limit the time span covered to the period since 1887, the date of the founding of the American Physiological Society. As the initial period moved on, and the operating machinery began to deliver great quantities of facts, it became impossible for the Central Committee to undertake the immense detail of operating the Survey. Dr. Reynolds' limited leave from ONR terminated and Dr. L. M. N. Bach, Associate Professor of Physi-

ology at Tulane University, was invited to become Executive Director during the critical Definitive Phase. The Central Committee undertook to advise on general policy, to review results before publication, and to stimulate active participation by Society members. It also recognized a responsibility for projects that might well be kept up after completion, presumably in 27 months, of the major study.

An Executive Committee, created to work more closely with the Director, first met informally in Washington in late November, 1952. It appointed a History Subcommittee, later redesignated as the Subcommittee on Trends and Perspectives; and it was also agreed that the Survey should join in the support of a conference, planned by Visscher in connection with the International Physiological Congress in Montreal in September, 1953, on the status of physiology in various countries. From the materials generated at this meeting, Dr. Ilza Veith edited the volume *Perspectives in Physiology*(117) for the Survey. Published by the American Physiological Society in 1954, it contains a further description of the Survey and of the development of American physiology, as well as important information on the international scene.

The final event of the Pilot Phase was a symposium on 'Educational Aspects of Physiology' held at the American Association for the Advancement of Science meeting at St. Louis in December, 1952. Summaries of the papers are on deposit: Reynolds, on the status of physiology as a profession and the inter-relationships of its various fields; E. G. S. Baker, on undergraduate courses in physiology; Julian L. Solinger, on physiological content of biology courses; David R. Goddard, on the role of physiology in botanical education; C. Ladd Prosser, on the role of physiology in zoological education; Julius Comroe, Jr., on the place of physiology in medical education; Craig Taylor, on the significance of physiology to engineering education; Visscher, on the relation of physiological science to general education; and Gerard (chairman), on the importance of physiology in professional education. Brief summaries are included in the report on the Pilot Phase. Discussion was enthusiastic, and the Symposium led to a number of personal contacts which proved of value to the Survey.

On January 1, 1953, the formal report on the Pilot Phase was presented to the National Science Foundation. It is on deposit with the other documents.

The Definitive Phase was originally planned as the period of intensive data collecting by the staff, and of assessing the findings by the staff, committee members, and consultants. But, with the transition from Reynolds, who could spend only part time after 1952, to Bach, unable to assume direction until mid-March, 1953, and with the continued examination of objectives and procedures, some delay and confusion were inevitable. Especially thorny problems were the combining of material obtained by several independent procedures to bear on a given problem, and the converse one of dividing the

results of one study among several topics; particularly, since the operations were the responsibility of the staff, while the committees joined in decisions on what data to seek and how to interpret them.

During the transition period, Reynolds and Bach discussed with Angus Campbell, Robert L. Kahn, and Charles F. Cannell of the Survey Research Center (of the Institute for Social Research, the University of Michigan) advantages and costs of professional administration of a comprehensive questionnaire. (This technique, and the interview, had from the beginning been regarded by the Central Committee as a major, but by no means only, tool for obtaining data.) Bach consequently devoted much of his first three months in office to translating multiple objectives, of varying priority, into items on a questionnaire. An experimental run, to test and improve the questionnaire materials as well as the sources and sampling procedures for reaching the population of physiologists, was carried out in collaboration with Dr. Seymour Lieberman of the Survey Research Center, and also required major attention by Bach and the Central Office staff. By June, it was apparent that a questionnaire could be constructed that would adequately survey the entire active population of physiologists on most of the topics included in the objectives of the Survey. During the summer of 1953 the Central Office assembled detailed lists needed for sampling scientists, institutions, and laboratories; and the questionnaire was drawn up by Bach and Lieberman in alternate forms and pre-tested on the Central Committee in July, 1953, at Bar Harbor, during its fifth meeting. The progressive steps in formulating the questionnaire are given in detail in the mimeographed *Preliminary Report*, Chapter III-B-1, on deposit. The Questionnaire as used is reproduced here as Appendix F. Tabular results, expressed in percentages, were published by the Survey Research Center under the title, *The Attitudes and Activities of Physiologists* (80). This basic publication is referred to in short form hereafter as 'Q' for Questionnaire results. The Center has also made further analyses of the findings, especially in relation to scientific productivity, in mimeographed and published papers (see, especially, Leo Meltzer, ref. 55). We are grateful for their fine contribution to the Survey.

The contract cost of this professionally administered questionnaire was well over 90% of all money the Survey spent, in grants or contracts, for collecting and analyzing data. In addition, a large portion of the time of the Executive Director and of an enlarged staff in the Central Office was required for the planning and administration of the questionnaire, a situation not entirely anticipated. Moreover, several other projects completed by the Central Office staff related directly to the questionnaire materials. Thus, not only were several important projects dropped but additional funds were required even to utilize fully the recommended questionnaire procedure. At this point extensive use of interviews was abandoned; an intended statistical sampling of

student physiologists, using a similar questionnaire technique, was dropped (hopefully, the attitudes and opinions of those already in professional work would adequately reflect the problems of selective recruitment, education and training); and, the most serious deletion, a survey of control groups from other professions was renounced.

By September the questionnaire, closely supervised by Bach and Lieberman, was ready for printing and in October it was mailed from the Central Office—which also handled the extensive details of preparing mailing lists and keeping records, writing or visiting non-respondents, and finally interviewing a small but representative sample. The coding, sorting, and tabulation of questionnaires was done by the Survey Research Center in Ann Arbor with further collaboration on technical content by the Central Office. By May, 1954, the resulting data were distributed to members of the Survey committees, in the two volumes of tables prepared by the Michigan group. A duplicate set of cards and coding data was given to the Society for use in future operations.

The lesser projects of the Survey were meanwhile continued. Eight summary reports, three done in the Central Office, had been distributed to committee members. Thirty-one other projects, including the questionnaire and related studies, were in various stages of completion, largely by the Central Office staff. Many of these were initiated by individuals not on the staff, but most had to be completed in the Central Office. By March, 1954, the data flow from many sources was large and much Central Office time was devoted to converting them into usable form by coding, card-punching and sorting, and to writing reports. These activities, together with distribution of report summaries, consumed most of the remaining time and funds of the Definitive Phase. The conference to consider the Survey findings, an important component of the initial plan, went by the boards as a result; and preparation of this final report, originally budgeted as a six-month job by a qualified writer, reverted largely to the voluntary and intermittent efforts of several people.

The Central Committee had been kept in close touch with developments. At its fourth meeting, in Washington in February, 1953, the Committee broadened its professional representation by adding Drs. Marion Parker and Perry Wilson, representing, respectively, plant physiology and bacterial physiology. Dr. Harry Borthwick made himself available as a consultant in the area of plant physiology and was on call for later developments. An Executive Committee was also formally established to maintain closer contact with the actual operations of the Survey, but all Central Committee members were to receive progress reports and financial statements. As always, such chores tend to fall behind in the press of actual operations; and some confusion continued to the end as to the actual content of some studies and the state of finances—the latter being additionally confused by mixed responsibilities between the Survey and Society offices.

During April, 1953, the Survey effort centered on activities connected with the meeting in Chicago of the Federation of American Societies for Experimental Biology. A symposium on the Survey (66) was arranged by Reynolds, Gerard presiding. Bach outlined the proposed operations of the Survey; Reynolds described the status of undergraduate physiology and physiologists; Dr. Anne Roe summarized her analysis of Rohrschach tests of physiologists; and Comroe presented plans for the First Teaching Institute of the American Association of Medical Colleges. Summary outlines of these papers are given in Appendix I. Attendance and interest were excellent; and the Survey was effectively made known to many of those who would be solicited later for information. At the teaching session of the American Physiological Society, Dr. Norma Hajek and Miss Helen Hislop presented a paper dealing with physiological teaching in schools of physical therapy and Drs. Baker and Solinger reported on their projects, an analysis of college catalogues and courses, respectively, for their physiological content. The Survey staff also prepared and manned a graphic exhibit illustrating the distribution of physiologists, research grants, literature citations, and similar information derived from Pilot Phase projects, and also distributed an informational booklet about the Survey—all part of a campaign to insure willing responses to Survey inquiries as well as more active participation by all physiologists. Actually, forty of the several hundred visitors at the exhibit filled out forms indicating a desire to participate in some phase of the Survey. Such participation was vigorously urged by the Committee, as a general policy; but little opportunity seemed to arise for using such individuals in a significant role, perhaps because of increasing dependence on the formal questionnaire. A few hardy souls did, nonetheless, pursue particular topics. Similarly, the strong recommendation that local groups be aided with materials and advice, so that seminar series, regional society meetings, and the like would discuss and recommend on one or another problem of concern, never got started. The success of the President-elect tours, somewhat related, reinforces belief in the worth of such meetings; the present report offers a spring board.

Attempts to coordinate the Survey with the incipient study by the American Psychological Association, especially 'Project B' in charge of Dr. Kenneth Clark, including a special meeting at the University of Minnesota (Clark, Bach, Steinbach, Visscher, and Cannell), only revealed that the particular aims and organizations were too unlike to permit joint use of a single questionnaire or other close tie-up. Similarly, only the passage of information seemed realistic in connection with the projected survey of mathematical instruction by the American Mathematical Association. Another curtailment resulted from a consultation with Dr. Paul Lazarsfeld of Columbia University, which indicated that any serious effort to ascertain the image of physiology held by the public would be beyond the Survey's resources.

The third and fourth meetings of the Executive Committee, in May, attempted to resolve uncertainty as to responsibility between administration and committees, by making the Executive Director formally responsible for directing and executing the Survey, subject to guidance by the Executive Committee. Particularly, the whole questionnaire procedure was reexamined; professional administration was virtually decided on (with the needed budget adjustments) and responsibility for its planning and execution, a joint effort of the Central Committee and of the Central Office, was placed wholly in the hands of the Executive Director and his staff.

In preparation for an especially decisive Central Committee meeting, in July, 1953, at Bar Harbor, an exhaustive collection of materials was prepared by the staff and sent to members of all the committees. Included were: minutes of all meetings, subcommittee reports from the New London meeting, a consolidation of all decisions to date, an analysis of priority ratings for the many projects, current and proposed budgets for the remainder of the Definitive Phase, and samples of questionnaire forms and a memorandum on the major questionnaire study. These are listed in Appendix K and all are on deposit with the American Physiological Society. At this Committee meeting, recommendations of the Executive Committee were accepted, each Survey project was examined and either approved for completion or dropped, a budget and operating procedures were recommended and, in general, the final year of the Survey was firmed up. The form of and responsibility for sections of this report were also agreed upon, but not well adhered to. (The Table of Contents, and assignments, is given in Appendix L.) Likewise concrete recommendations for a conference at the close of the Survey, and for questionnaire surveys of students in physiological fields and of control groups in other fields of science, although included in the supplementary budget requested, still fell through finally for lack of funds. In September, 1953, at the International Physiological Congress in Montreal, the Council of the American Physiological Society approved the Committee recommendations and an application for additional funds. These were generously made available by the National Science Foundation.

The Congress was also a time of Survey activity; copies of a special Survey questionnaire were distributed to foreign physiologists as they registered; in the symposium on the future and limitations of physiological science, Gerard described the Survey; Visscher and Veith represented the Survey at a related conference of international participants; and the volume on *Perspectives in Physiology*, already mentioned, got under way.

With the major decisions about operations thus finally approved, and the Central Office intensely active during the fall and winter of 1953, the Central Committee received only general progress reports and did not meet again until the spring meeting of the Society in April, 1954. Problems of handling data,

distribution of draft chapters of the report, and arrangements for a forthcoming symposium on the preliminary results of the Survey to be held at the September meeting of the Society were considered. Decisions regarding future activities arising from the Survey were deferred until a Final Report was near completion.

During April and May Dr. Bach returned to Tulane University, to honor prior commitments, but commuted to Washington week-ends to guide the faithful Central Office staff. Much of this period went to preparing statistical data for machine processing, notably those collected in Projects 1, 30, 3D, 7, 12A, 13A and 13J (see Appendix C). Despite a last-minute rush, much of the data remained incompletely utilized when the Survey office closed on June 30, 1954. Fortunately, it was possible later to make additional correlations, using machine facilities made available by courtesy of the Urban Life Research Institute at Tulane University. The necessary Survey files and equipment were temporarily transferred to New Orleans and Bach devoted much of the summer to finishing remaining project reports. The punched cards, codes, and some tabular statistical information were made available to the Committee members and remain so for use by other interested persons; the lode of facts is far from mined out. Appendix M gives some of the codes used for materials culled from published data, such as *American Men of Science*, or collected by the Survey.

Although the Survey was not ended, some preliminary report to the Society membership seemed necessary, as soon as possible after the formal closing date. A two-session conference was therefore arranged at the Fall Meeting of the Society at Madison, Wisconsin, on September 8. Eight speakers interpreted the data from some forty Survey project summaries, including the tabulated questionnaire results. At the afternoon session (Gerard, chairman), Fenn spoke on 'Research in Physiology,' Reynolds on 'Financial Support,' Visscher on 'Communication and Teaching,' Galambos on 'Personnel,' Field on 'Applications and Consequences,' and Bach and Lieberman on 'Operation of the Survey.' In the evening session (Fenn, chairman), Gerard drew overall inferences and made some specific recommendations and Adolph compared the findings of the present Survey with those of the earlier study by his committee. The materials in these talks are incorporated in this report. A general discussion revealed great concern with teaching at the college and the high school levels and with the inadequate preparation of future physiologists.

The Report Phase of the Survey still involved analyzing, verifying, and interpreting the mass of data collected and preparing and distributing to the Committee a mimeographed preliminary version of a report. This tremendous task was continued by Bach, with minimal assistance and compensation, over another two years. The first detailed draft of each chapter, of the presumptive

final report, was to be forwarded to members of the Committee and others who had accepted editorial responsibility for a section, returned to Bach for consolidation, and sent to Gerard for final revision. The first sections were circulated in March, 1955; but even a year later, the 1500 mimeographed pages had not been completed. This Preliminary Report details all aspects of the Survey's activities, administration, objectives, and methods of data collection, as well as the manifold results of an exceedingly complicated operation. It is deposited in the office of the Society with other archives of the Survey and was transmitted to the National Science Foundation.

In March, 1956, representatives of the Survey and of the National Science Foundation met in Washington to discuss means of bringing the Survey Report to final conclusion. A small additional grant was made by the Foundation; the Society and Board of Publication Trustees committed funds for publication, and Mr. William G. Land of Washington, D.C., who had earlier served as a consultant to the Survey, was commissioned to collate and condense the material and prepare a compact report, in association with Gerard. All data were reviewed for completeness, accuracy and validity, and a number of discrepancies and errors—hopefully all of them—were corrected, so that the Report should supply a factually sound basis for future discussions. This second draft, completed in October, 1956, was reproduced under Gerard's direction and again circulated to the responsible group. Some responses trickled in through the winter and this final version was prepared during the summer of 1957.

This account of the proposal, development, and administration of the Survey has shown the close relationship of all phases of operation—objectives, administrative policies, methods of collecting and handling data, and presentation of results—to the basic factor of financial support. The financial aspects of the Survey are now presented, partly as an indication of costs in the area of social science research, since the Survey is such a research, related more to problems of scientific manpower, education, recruitment, professional training, and utilization than to the scientific content of physiology.

In the original proposal, March, 1952 (Appendix A), the total cost of the Survey was estimated at \$117,500, and Contract NSF-C3 was written to cover this amount, allotted between the Pilot and the Definitive Phase. An additional \$35,000 was granted in December, 1953, enough to execute the main questionnaire with professional aid, but not for surveys of a student population and of comparative professional groups nor for holding a final conference. Even so, it became necessary to make further applications in September, 1954, and in April, 1956, for a total of \$11,600, to complete the Report. In addition, the Southern Regional Education Board contributed \$750 in return for a separate report on the status of physiological science in the South (4a).

The funds for the Survey thus consisted of the following:

National Science Foundation	
Pilot Phase	\$ 33,500
Definitive Phase I.....	84,000
Definitive Phase II.....	35,000
Report Phase I.....	6,000
Report Phase II.....	5,600
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Southern Reg. Ed. Board.....	750
Am. Physiol. Soc. for pub.....	6,000
	<hr/>
Total	\$170,850

The expenditures of the Survey from April 1, 1952 to October, 1957 are shown below. After that date, the expenses of publishing were to be borne by the Publications Fund of the American Physiological Society.

Salaries	\$ 70,700
Meetings and travel.....	23,700
Supplies and services.....	17,700
Grants and contracts.....	35,900
Overhead to Society.....	16,600
Reserve for publication.....	6,200
	<hr/>
Total	\$170,800

Most of the funds in the Grant and Contract category were paid to the Survey Research Center for the questionnaire study. To the questionnaire cost must be added the short-term employment of several clerical assistants and much time of the Executive Director and the Central Office staff over several months, as well as printing and mailing expenses; so that the total cost of planning and administering the questionnaire was considerably more than its contracted price. Specifically constructed to meet the objectives of the Survey, the questionnaire surely yielded the largest amount of useful data; but important results were also obtained by members of the Central Office staff and consultants to the Survey, at comparatively small cost.

Funds in the category of Supplies and Services were spent largely for mimeographing the many lists, summaries, reports, and minutes of meetings supplied to the committees. Meeting and travel funds were kept down by holding many committee meetings in conjunction with Society meetings or other activities, mainly in Washington, which committee members attended.

The variety of individual Survey projects illustrates the complexity of the material handled and something of the many methods of handling it. At one time it was planned that the Survey would sponsor separate publication of each study by its author, aside from integration of full results by the Survey; but the impact of the large questionnaire project, and the tendency for most other projects to revert to the Central Office, made this possible in only a few instances. Much of the detail is still only in mimeographed versions of such

studies, some of which merit printing. All are on deposit with the American Physiological Society; a list is given in Appendix C.

Summary

The Survey was thoughtfully planned, well financed, widely supported, and energetically pursued; but the achievement fell short of expectations. Those closest to it have speculated on the flaws in formulation or execution, but with limited insight to communicate. The scope was perhaps too inclusive and amorphous, at least for the experience and resources of the responsible group. The discontinuity in direction was obviously undesirable and, for one thing, exacerbated the problem of shifting responsibilities, between Society office, Survey Director, and guiding Committees. But the main defect was the progressive attenuation of interest of many, on and off committees, who were initially eager to work; and the causes of this are critical. Naturally, some initial enthusiasms simply burned out. Partly, so much was begun by so many within a short time that the staff could not keep up with developments; the litter became cats too quickly.

Probably most important, there was too great a separation in time and operation between plan and execution. This depended on at least three factors, all related to the formulation of objectives by one group and the carrying out of operations by another: the initial urge of persons not on the staff to do a particular job was frustrated; the job to be done lost clarity, so that the study as carried through sometimes missed critical points of the inquiry; and the critical questions were themselves sometimes forgotten or otherwise not related to the answers because of the long time lapse between query and reply, or proved unanswerable, at least by the material collected. Finally, this separation resulted largely from the operating plan; namely, that each research instrument was to contribute information to many of the problem areas.

Thus, for example, information on teaching problems might come from analysis of available data on courses, students, degrees, finances, and the like; from examination of the journal literature for authorship and laboratory of origin; from fresh studies of course content, teacher skills and attitudes, student opinions, and the like; and from the questionnaire probe of the experience of our professional colleagues. Similarly, on problems of personnel, from recruiting of students to employment of graduates; or on problems of research, involving freedom, facilities, finances, and followers; or of communication, from the preliminary struggle with a sea of literature to the final addition of new spit to the ocean—all depend on information of the same three types (comparative contemporary data, historical trends, informed opinions) and even on the same individual studies. Perhaps this crossing-over could be obviated another time by a different conceptual approach or operating machinery; certainly to be avoided are the temporal, ideational, and emotional gaps between input and output.

IV

DEFINING PHYSIOLOGY AND PHYSIOLOGISTS

THE PROBLEM OF DEFINITION

Theoretical Definition

A primary problem inherent in the study of any human activity is the definition of the area of investigation; no simple method differentiates those individuals who are physiologists from those who are not. Furthermore, there are many views of physiology as a science: some would include in it nearly all biology; others would restrict it to a study of the mechanisms of organic activity. One type of definition tends to claim other biological disciplines that use techniques and methods of analysis derived from mathematics, physics and chemistry; thus, "Physiology is the science of the phenomena of living nature, and its task is the investigation of life," or "Physiology is the study of the physical and chemical processes in living units." Another focuses on objectives: "Physiology is the study, not of mechanisms, but of *functions* or processes that have a referred meaning for the whole." Such is the intent of Claude Bernard's classic formulation, expressed in the easier teleologic phrasing of a century ago: "Admitting that vital phenomena rest upon physico-chemical activities, which is the truth, the essence of the problem is not thereby cleared up, for it is no chance encounter of physico-chemical phenomena which constructs each being according to a pre-existing plan, and produces the admirable subordination and harmonious concert of organic activity. There is an arrangement in the living being, a kind of regulated activity, which must never be neglected, because it is, in truth, the most striking characteristic of living things. . . ."

Even though Adolph's report concluded that physiology ". . . has several definitions, and those who belong to it by profession will inevitably characterize it", the Survey attempted to identify physiologists on the basis of a theoretical definition of their subject. For this purpose, the Central Committee reluctantly agreed that "A physiologist is anyone who teaches, investigates or applies the physical and chemical processes involved in the dynamics of living organisms"—a definition in which "dynamic" implies a pattern of forces and a functional relation of parts to whole. When tested operationally, results

proved only that the definition obviously meant many different things to those who applied it. The world of physiology seems largest to physiologists; but on the most limited categorization, the number of physiologists theoretically defined could have included almost the entire biological profession.

Operational Definition

This left the operational definition used by the Adolph Committee, "the individuals who profess the science . . . can be accepted in part as representing it," and the Survey made a comprehensive contemporary listing of those who might be physiologists, assuming that anyone who had once indicated his interest in physiology by joining a society bearing the name Physiology, or by using the word in a self-classifying scheme, was a potential member of the population of physiologists. Names and addresses were therefore drawn from the following sources: *a*) current members of the American Physiological Society, the American Society of Plant Physiologists, the physiological section of the Botanical Society of America, the Society of General Physiologists, the experimental (physiological) section of the American Psychological Association, and the Canadian Physiological Association; *b*) members of the physiological section of the Society of American Bacteriologists who had indicated a primary competency in physiology in the records of this society; *c*) those members of some 65 other biological societies, listed with the National Research Council, who were judged by the society secretary to be physiologists in their particular fields; *d*) those who had indicated, in the National Science Roster of 1951 or in the 1949 edition of *American Men of Science*, a first competency in those biological science categories judged to be primarily physiological; *e*) all names used in the Adolph Survey of 1945; and *f*) all recipients of the Ph.D. or Sc.D. degree in the period 1948-52 in the United States and Canada, whose thesis titles were judged to be physiological, from the H. W. Wilson Company listings of doctoral dissertations in the U.S. and Canada. To list, as a base for longitudinal studies, all graduate students currently working in physiology in a variety of departments was impractical because of the difficulty in obtaining names. Even the above listing of physiologists was incomplete, not only through unavoidable inadvertence, but also through necessary omission of other specific groups also omitted in past rosters. For example, the large population of teachers of courses considered physiological, from elementary school through small colleges, is omitted except as some individuals achieved professional status by more than their regular teaching activities. Yet these teachers, more than any others, represent to the population of students what physiology is and perhaps correspond most closely to the popular notion of a physiologist as a teacher of hygiene. In 1956 the Committee on Education of the American Physiological Society made a roster of teachers of college physiology. Only

one fourth of the 700 names on this list is included in the questionnaire population of the Survey. A list of those who teach physiology in secondary schools would be larger and the fraction included, smaller.

Estimating the Number of Physiologists

From the various sources listed, 7615 names were obtained, including 99 duplicates. From the 7615, wrong or inadequate addresses, derived mainly from the Adolph lists and those of recent doctorates, lost 412. Thus a total group of 7104 potential physiological scientists was available for study. Each person was mailed a copy of the *Attitude and Opinion Questionnaire* (see Appendix F), prepared with the Survey Research Center as part of Project 18. The number of usable replies was 4571 (Table IV-1). By follow-ups, including personal contacts of a 10% sample of final non-responders, all but about 5% were reached and the respondents shown to be representative. Correcting the data for non-respondents, it is estimated that 5130 persons judged themselves to be physiologists in some degree. Another 159 replies, not completely usable, were clearly from workers in physiological fields, giving a total of 5291 self-classified or obvious (though not admitted) physiologists. A further group of approximately 450 was also added as an estimate of those omitted from the lists used, either by failure to include themselves in the basic categories or because of recent entrance into the profession. The net result is an estimated total of 5750 physiological scientists in the United States and Canada as of October, 1953.

These 5750 physiologists constitute 43% of the 13,300 biologists (excluding medical scientists), estimated by the National Manpower Council in 1950, or 41% of the 13,800 biologists with doctoral degrees estimated in 1953 by the Commission on Human Resources and Advanced Training (122, p. 81); and 31% of the 18,500 biologists (including medical scientists not listed as physicians or surgeons) enumerated by the 1950 Census, 27% of the 21,100 biologists (including agriculturists but excluding biochemists) surveyed by the National Scientific Register in 1951 (93, p. 35); but only 11.5% of the estimated 50,000 total of biologists in the United States (*ibid.*, p. 1), and only 9% of the 63,800 biologists materialized by the Scientific Manpower Commission (56). Because of their differing bases of compilation, comparative statistics from these various sources must be scrutinized carefully; but perhaps it is fair to say that physiologists constitute a tenth of all biologists, 'pure' and 'applied', in the United States; a third of the 'pure' biological scientists. To some extent individuals would equally well fall into categories other than physiology, certainly so for the 'peripheral' group, which would make our population overlap others; clearly this population is far more inclusive than that of the earlier study.

KINDS OF PHYSIOLOGISTS

'Central' and 'Peripheral' Physiologists

Having identified physiological scientists by self-classification, one may expect their activities in turn to indicate the scope of physiology. To the extent that a scientific discipline is homogeneous and delimited, those working therein would identify themselves primarily with it; conversely, the greater its impingement on other disciplines the more would known members of the profession identify themselves primarily with these other fields. Thus, by classifying the total population as *central* or *peripheral* physiologists, and subdividing further, on the basis of organisms studied, into animal, plant, and bacterial physiologists, two classes and six subclasses of physiological scientists are presented for analysis.

A '*central*' physiologist is defined as a member of the known population of physiologists who identifies himself primarily with physiology (animal, plant, or bacterial) before identifying with any other biological field. A '*peripheral*' physiologist, conversely, is one who identifies himself primarily with some biological field other than physiology. (Or is one of the 159 Survey questionnaire respondents not self-classified as a physiologist but obviously working in a physiological field.)

Approximately one-third of the respondents were classified as central physiologists; two-thirds, as peripheral. In the earlier study, just over half were central physiologists; undoubtedly a reflection of the less widespread sources used in establishing the population, but perhaps involving also some change of mind in self-identifications over time. Minor errors only could occur, as in processing the Survey questionnaire, due to erroneous assignment of individuals to categories in the course of machine coding.

Animal, Plant, and Bacterial Physiologists

Within both central and peripheral groups there is a major professional subdivision according to the type of organisms studied. Nearly two-thirds of all physiologists are animal physiologists and, as shown by Table IV-1, this proportion holds for both central and peripheral groups. Likewise, the proportion of bacterial physiologists in each group is practically constant, at 12%. (Differences are not significant, due to the small numbers.) Only for plant physiologists, 25% of the central and 19% of the peripheral groups, is a difference significant—at the .05 level of confidence. The 9% lower representation of total bacterial than of plant physiologists is significant; the 6% difference within the peripheral group, barely so. The differences between animal, plant, and bacterial physiologists in Table IV-2, however, are all well within the stated statistical levels of significance.

TABLE IV-1. NUMBER OF PHYSIOLOGISTS BY FIELD OF PRIMARY IDENTIFICATION (a—Number of usable Survey questionnaire responses; b—estimated number of physiologists as of October, 1953; c—percentage of total in column).

Primary Identification	Central			Peripheral			Total		
	a	b	c %	a	b	c %	a	b	c %
Animal	961 ^a	1209	64	1951	2454	64	2912	3663	64
Plant	382 ^a	480	25	595	748	19	977	1229	21
Bacterial	171	216	11	385	484	13	556	699	12
Other ^b				126 ^a	159	4	126	159	3
Total	1514 ^a	1905	100	3057 ^a	3845	100	4571	5750	100

^a Apparent discrepancies in the published volumes on the Survey questionnaire are explained by the use of variant codings in tabulating the data. Fifty respondents (44 animal, 6 plant) were classified as shown above on the basis of internal evidence. In the analysis of some sub-groups, however, only those who had directly marked a primary field of identification on the questionnaire were counted. Consequently certain tables are based on data from 1464 central physiologist respondents (917 animal, 376 plant) and 3107 peripheral ones (176 instead of 126 classified as 'other').

^b Those who did not give any rank to animal, plant, or bacterial physiology as a field of identification, but who reported a specialty, or reported research or teaching in an unspecified physiological field.

Since these data are basic to further discussion, Tables IV-1 and IV-2 give the actual number of usable survey questionnaire replies and also the projection of figures to the estimated total number of 5750 physiologists. The 4571 usable replies represent 79.5% of the estimated total, so that a correction factor of approximately 5/4 may be applied to numerical data derived from the Survey questionnaire. As already noted in the Preface, the percentage tables must be used with caution because of some small sub-groups.

Fields of Primary and Secondary Identification

The disperseness of the fields with which physiologists identify themselves indicates the breadth of the subject and measures its normal confines; and the strength of physiology as a discipline may be gauged by the number of peripheral physiologists who, having primary allegiance to other subjects, utilize its methods and represent its point of view. Table IV-3 shows the number and percentage of Survey questionnaire respondents, and the projected total number, indicating their primary subject (or assigned to one on internal evidence). The three central groups comprise 33% of all physiologists; and 1400 biochemists in the peripheral group constitute one-fifth of

TABLE IV-2. PERCENTAGES OF CENTRAL AND PERIPHERAL PHYSIOLOGISTS IN EACH FIELD OF PRIMARY IDENTIFICATION

	Central %	Peripheral %	Total %	Number	Est. N
Animal	33	67	100	2912	3663
Plant	39	61	100	977	1229
Bacterial	31	69	100	556	699
Other	0	100	100	126	159
All	33	67	100	4571	5750

TABLE IV-3. NUMBER OF RESPONDENTS, ESTIMATED NUMBER OF PHYSIOLOGISTS, AND PERCENTAGE OF PHYSIOLOGISTS IN EACH FIELD OF PRIMARY IDENTIFICATION (Q, II, 19, 20).

Primary Field of Identification	Central		Peripheral		% of Total N = 4571 ^c	% of Peripheral N = 3057 ^c
	Number	Est. N ^b	Number	Est. N ^b		
Animal physiology	961 ^a	1209			21	
Plant physiology	382 ^a	480			8	
Bacterial physiology	171	216			4	
Agriculture			365	459	8	12
Anatomy			93	117	2	3
Biochemistry			941	1384	20	31
Biophysics			121	152	3	4
Botany			162	204	4	5
Clinical medicine			264	332	6	9
Home economics			42	53	1	1
Microbiology			292	367	6	10
Pharmacology			132	166	3	4
Psychology			183	230	4	6
Zoology			164	206	4	5
Other physiological fields						
Specified (less than 1% each)			106	133	2	3
Not specified			126 ^a	158	3	4
Other non-physiological fields			57	72	1	2
No answer			9	10	#	#
Total	1514 ^a	1905	3057 ^a	3845	100	99

[#] Less than .5%.

^a See note ^a to Table IV-1.

^b Assuming that the proportion for projection in each sub-group is the same as for the whole.

^c Rounded to nearest whole number.

all physiologists and roughly one-sixth of the biochemists in the United States (86, pp. 1, 53). Agricultural physiologists account for 8% of all physiologists, medicine and microbiology for 6% each, and other fields for smaller fractions; the exact figures are not significant for the smaller groups. The primary field of identification does not necessarily coincide with that of highest competence or of employment, both of which are bases commonly used in professional manpower surveys.

One-fourth (24%) of all physiologists identify themselves with only one field, 36% with two, 28% with three, and 12% with four. There is no essential difference between the central and peripheral groups; but very few bacterial physiologists identify themselves with only one field and over half with three, plant physiologists are mostly in three or four, and animal physiologists mostly in only one or two (Q, II, 21). Animal physiologists collectively, however, identify with a greater variety of fields. As shown in Table IV-4, about a quarter of the central animal physiologists did not indicate any secondary field of interest, in comparison to one-eighth of the central plant physiologists and only one-sixteenth of the bacterial physiologists.

TABLE IV-4. FIELDS OF SECONDARY IDENTIFICATION INDICATED BY CENTRAL PHYSIOLOGISTS (Q, II, 22).

Secondary Field	Primary Field (Central)					
	Animal		Plant		Bacterial	
	N ^a	%	N ^a	%	N ^a	%
Animal physiology			2	1	1	1
Plant physiology	5	1			1	1
Bacterial physiology	6	1	2	1		
Agriculture	20	2	80	20	2	1
Anatomy	39	4	2	1	0	0
Biochemistry	131	14	64	17	56	33
Biophysics	78	9	7	2	0	0
Botany	2	#	157	41	0	0
Clinical medicine	101	11	0	0	2	1
Home economics	0	0	0	0	0	0
Microbiology	8	1	6	2	92	53
Pharmacology	79	9	0	0	1	1
Psychology	22	2	0	0	0	0
Zoology	134	15	2	1	3	2
Other fields	42	5	8	2	2	1
No answer (i.e. no secondary field of identification)	250	26	46	12	11	6
Total	917 ^a	100	376 ^a	100	171 ^a	100

Less than .5%.

^a Number of Survey questionnaire respondents. See note ^a to Table IV-1. Proportional projections to the estimated total number of central physiologists, using a factor of 5/4, are possible for large groups only.

The secondary fields with which central physiologists identify are shown in Table IV-4. Very few cross into another central field, a striking evidence of the separateness of these branches of the discipline. Secondary interests of central bacterial physiologists are heavily concentrated (86%) in biochemistry and microbiology, and of central plant physiologists (78%) in biochemistry, botany, and agriculture. No other subject attracts more than 2% of either of these groups. The secondary identifications of central animal physiologists, in contrast, are widespread; only 40% falling in the top three subjects—biochemistry, zoology, and clinical medicine.

Table IV-5 shows how the secondary identifications of peripheral physiologists are distributed among the three main branches of physiology. Plant or bacterial physiology is seldom indicated as a secondary field except by agriculturists, botanists, and microbiologists. Microbiologists naturally choose bacterial physiology (51%) as their secondary field, as agriculturists (44%) and botanists (52%) choose plant physiology. The wide relations of animal physiology to biological endeavor are emphasized by the frequency with which pharmacologists, clinicians, anatomists, psychologists, zoologists, and others show physiology as their second field. Although the core of physiology seems to be a tri-compartmented science, its peripheral relationships pervade a large segment of biology.

TABLE IV-5. FIELDS OF SECONDARY IDENTIFICATION INDICATED BY PERIPHERAL PHYSIOLOGISTS (Q, II, 23 corrected).

Secondary Field	Primary Field (Peripheral)											
	Agricul.		Anat.		Biochem.		Biophys.		Botany		Clin. Med.	
	N	%	N	%	N	%	N	%	N	%	N	%
(a) Animal physiology	25	7	42	46	178	19	32	26	1	1	144	56
(b) Plant physiology	160	44	1	1	52	6	1	1	85	52	0	0
(c) Bacterial physiology	1	#	2	2	34	4	5	4	0	0	3	1
(d) Other fields (peripheral)....	111	30	29	31	374	37	46	39	48	30	51	18
(e) No answer (no second field) .	68	19	19	20	330	34	37	30	28	17	66	25
(f) Total respondents												
(N = 3107 ^a)	365	100	93	100	941	100	121	100	162	100	264	100

	Home Econom.		Microbiol.		Pharmacol.		Psychol.		Zool.		Other	
	N	%	N	%	N	%	N	%	N	%	N	%
(a)	3	7	7	2	81	61	76	41	59	36	44	13
(b)	0	0	12	4	0	0	0	0	0	0	5	1
(c)	0	0	146	51	0	0	0	0	0	0	10	3
(d)	25	60	80	27	34	26	31	17	64	49	229	68
(e)	14	33	47	16	17	13	76	42	41	25	60 ^b	15
(f)	42	100	292	100	132	100	183	100	164	100	384 ^b	100

Less than .5%.
^a See note to Table IV-4.
^b Includes 9 who reported only research or teaching in an unspecified physiological field. See note ^b to Table IV-1.

Specialties in Physiology

Another operational definition of physiology can be arrived at by analyzing the special sub-fields of interest of physiologists. The distribution of these specialties within animal physiology is shown in Table IV-6. Specialties in plant and bacterial physiology were also analyzed by the Survey, despite the small size of the groups; but so many respondents reported either non-physiological specialties or ones not readily classified that no brief summary is possible (*Preliminary Report IV-3-B*, pp. 6, 7).

Over half the specialization of animal physiologists is in metabolism or nutrition, endocrines, circulation, and neurophysiology. Of the central group, 58% are concerned with these four fields, in nearly equal proportions; and of the peripheral group, 45% so specialize. The proportion of central to peripheral animal physiologists within the specialty is particularly high in renal and endocrine physiology and low in physiological psychology, metabolism, sensory physiology, and biophysics.

Since metabolism and nutrition is an important specialty within all three branches of physiology, Table IV-7 gives the percentage of physiologists in each specialized branch. Of the bacterial physiologists, 58% of the central and 38% of the peripheral group specialize in metabolism; the latter constituting 42% of the specialists. Of the animal physiologists specializing in metabolism, 82% are from the peripheral group, almost a third of which is in this specialty. Projected to the estimated total, about 1590 physiologists

TABLE IV-6. SPECIALIZATION WITHIN ANIMAL PHYSIOLOGY (Q, II, 38 corrected, 39).

Field of Specialization	Number and Percentage of Respondents ^a						% Within Field	
	Central		Peripheral		Total		Central	Peripheral
	N ^a	%	N ^a	%	N ^a	%		
Biophysical	14	1	53	3	67	2	21	79
Circulatory	155	16	86	4	241	8	64	36
Drugs: anoxia	2	#	21	1	23	1		
Endocrine	137	14	155	8	292	10	47	53
Environmental	30	3	9	#	39	1	77	23
Gastrointestinal	25	3	21	1	46	2	54	46
General, comparative	41	4	64	3	105	4	39	61
Growth	41	4	76	4	117	4	35	65
Metabolic, nutrition	138	14	638	33	776	26	18	82
Muscle	13	1	8		21	1		
Neurophysiology	136	14	78	4	214	7	64	36
Physiologic psychology	6	1	91	5	97	3	6	94
Renal	44	5	30	2	74	3	59	41
Respiratory	64	7	15	1	79	3	81	19
Sensory	15	2	65	3	80	3	19	81
Other physiological fields ^b	59	7	206	10	265	9	22	78
Non-physiological fields	10	1	160	8	170	6	2	98
Other ^c	13	1	144	7	157	5	8	92
No answer	18	2	31	2	49	2	37	63
Total (N = 2912)	961 = 100		1951 = 100		2912 = 100			

Less than .5%.

^a Proportional projections to the estimated total number of 3663 animal physiologists, using a factor of 5/4, are possible for large groups only.

^b Less than .5% each.

^c Cannot determine whether physiological or non-physiological.

specialize in metabolism and nutrition; as compared with about 1770 other biologists, whose primary competence is in nutrition, in biology and agriculture (92, pp. 1, 22, 23).

In contrast to metabolism and nutrition, many physiological specialties attract relatively small percentages of the profession; which of these are anlagen of future developments and which are vestiges of past ones is an important question, to be examined later.

TABLE IV-7. PERCENTAGE OF PHYSIOLOGISTS INDICATING METABOLISM-NUTRITION AS A SPECIALTY (Based on Preliminary Report IV-B-3, p. 6).

	Percentage of Major Groups ^a			Percentage Within Specialty	
	Central	Peripheral	Total	Central	Peripheral
Animal	14	33	26	18	82
Plant	46	31	36	48	52
Bacterial	58	36	43	42	58

^a See Table IV-1 for the total number of physiologists in each category.

THE DEVELOPMENT OF PHYSIOLOGY

Numerical Growth of the Profession

Among other criteria, sequential or longitudinal data on the growth of physiology as a profession help determine the number of physiologists. In the forty years 1915-54 inclusive, 1704 doctoral degrees in physiology were granted in the United States, as detailed in Table IV-8. Since 80% of all physiologists have Ph.D. (or Sc.D.) degrees, the increase in number of these degrees may be considered a valid measure of professional growth. (About 7%, mostly animal physiologists, have an M.D. degree in addition to one of the others; and another 9% have only the M.D. degree, Q, I, 133 corrected. Thirty-seven per cent of medical school physiologists have an M.D.; ref. 3.) A degree above the M.S. is held by 96% of animal, 81% of plant, and 83% of bacterial physiologists (Survey Project 13A).

In three earlier years, 1912-14 inclusive, there were 22 degrees in physiology, an average of 7.3 per year. Thus physiology grew but little before World War I, since then has reflected—with a time lag for graduate study—the ups and downs of war, boom and depression. Even so, during the war years, 1945-49, there were nearly as many physiological doctorates as during the post-war boom period, 1925-29. The annual increment of new doctorates reached its zenith in 1935-39, a decade after the booming twenties, and its nadir in 1945-49, a decade after the depression and during World War II.

The number of Ph.D. theses judged physiological doubled, from 300 given in 1940 to 600 in 1952. The fraction of these in botany remained roughly constant at 7% and in physiology and biochemistry at 55% (the two varied inversely, physiology between 12% and 25%, biochemistry between 25% and 40%); but those in microbiology doubled, from 6% to 13%, as did those in agriculture, from 5% to 9%.

The proportion of physiological doctorates to all science doctorates remained relatively constant for thirty years, except for a spurt in the thirties, then diminished abruptly; partly as a result of the greatly increased attraction

TABLE IV-8. DOCTORAL DEGREES CONFERRED IN PHYSIOLOGY, 1915-54 (93, p. 36).

	Degrees		Increment		% of Total Science Doctorates	% of Total Biology Doctorates ^a
	No.	Per Year	5-Years	Per Year		
1915-19	52	10		3	3.5	10.0
1920-24	76	13	24	3	3.3	10.4
1925-29	160	32	84	19	4.0	12.9
1930-34	245	49	85	17	3.9	12.7
1935-39	387	77	142	28	5.0	13.7
1940-44	305	61	— 82	—16	3.5	9.5
1945-49	123	25	—182	—36	1.5	5.0
1950-54	356	71	233	47	1.6	5.3

^a Including agriculture and medical science.

of chemistry, engineering, and physics compared to biology. Even in proportion to the total doctorates in biology (including agriculture and medical sciences) physiology has been declining, however—largely due to the creation of separate departments of biochemistry in the 1930's. In 1945, as estimated by the Adolph Committee, about 10% of all biological doctorates were in physiology; earlier the proportion was definitely higher, since then it has dropped markedly, to around 5%, and shows signs of falling even further—to 4.1% in 1955.

In the decade from 1935 to 1944, physiology (580) ranked eighth of all departments in Ph.D.'s, constituted 11% of those in biology (5318), and was exceeded only by zoology (955), biochemistry (922), and botany (902). In 1951, 75 degrees in physiology constituted only 9% of those in biology (828) and ranked sixth; by 1955 the fraction in physiology had fallen to 4.1%, but Ph.D. degrees in medical and related areas had risen to 19% (Statistical Abstracts of the U.S. 1956, p. 131). Estimates of doctoral degrees in physiological science (Survey Project 7) fell from 295 in 1939-40 to 145 in 1944-45, then rose to 555 in 1950-51, and to 600 in 1951-52. The earlier values constitute about half of all biology degrees, that for 1951 has risen to two-thirds. To those who foresee in this the demise of a profession, the trend may be disturbing; to those concerned less with the name of physiology than with its body, the trend may reflect the penetration of physiological orientation into many departments of experimental biology and a lessening of its strict departmentalization.

Further evidence on the numerical growth of physiology, and on central and peripheral relationships within the profession, was obtained in Project 13A of the Survey. In each issue of *American Men of Science*, from 1906 to 1944, the scientists selfclassified as physiologists were determined. The results are shown in Table IX-9, together with a comparative estimate for 1953. Physiology is growing in an average way for science as a whole. Further relations to total and special populations are shown in Table IV-10. A comparison of Tables IV-8 and IV-9 reveals the same trend in expansion

TABLE IV-9. NUMBER OF PHYSIOLOGISTS IN SUCCESSIVE EDITIONS OF *American Men of Science* (Project 13A).

	Editions								
	1906	1910	1921	1927	1932	1938	1944	1949 ^a	1953 ^b
Number of entries.....	4500	6000	10,000	14,000	22,000	28,000	35,000	50,000	93,000 ^c
Number of physiologists.	97	135	210	331	561	719	881	1,834 ^a	1,905
Increment of physiologists		38	75	121	230	158	162	953 ^a	71
Physiologists as percentage of all entries ....	.022	.021	.021	0.24	0.25	0.26	0.25	0.37	0.21

^a Data from the Office of Naval Research.

^b Estimated total number of central physiologists. See Table IV-1.

^c 1955.

TABLE IV-10. GROWTH OF PHYSIOLOGISTS AND OTHER SPECIAL GROUPS IN RELATION TO POPULATION SINCE 1920 (=100%).^a

	% of 1920		
	1930	1940	1950
U.S. population	112	117	136
U.S. labor force.....	118	128	185
Living Ph.D.'s	250	500	800
Living science Ph.D.'s	200	400	750
Five-year output—Ph.D.'s	300	550	750
Five-year output—biology Ph.D.'s	350	700	650
Total scientists	150	250	450
American Men of Science.....	200	300	450
Amer. Assoc. Adv. Sci.....	150	200	350
Fed. Am. Soc. Exp. Biol. ^b	200	300	800
Am. Physiol. Soc.....	150	200	650
Am. Chem. Soc.....	100	150	400
Am. Psychol. Assoc.....	300	700	1850
Am. Econ. Assoc.....	150	150	350
Am. Sociol. Assoc.....	200	150	400

^a Estimates from various sources; roughly rounded figures—mostly to nearest 50%.

^b Attendance at meetings increased thirty-fold from 1923 to 1953 (6400).

of the profession. (The out-of-line increase in the 1949 data is due to a difference in coding.) Chapter XII adds further information.

The foregoing data, concerned with central physiologists, can be supplemented by a longitudinal view of the ratio of the central and peripheral groups. Table IV-11 gives the percentage of authors of papers published in three major journals (*American Journal of Physiology*, *Journal of Cellular and Comparative Physiology*, and *Journal of Neurophysiology*) who had classified themselves as physiologists in *American Men of Science*.

A comparison of Table IV-11 with Table IV-8 shows that, with the increased percentage of physiological doctorates up to 1940, relative to all biological doctorates, there was a rise in the proportion of central physiologists reporting research in these journals. The sharp fall in the 'forties in the ratio of central physiologists publishing, similarly goes with the smaller proportion of physiological doctorates conferred since 1940, since younger men publish most

TABLE IV-11. AUTHORS OF PAPERS IN THREE PHYSIOLOGICAL JOURNALS, 1900–1950, AS CLASSIFIED IN THE NEAREST EDITION OF *American Men of Science* (Project 12, 13A).

Years Sampled ^a	(a) % Classified as Physiologists (Central)	(b) % Not Classified as Physiologists	Ratio of (a) to (b)
1904, 1909	25	75	.33
1914, 1919	27	73	.37
1924, 1929	31	69	.44
1934, 1939	33	67	.49
1944, 1949	23	77	.29

^a Every paper in the three journals was analyzed for departmental source and other characteristics for a period of a year selected at five-year intervals. The data for the two five-year intervals have been combined as a sample for that decade.

heavily. The Survey questionnaire in 1953 showed twice as many peripheral as central physiologists; the present tendency appears to be towards a still larger proportion in the periphery.

Personal Characteristics of Physiologists

The personal characteristics and backgrounds of physiologists are of interest, especially if in any way distinctive. Ninety per cent of Survey respondents were male, and the median age was slightly less than forty. The median age of biologists in general is 39; of physicists, 37; of chemists and geologists, 35; of mathematicians, 34 (National Science Register data). The 466 women physiologists were distributed about as men among the various background groups.

A clinical psychological comparison by Anne Roe, on the basis of available Rorschach data, indicated no important difference between physiologists and other biologists, although a related study of scientific eminence (Chapter VI) did show distinctive characteristics of successful scientists. The Survey also made a statistical study of a group of eminent as compared to average physiologists, but except for some small and expected differences in degree, the groups were similar (*Preliminary Report IV-H-4*). (But see Appendix to this chapter.) Geographic and socio-economic origins and undergraduate grade averages reported by physiologists do not differ significantly from those of professional scientific personnel in general. Typical physiologists might have been born in almost any part of the country, most probably in the Middle Atlantic and East North Central regions; their families were mostly with a higher-than-average socio-economic background, half in the professional or managerial class; and they were more likely to have been raised in a fairly large city or town than in another sized community (Q, I, 146-152; II, 4-7).

A longitudinal analysis of the ages of physiologists, as obtained from successive editions of *American Men of Science*, is given in Table IV-12. The

TABLE IV-12. AGE OF PHYSIOLOGISTS GIVEN IN SUCCESSIVE EDITIONS OF *American Men of Science* (Preliminary Report IV-E-1, p. 9).

Age	Edition							
	1906 %	1910 %	1921 %	1927 %	1932 %	1938 %	1944 %	1949 %
Under 30	5	7	4	6	6	2	3	4
30-39	42	40	35	35	36	35	27	39
40-49	31	29	33	31	31	33	33	28
50-59	13	13	17	15	16	17	21	16
60-69	5	6	9	9	7	9	10	8
70 and over	2	2	1	3	3	3	5	4
No data	2	3	1	1	1	1	1	1
Total	100	100	100	100	100	100	100	100
Median (est.)	40 yr.	40 yr.	43 yr.	42 yr.	42 yr.	44 yr.	47 yr.	41 yr.
N (total = 4768) .	97	135	210	331	561	719	881	1854

TABLE IV-13. AGE OF PHYSIOLOGISTS IN RELATION TO BRANCH OF PHYSIOLOGY (Q, I, 145; II, 4) 1953.

Age	Central				Peripheral					Total
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Under 30	7	13	27	11	10	8	19	11	11	11
30-39	35	44	49	39	40	42	50	47	42	42
40-49	32	19	17	26	28	23	22	21	25	26
50-59	16	13	5	14	13	15	6	13	13	13
60-69	6	7	1	6	6	9	2	6	6	6
70 and over	3	3	0	3	2	2	1	1	2	2
No answer	1	1	1	1	1	1	0	1	1	#
Total	100	100	100	100	100	100	100	100	100	100
N	961	382	171	1514	1951	595	385	126	3057	4571

Less than .5%.

distribution among age groups over the years is relatively constant; but it does strongly suggest a slowly aging population. Such fluctuations, as in 1944 in the 30-39 and 50-59 age groups, reflect the dislocation of scientific productivity during wartime. The relation of age of Survey respondents to branch of physiology chosen and to sub-specialty is shown in Table IV-13, IV-14, and IV-15; to employment, in IV-16.

From these tables it is clear that not only are physiologists as a group aging (more rapidly than are wider populations), presumably because young men are more attracted elsewhere; but also that animal physiology, and especially central animal physiology, is handing on the torch to the other branches, notably to bacterial physiology. Some skewing toward youth in this group may result from an open door policy of the Society of American Bacteriologists and a consequently high student membership; but Ph.D.'s given before 1940 are only 20% of those in the bacterial area (50% for animal physiology), those given since 1950 are 44% (16%), and Ph.D.'s in the animal area constitute only 45% of all in physiology since 1950. The higher percentage of younger members with primary allegiance to bacterial physiology,

TABLE IV-14. AGE OF PHYSIOLOGISTS IN RELATION TO PRINCIPAL BRANCHES OF PHYSIOLOGY * (Derived from Q, II, 94 and Table IV-1, 1953).

Age	All Animal Physiology		All Plant Physiology		All Bacterial Physiology	
	%	N	%	N	%	N
Under 30	9	249	10	94	21	116
30-39	40	1147	42	413	49	275
40-49	28	826	21	204	20	109
50-59	14	408	14	133	5	30
60 and over	7	219	10	101	2	11
No answer	2	63	3	32	3	15
Total (N = 4445)	100	2912	100	977	100	556

* Not including 126 respondents classified as 'Other Peripheral'. See Table IV-1.

TABLE IV-15. RELATION BETWEEN MEDIAN AGE AND PRIMARY FIELD OF IDENTIFICATION (Q, II, 20 corrected).

Primary Field	Age			Number of Cases ^a
	Under 40 %	Over 40 %	No Answer %	
Animal physiology	42	57	1	917 ^b
Plant physiology	58	41	1	376 ^b
Bacterial physiology	76	23	1	171
Agriculture	54	45	1	365
Anatomy	45	53	2	93
Biochemistry	59	40	1	941
Biophysics	43	56	1	121
Botany	36	62	2	162
Clinical medicine	31	69	0	264
Home economics	31	67	2	42
Microbiology	71	29	0	292
Pharmacology	42	58	0	132
Psychology	68	31	1	183
Other fields	47	53	0	339 ^c
No field indicated				9
				4407

^a For estimated number of physiologists, projected within the total of 5750, see Table IV-3.

^b See note ^a to Table IV-1.

^c Other specified physiological fields, 106; other non-specified physiological fields, 176 ^b; other non-physiological fields, 57.

microbiology, and psychology reflects the relatively recent development of these subject fields; the high percentage of older physiologists in home economics, clinical medicine, and botany indicates a shift from these established areas. Perhaps, also, there has been some transfer of training students to other professional groups, as home economics and physical education. A similar analysis made of specialties, within animal physiology, points in the same direction. Of that group, nearly 60% of the physiological psychologists are below the median age, while 65% of the respiratory physiologists, 61% of the biophysicists, and 59% of growth physiologists are over the median age (Q, II, 40). In other specialties within animal physiology differences

TABLE IV-16. AGE OF PHYSIOLOGISTS IN RELATION TO TYPE OF INSTITUTION IN WHICH EMPLOYED (Derived from Q, I, 36; II, 95).

Age	Institution ^a					
	Academic		Industrial		Governmental	
	N	%	N	%	N	%
Under 30	300	10	55	12	47	8
30-39	1198	42	225	50	285	46
40-49	754	26	101	23	173	28
50-59	404	14	42	9	75	12
60 and over	166	6	15	3	28	4
No answer	45	2	11	2	13	2
Total (N = 3937) ^a	2867	100	449	99	621	100

^a Includes only those employed in a single type of institution. See Table V-6.

are unimportant. Finally, in terms of employment, industry also boasts a larger proportion of young men (64% under 40 years) than does academia (54%) or government (53%).

Geographical Mobility

The statistical data obtained by the Survey do not show how extensively individuals have moved about in the course of their careers. It is interesting (Table IV-17), however, that about one-fifth of all physiologists in each case were born in the East North Central region, went to undergraduate college there, and are now employed there; but that an additional 10% obtained doctoral degrees in that region. New England employs as many as it bears (7%), educates rather more (10%); indicating an influx of students at both undergraduate and graduate levels. The Middle Atlantic region more or less holds its own, but the West North Central region is under-represented in employment. Much higher employment appears in the South Atlantic area than is really representative, because of the concentration of research facilities in the Washington-Bethesda area; otherwise the South seems in balance, except for the much smaller proportion of graduate than of undergraduate work

TABLE IV-17. GEOGRAPHICAL MOBILITY OF PHYSIOLOGISTS.

Region ^a	Birthplace (Q, I, 149) %	Institu- tion of Bachelor's Degree (Q, I, 137) %	Institu- tion of Doctoral Degree (Q, I, 141) %	Institu- tion of Present Employment (Q, I, 40) %	U.S. Population ^b	
					1955 %	1930 %
Northeast						
New England	7	10	10	7	6	6.5
Middle Atlantic	21	18	19	19	20	21.5
North Central						
East North Central . . .	19	21	29	19	20.5	20.5
West North Central . . .	13	12	13	8	9	11
South						
South Atlantic	6	7	7	16	14	13
East South Central . . .	3	3	#	3	7	8
West South Central . . .	4	4	2	5	9.5	10
West						
Mountain	5	5	1	3	3.5	3
Pacific	5	10	11	12	10.5	6.5
Canada	5	6	4	5		
Other countries and U.S. Territories	10	3	3	1		
No answer	2	1	1	2		
Total	100	100	100	100		
N	4571	4349 ^c	3683 ^d	4363 ^e		

Less than .5%.

^a See Appendix E for census regions.

^b Nearest 0.5%. (From: *Statistical Abstract of the U.S.*, 1956, ref. 83.)

^c Not including 222 respondents not having a bachelor's degree.

^d Including only respondents who indicated that they have a Ph.D. or Sc.D.

^e Number of respondents employed full-time and part-time.

done there. The Mountain region, comparably, lacks graduate institutions and also opportunities for employment; whereas the Pacific region attracts double its native physiologists for both undergraduate and graduate work, and employs an even larger proportion. The extent to which physiologists remain within any one region or move from it, at one or more steps in their career, could probably be obtained from the questionnaires; but this analysis has not been done. Studies of other scientific groups indicate mobility between the institutions of study for bachelors' and doctors' degrees, and also during the period of employment; and it has been suggested that, for scientists, the nature of the job and the salary it offers will usually outweigh the advantages or disadvantages of location (85, p. 49). Job stability and mobility are discussed in Chapter VI.

In general, there are no significant differences between various sub-groups of physiologists as to region of birth or of undergraduate training (except that plant physiologists tend to be educated in the Middle Atlantic states less and in the Pacific states more often than are other groups) or even of graduate training, despite larger inter-group differences. Approximately 46% of all physiologists received their doctorate from institutions with over 12,000 students enrolled (25 such in the U.S. in 1953), 46% from those with less than 12,000, and 7% from foreign institutions (Q, I, 140). (The size of an institution is not necessarily indicative of other characteristics.) Inter-group differences are also minor as to region of present employment; except that, again, fewer plant physiologists appear in the Middle Atlantic and more in the Pacific region. A greater proportion of bacterial physiologists than of other groups is employed in the North Central region. With these exceptions, the data in Table IV-17 are representative of all physiologists.

SUMMARY

Physiology is today more meaningfully defined by what physiologists say than by what they do. The field has become so varied and extensive that no a priori definition effectively distinguishes physiologists from non-physiologists, and an operational approach, based on self-classification, mainly on a questionnaire, was used by the Survey. In October, 1953, there was an estimated total of 5750 physiological scientists in the United States and Canada, about a third of 'pure' biological scientists, a tenth of all biologists. Approximately one-third of the questionnaire respondents are primary or 'central' physiologists, two-thirds are secondary or 'peripheral' physiologists. Nearly two-thirds of both central and peripheral groups are animal physiologists, one-fourth are plant physiologists, and one-eighth are bacterial physiologists. Nearly a third of the peripheral physiologists are biochemists—roughly one-sixth of the biochemists in the United States—and three-fourths of all physiologists are interested in two to four specialties. Central animal physiologists

are concentrated in zoology and biochemistry, roughly one-seventh each, and in medicine, pharmacology, and biophysics, one-tenth each; plant physiologists, in botany, two-fourths, and agriculture and biochemistry, one-fifth each; bacterial physiologists, in microbiology, one-half, and biochemistry, one-third. Peripheral animal physiologists are mostly in metabolism and nutrition, one-third (endocrines, one-twelfth, and physiological psychology, one-twentieth, are next); and this specialty absorbs one-fourth of all animal, one-third of all plant, and two-fifths of all bacterial physiologists.

Over three decades, the population of physiologists has increased some eight-fold, as compared with seven-fold for all Ph.D.'s or those in biology, four-fold for all scientists, and two-fold for the total labor force. From *American Men of Science* listings, there were about 100 in 1905, 300 in 1925, 1000 in 1945, and 2000 in 1955—a good exponential growth curve. Nonetheless, there are many signs that physiology as a whole, and central animal physiology in particular, is lagging.

From 1915-44, 3.5% to 5% of all Ph.D. degrees, and 10% to 14% of those in biology, were in physiology; from 1945 to the present, the proportion has been only one-third as much, 1.5% and 5%, respectively. The central animal physiologists, nearly half of all in 1945, are now a third; and the authors of papers in physiological journals were one-fourth central in the 1900's, one-third in the 'twenties, but below one-fourth in the 'forties. Finally, while the age level of the total population of physiologists has risen slightly in the past fifty years, at present men under forty constitute three-fourths of the bacterial, three-fifths of the plant, but only two-fifths of the animal physiologists. Such burgeoning fields as microbiology and physiological psychology are manned about seven-tenths with men under forty; industry about two-thirds, as compared to little over half in academia and government.

Not only in subjects but in geography, have there been shifts over recent decades. In most areas of the United States about as many physiologists are now employed as were born or educated there. But an important influx of foreign-born physiologists has supplied 10% of our pool, and the South Atlantic region employs (many in the Washington area) over twice as many as it generated. The East North Central region has educated a disproportionately large fraction of physiologists; the Pacific region has educated and now employs over twice as many physiologists as were born there. Many of these shifts apply to the population as a whole or to large segments thereof—as the trek to the Southwest, especially of older persons—but other evidence, as the high proportion of elite physiologists (see Chapter VI) in California, shows that particular factors are operating for physiologists, or scientists as a whole.

Physiologists are medium people. They tend to come from moderate-size communities, moderate income and status homes (many fathers in professional

or managerial occupations), and half from large, half from small universities or colleges. In personality they are not strikingly different from their colleagues. Material on school and test performance appears in Chapter X.

In sum, physiology, though growing, is lagging. Whether the relative shrinkage of physiology and its most traditional sub-areas is to be viewed with alarm, in terms of the encroachment of other disciplines (especially the more chemical ones) upon it; or with pride, in terms of the infiltration of physiological attitudes and methods into other disciplines (including microbiology and psychology), is perhaps a matter of taste. Certainly young scientists, especially the abler ones, are attracted into those topics which are intellectually exciting during their formative years.

An appendix considers some findings on personal traits, external factors, subject matter, and area as related to productivity. It also exemplifies the rich materials available for further analysis in the coded card deck of the Survey.

APPENDIX

The statement earlier about eminent and average physiologists dismisses a great deal of work which, on the ordinary analysis, does not show interesting or significant findings. Partly because the study of psychologists emphasized the comparison of high producer and control groups, and partly to exemplify the richness of the materials collected by the Survey, and their possibilities for further exploitation, the following are presented. The material is based upon Survey Project 3D; for the second analysis we are indebted to the Survey Research Center.

A select group of 402 names was obtained by selecting men with two or more citations in the *Annual Review of Physiology* analysis, plus one other criterion of eminence (department head or full professor, officer in a society, editor of a journal, author of a professional book, starred in *American Men of Science*, member of National Academy of Sciences or Nobel Laureate; see Preliminary Report). Of these, 382 were classified and 293 fully analyzed. With three criteria, 318 (of 382) remained; with four, 193; five, 131; six, 43. In the 2 or 3 criteria group, 50% had over fifteen citations; in the 4 or 5 group, 29%; and in the 6 to 8 group, 36%—a strong suggestion that, above a moderate level of attention, merit does not parallel decibels (see below also). The separation of the group with less than six criteria from that with six or more depended mainly on AMS starring (18% below 6; 93% six and up) and Academy membership (12% and 72%).

Using just the two-level criterion, an age factor was clearly present—under 40 years, 20% of the select group (S) and 49% of the control group (C; N = 4275); 40–49 years, 40% S and 26% C; 50 and up, 40% S and 24% C—and an appropriate correction should be applied to the following relations. Most variables examined showed no interesting differences, one or two showed a deficit in the select group (for example; workers in the area of animal metabolism, or with a B.S. in agriculture, horticulture, or zoology), and a few seemed definitely higher for the select group. Thus: 77% of S and 44% of C had published five or more papers in the past three years; 59% vs. 7% were cited nine or more times; and 75% vs. 50% had a salary of \$8000 or above. Other attributes positively related to the select group were: a B.S. in biochemistry; a Ph.D. in physiology or psychology; training in England or Canada (not Europe in general), or at Harvard; employment in California; work in the areas of circulation, neurophysiology, or plant nutrition.

In the Survey Research Center study the population was grouped into high publishers

(H), with five or more papers, and low publishers (L), with four or less (which proved a good dividing line and closely paralleled a division at 3 or more versus 2 or less citations); and correlations with other attributes were then determined. As an example, the relation to school grades was obtained by coding these into top (A), middle (B), and bottom (B- and C) ranges and finding the fraction of all in the group that were H. The N's for the following comparisons were 485, 686, and 400; and the % H, 61, 40, and 37. N's in general were between 400 and 2100.

High publishers related to top group at least as clearly as for grades in half a dozen other attributes. A good positive correlation appeared between productivity and: grades, keeping abreast of the field, amount and ease of obtaining research funds (but not with perceived adequacy), perceived opportunity to do good research, freedom, and salary. Correlations were low or absent for: laboratory space or equipment, supply of assistants or of living material, size of group, job satisfaction, fraction of time for research, and several other variables. An inverse relation appeared with the amount of guidance by superiors. (See Chapter VI.)

For comparison, the elite psychologists differed from their less distinguished colleagues (Clark, *op. cit.*) in that they: spent more time on research and judged it more important; read more professional articles, had higher college grades—in general and in their major; did more graduate and less undergraduate teaching; and were more inclined to judge as important to research achievement, money, good equipment, a university environment and stimulating coworkers, and freedom—but not too much too early. The elite also were rather more likely to be involved in group research and liked it more. Perhaps these favorable reports mean they ran the groups; but the mine run workers also generally liked team efforts. The high producers in general stood out early in their schooling, obtained superior training and better positions, and attracted (rather than produced) superior students. They did not publish the greatest number of papers (suggesting that much that is published could be spared!) but the most cited ones; and they did not, contrary to current belief, drift into their chosen field after high-level training in another.

Another thorough study from the Center (Pelz *et al.*, 62) considered age and productivity, primarily in terms of Survey data. Publication reaches a peak at 35–39 years; but the subsequent slow decline can be attributed more to decreasing external conditions than to decay of capacity. Time, motivation, resources, stimulation, and freedom are involved in productivity; and top performance may not be favored by maximum research funds or time allotment. A decline with age is related most to staleness and diversionary influences.

A different sort of analysis was made for this report, based on *Annual Review* citations, indicating the subject emphases. Table IV-18 indicates the emphasis given ani-

TABLE IV-18. CITATION OF MEMBERS OF THE AMERICAN PHYSIOLOGICAL SOCIETY IN VARIOUS *Annual Reviews* DURING 1950–52.

<i>Annual Review</i> of:	Total Citations	APS Members	% Total of APS Members	Number APS Members Cited ^a	Average Citations Per Member
Physiology	24,700	4480 ^b	18	855 ^b	5.2
Medicine	17,500	1280	7	440	2.9
Biochemistry	29,400	1035	3.5	305	3.4
Psychology	7,300	370	5	130	2.8
Microbiology	14,400	210	1.5	85	2.4
Plant Physiology	10,200	95	1	60	1.5
Physical Chemistry	12,200	25	0.2	15	1.5

^a 1300 members.
^b Number rounded.

TABLE IV-19. SPECIALTY DISTRIBUTION OF THE 110 MEN MOST CITED IN *Annual Reviews* DURING 1950-1952.

Specialty	Number of Men	Number of Citations	Average Citations Per Man
Nervous system	21	439	21
Circulation	11	343	31
Endocrinology	10	307	31
Metabolism	9	295	34
Gastrointestinal	6	152	25
Respiration	5	88	18
Kidney	3	59	20
Blood	2	32	16
Other or unidentified.....	43	1004	23
All			25

mal physiology in related areas and Table IV-19 shows the attention to the specialties of animal physiology. Finally, high producers are likely to have come from abroad, to be concentrated in academia (industry has a very low representation), and to be located in California—to what extent, as a result of the climatic lure for older men, was not examined.

V

ACTIVITIES, EMPLOYMENT AND INCOME OF PHYSIOLOGISTS

ACTIVITIES OF PHYSIOLOGISTS

Principal Functions

The major functional activities of all types of scientists are research, teaching, and administration. The Survey questionnaire showed 3980 respondents to some extent engaged in research (Q, I, 73); 2520, in teaching (Q, I, 104). A more accurate measure is by time distribution, 4363 employed respondents spend approximately 54% of their total effort in research, 27% in teaching, 16% in administration, and 3% in other activities, including consulting. The detailed analyses of these replies, together with their projection in terms of average work-units or equivalent in full-time physiologists, are given in Tables V-1 and V-2.

Allowing for the tendency of respondents to estimate in simple fractions,

TABLE V-1. DISTRIBUTION OF TIME AMONG PROFESSIONAL FUNCTIONS OF EMPLOYED PHYSIOLOGISTS (Q, I, 52-55 corrected).

% Time Reported	Function							
	Research		Teaching		Admin.		Other	
	N ^a	%	N^{a}	%	N^{a}	%	N^{a}	%
0-9 ^b	355	8	1748	41	2085	49	3920	75
10-19	304	7	412	9	797	19	374	8
20-29	460	11	562	13	588	12	262	6
30-39	332	8	393	9	218	5	92	2
40-49	321	7	318	7	134	3	53	1
50-59 ^b	654	15	407	9	219	5	115	3
60-69	329	7	141	3	61	1	26	1
70-79	385	9	139	3	67	2	41	1
80-89	301	7	98	2	40	1	24	1
90-99	354	8	72	2	49	1	18	#
100	524	12	29	1	61	1	24	1
No answer	44	1	44	1	44	1	44	1
Total ^c	4363	100	4363	100	4363	100	4363	100

Less than .5%.

^a Number of respondents. Proportional projections to the estimated total number of physiologists, using a factor of 5/4, are possible for large groups only.

^b Clustering at 0% and 50% respectively is indicated by the data.

^c 208 respondents of the total 4371 were retired or unemployed.

TABLE V-2. APPROXIMATE EQUIVALENT IN WORK-UNITS, OR IN FULL-TIME PROFESSIONAL EFFORT, OF TIME DISTRIBUTION AMONG PROFESSIONAL FUNCTIONS OF EMPLOYED PHYSIOLOGISTS ($N \times \text{Mean } \%$).

% Time Reported	Function			
	Research ^a	Teaching ^a	Admin. ^a	Other ^a
0-9				
10-19	44	60	116	54
20-29	117	138	144	64
30-39	115	236	75	32
40-49	136	142	60	23
50-59	327 ^a	204 ^a	110 ^a	58 ^a
60-69	212	91	39	18
70-79	287	104	50	31
80-89	254	83	34	20
90-99	334	68	46	17
100	524	29	61	24
Total	2350	1155	725	121
($N = 4363^b$) 100%	53.9%	26.5%	16.8%	2.8%

^a $N \times 0\%$ and $N \times 50\%$ respectively, at these levels. See note ^b to Table V-1.

^b Total of approximate equivalencies is 4351.

with a resultant clustering at zero, quarter and half-time, the data in Table V-1 show that about three-fifths of all physiologists spend half or more of their time in research, whereas only 20% spend that proportion of time in teaching, and 11% in administration. At the 6/10th level, which is perhaps a better index of major or principal activity, these proportions are 44%, 11%, and 6% respectively. It is notable that 12% of the physiologists devote all their time to research, and 41% do practically no teaching. Equal numbers of physiologists give under 60% of their time to research or to teaching, in contrast to the proportion of four putting major effort on research to one on teaching. In terms of equivalent full-time physiologists, however, the total professional effort in research is just over twice that in teaching (Table V-2).

Research and Teaching Activities Compared

Two-thirds of all physiologists are employed in academic institutions (Q, I, 36) and three-fourths of these are of some professorial rank, thus carrying more than instructional burdens; so it speaks for the health of the profession that so large a proportion of physiologists is active in disseminating present knowledge of their subject while also endeavoring to add to it. A rich cross-fertilization must exist between teaching and research; and, even if much teaching is to special interest groups, this favors recruiting into graduate research.

Between central and peripheral, and animal, plant, and bacterial physiologists there are few differences in the proportion of time devoted to major activities. Animal physiologists are somewhat less likely than others to spend

over 60% of their time in research (Q, I, 52); perhaps reflecting the larger proportion of plant and bacterial physiologists in government and industry, as well as the predominance of academic courses in animal physiology. Other data, however, suggest that animal physiologists do considerably more research than teaching. The replies of questionnaire respondents with Ph.D. or Sc.D. degrees (3680) give the major activities of the professors who had supervised their doctoral researches. Such data, analyzed in Table V-3, show that these supervisors are likely to be primarily investigators. Bias may be introduced by personal recollection, and by sampling in Ph.D. supervisors a relatively small fraction of physiologists. The variations between groups are of little moment, but central bacterial physiologists regard their supervisors equally as teachers or research workers; animal physiologists, nearly twice as often as research workers. Apparently teaching and research are more associated in the smaller bacterial physiology student-faculty groups.

Comparison With Other Scientific Professions

The actual number of physiologists primarily engaged in each function is not available, but the totals in Table V-2 which represent, in terms of full-time physiologists, the equivalent proportion of the total time respondents allotted to those functions supply a reasonable approximation. In Table V-4 this is compared with the percentages of other professional groups. Physiology resembles physics, chemistry, and geology, rather than biology, in its high proportion of research activity; and mathematics in the low level of 'other' (including consulting) functions. Many agriculturists and medical scientists are included among the biologists.

TABLE V-3. MAJOR ACTIVITY OF SUPERVISORS OF THEIR THESIS WORK, AS REPORTED BY PHYSIOLOGISTS HAVING PH.D. AND SC.D. DEGREES (Q, I, 131).

	Central			Peripheral			Other %	Total %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %		
Research	44	34	38	45	39	46	47	43
Teaching	25	40	38	29	33	35	18	30
Administration	13	11	14	11	14	13	23	13
Teaching, research	7	7	4	7	8	4	7	7
Teaching, admin.	1	4	1	1	2	0	1	1
Research, admin.	1	0	1	2	1	1	0	1
Teach., research, admin..	5	2	0	3	2	1	2	3
Other	0	0	0	#	#	0	0	#
No answer	4	2	4	2	1	#	2	2
Total	100	100	100	100	100	100	100	100
N (Respondents)	750	307	138	1565	520	298	105	3683
Estimated N (physiologists)	943	386	174	1969	654	375	132	4633

Less than .5%.

TABLE V-4. PERCENTAGE OF SCIENTISTS, BY PRINCIPAL FUNCTION
(Data from National Scientific Register, 1951).

Function	Scientific Profession ^a					
	Physiology (Table V-2) %	Biology (p. 40) %	Physics (p. 41) %	Chemistry (p. 75) %	Geology (p. 39) %	Mathe- matics (p. 20) %
Research	54	32	47	45	58	15
Teaching	26	35	37	11	12	79
Administration	17	18	8	11	14	4
Other	3	15	8	33	16	2
Total	100	100	100	100	100	100

^a Rough estimates for psychology (12, p. 74) and anatomy (4, p. 117) are: research, 22% and 40%; teaching, 29% and 42%; administration, 27% and 29%; other, 22% and 6%. These figures are not directly comparable to the others or to each other.

The variation in percentage principally teaching, from 11 to 80, while due in part to differences in handling the manpower data, reflects the emphases of different disciplines on research, including applied research, and on teaching. Mathematics, for instance, is taught at many levels and, like biology and physics, has large enrollments in the lower undergraduate years. Physiology, except perhaps on the plant side, on the other hand, administratively is largely a graduate or a medically-oriented subject and its principal official teaching activity is at the upper class, professional, and graduate levels. Psychology and anatomy show like differences for like reasons. This organizational peculiarity of course placement, discussed more fully in Chapter X, is thus partly responsible for the degree of teaching in physiology.

The 'other' activities, in which physiologists take little part, include consulting work engaged in by 10% of geologists, analysis and testing done by 26% of chemists (excluding chemical engineers) and 10% of biologists working mainly in production, operation, inspection, and testing. Allowing for these, there is more uniformity among disciplines than first appears.

Attitude of Physiologists Toward Activities

To the question, 'How do you feel about the amount of time you spend on these activities?', 37% of questionnaire respondents indicated a desire to devote much more time to research, 20% a little more, 32% about the same, and 6% less (5% gave no indication). Teaching, however, holds less attraction; 35% would give the same amount of time to it, and only 7% wanted much more and 18% a little more, while 15% wanted less and 3% much less (over one-fifth made no reply). With regard to administrative duties, 30% seemed satisfied with their present amount, only 8% desired more, 35% less (27% no reply) (Q, I, 56-58). Anatomists also would like more research time, less administration, and a shift of teaching from routine to special courses (*op. cit.*). These attitudes, plus the statement of 82% of all respondents, that 'interest in the content of the field' was a factor con-

tributing to their becoming physiologists, as compared with 40% who credited their undergraduate and 27% their graduate teachers, suggest that physiological scientists tend to be more interested in subject matter than in people, and more concerned with immediate research than with teaching activities. The implications concerning professional recruitment are discussed in Chapter X.

EMPLOYMENT OF PHYSIOLOGISTS

Institutional Distribution of Employment

In 1953, 91% of all physiologists were employed full time, 4% were employed part time, and 3% were retired (Q, I, 35, 153). The employed group, 4363 of the 4571 Survey respondents, is equivalent to 5306 of the estimated 5750 total physiologists. Table V-5 shows the percentage distribution of those employed, by type of institution; and Table V-6, the actual number of respondents and the projected number of physiologists. The questionnaire did not allow for listing multiple types of employment, yet over 6% of the respondents so reported. For academic institutions, but not others, the tables give data on employment in small as well as major degree. An attempt by the Survey (*Preliminary Report 4A-1*) to identify and categorize the different kinds of educational institutions, industrial groups, and governmental establishments in which physiologists were employed was not successful.

Considered together, Tables V-5 and V-6 show that, within any type of

TABLE V-5. PERCENTAGE OF PHYSIOLOGISTS EMPLOYED, BY TYPE OF INSTITUTION (Q, I, 36 corrected).

Institution	Central				Peripheral					All Total %
	Animal %	Plant %	Bacterial %	Total %	Animal %	Plant %	Bacterial %	Other %	Total %	
Sole employment										
Acad.	76	61	63	71	65	65	53	63	63	66
Indust.	4	9	12	6	10	11	24	17	12	10
Govt.	13	21	19	16	12	18	16	11	13	14
Clin. ^a	1	0	0	#	2	0	#	0	1	1
Private ^b	1	1	1	1	2	1	3	2	2	2
Multiple employment										
Acad., indust. ...	#	1	1	#	1	0	#	0	#	#
Acad., govt. ...	2	2	1	2	2	2	1	2	2	2
Acad., clin.	1	0	0	1	1	0	#	0	1	1
Acad., private ...	#	0	0	#	1	0	#	0	1	1
Other ^c	2	4	2	3	4	3	3	4	4	3
No data	#	1	1	#	#	#	1	1	1	#
Total	100	100	100	100	100	100	100	100	100	100
N	915	352	163	1430	1873	564	377	119	2933	4363

Less than .5%.
^a Clinical or hospital.
^b Private institution or private practice.
^c Other institutions or other combinations.

TABLE V-6. NUMBER OF EMPLOYED RESPONDENTS (N), AND ESTIMATED TOTAL NUMBER EMPLOYED PHYSIOLOGISTS (N-ESTIMATED), BY TYPE OF INSTITUTION (N data of Q, I, 36).

Institution	Central				Peripheral				All Total	
	Ani- mal	Plant	Bact.	Total	Ani- mal	Plant	Bact.	Other Total	N	N, Est. ^d
Sole employ.										
Academic	689	215	104	1008	1223	365	196	75 1859	2867	3606
Industrial	38	32	19	89	187	62	90	21 360	449	565
Government	122	75	31	228	223	98	59	13 393	621	781
Clinical ^a	5	0	0	5	40	0	1	0 41	46	58
Private ^b	9	4	1	14	33	8	10	2 53	67	84
Multiple employ.										
Acad., industry ...	3	2	1	6	10	0	1	0 11	17	21
Acad., government.	14	8	2	24	36	12	5	2 55	79	99
Acad., clinical ...	7	0	0	7	23	0	1	0 24	31	39
Acad., private ...	4	0	0	4	18	0	1	0 19	23	29
Other ^c	22	14	4	40	72	17	11	5 105	145 ^e	184
No data	2	2	1	5	8	2	2	1 13	18	22
N	915	352	163	1430	1873	564	377	119 2933	4363 ^f	
N, estimated ^d	1151	443	205	1799	2356	709	474	150 3689		5488

^a, ^b, ^c See note to Table V-5.

^d Number of respondents $\times \frac{100}{79.5}$.

^e 39 'Acad.', 'Other'; 106 not designated.

^f Employed respondents only; 208 respondents were retired or unemployed.

institution, the only statistically significant differences are in the higher percentage of central animal physiologists and lower percentage of peripheral bacterial physiologists employed in academic institutions. The peripheral groups outnumber the central ones almost two to one. In industrial institutions, the percentage of peripheral physiologists employed is twice that of central physiologists, but the actual number is four times as great, and over half are peripheral animal physiologists. In government institutions, all groups are employed in about the same proportion; so that numerically, except in the plant group, there are about twice as many peripheral as central physiologists.

Over the years, the proportion of physiologists employed in academic institutions has remained relatively constant, rising slightly in periods of economic prosperity, although up to 1930 the figure averaged 78% and after this about 70%. In industry, this employment rose during the depression years, but then returned to its earlier level. Government employment has increased, from an average of 8% until the 30's to one of 14% since, with the expansion of public health and welfare activities. Table V-7 presents the data in detail.

Correlations of Survey questionnaire data show that 65% of industrial physiologists, compared to 53% of those in government and 52% in academic institutions, are under forty years of age (Q, II, 80). This may result partly from the high percentage of young men in bacterial physiology (Table IV-13), and the large proportion of bacterial physiologists. Peripheral animal physiologists also tend to be young and comprise half the industrial physi-

TABLE V-7. TYPES OF INSTITUTIONS OF PRIMARY EMPLOYMENT OF PHYSIOLOGISTS LISTED IN SUCCESSIVE EDITIONS OF *American Men of Science*, 1906-1949; COMPARATIVE DATA FOR 1953 (Project 13A) (Q, I, 36).

	AMS Editions								1953 Survey	
	1906 %	1910 %	1921 %	1927 %	1932 %	1938 %	1944 %	1949 ^a %	Central %	All %
Academic	74	79	76	80	73	71	68	64 ^b	74 ^b	70 ^b
Industrial	13	10	13	10	17	13	13	10	6	10
Government	8	7	8	9	9	10	18	9	17	14
Clinical, private									1	3
Other								13	2	3
No data	5	4	3	1	1	1	1	4	#	#
Total	100	100	100	100	100	100	100	100	100	100
N	97	135	210	331	561	720	882	1834	1430	4363

Less than .5%.

^a 1949 data classified differently; separate source.

^b Includes combinations of institutions of which academic is one.

ologist group. The various factors which account for this distribution, in terms of attitudes and job satisfaction, are discussed in Chapter VI.

Academic Status

Of 3056 physiologists who responded about academic rank and tenure, three-fifths were secure in their positions. The proportion of bacterial physiologists, both central and peripheral, with tenure was noticeably lower, possibly due to the type of institutions in which they are employed (Q, I, 37). Three-fourths of all physiologists have the rank of assistant professor or higher, 18% hold other faculty positions (Table V-8).

TABLE V-8. FACULTY RANK HELD BY ACADEMIC PHYSIOLOGISTS (Q, I, 38).

	Central			Peripheral				Total %
	Animal %	Plant %	Bac- terial %	Animal %	Plant %	Bac- terial %	Other %	
Professor	35	24	18	30	37	19	28	31
Assoc. prof.	28	26	32	25	22	28	25	26
Assist. prof.	17	22	22	23	17	20	18	20
Lecturer or assoc.	1	1	1	1	2	#	0	1
Instructor	5	4	6	7	4	6	6	6
Teaching assist.	0	1	1	#	0	1	0	#
Research assoc.	3	1	3	2	3	6	4	3
Research assist.	1	2	1	#	1	2	3	1
Other or unspec. rank...	5	11	4	7	10	9	10	7
No faculty rank.....	4	7	11	4	3	8	6	4
No data	1	1	1	1	1	1	0	1
Total	100	100	100	100	100	100	100	100
N	722	227	108	1331	384	207	77	3056 ^a

Less than .5%.

^a Does not include the 1289 respondents not employed in an academic institution, or 18 respondents not answering the question.

The higher percentage of full professorships in central animal physiology and in peripheral plant physiology reflects the financial support given established fields oriented to medicine and to agriculture. In anatomy, however, the percentages are: professor, 24; associate professor, 19; assistant professor, 21; instructor, 22; other, 15 (4, p. 21). Animal physiology has a slight percentage advantage in professorships in all grades and, of course, far exceeds the other groups in number. Bacterial physiology has the smallest percentage of some professorial ranks, but not significantly less than plant physiology. Over a period of years, as shown by Table V-9, the proportion of full professorships fell steadily; but recently it has risen. Likewise, the proportion of associate professorships, which increased slowly for some time, and of assistant professorships, which remained nearly constant, seems to have increased greatly in recent years. These changes suggest a more active personnel flow in departments, but may be spurious due to altered coding.

Even though not deliberately analyzed in compiling Survey data, the fraction of positions established in connection with research activities, and especially based upon research grants, has shown a gradual increase; a reflection of the influence of transient research support on faculty status and university finance.

Teaching activities of physiologists may be estimated on several bases. As shown by Table V-1, 58% of employed physiologists spend over one-tenth of their time teaching, although only 12% spend over six-tenths. On another basis, 2520 of 4571 respondents were currently engaged in teaching; 55% of all physiologists are teachers. Also, 82.5% of those employed in any

TABLE V-9. FACULTY RANK HELD BY PHYSIOLOGISTS, *American Men of Science*, 1906-1944, WITH COMPARATIVE DATA FOR 1953^{a, b} (Project 13A).

	AMS Editions							
	1906 %	1910 %	1921 %	1927 %	1932 %	1938 %	1944 %	1953 %
Professor	43	51	47	41	34	31	27	31
Assoc. prof.	5	4	8	14	12	13	13	26
Asst. prof.	13	13	14	13	15	13	12	20
Lect., assoc.	3	4	1	2	3	3	2	1
Instructor	12	9	6	5	6	8	8	6
Teaching asst.	2	1	1	1	1	1	1	#
Research dir.	0	0	0	0	1	1	2	^c
Research prof.	0	0	0	#	1	1	1	^c
Research assoc.	1	1	#	2	3	2	4	3
Research asst.	0	0	0	2	3	4	4	1
Tech. consultant	0	0	1	1	#	#	#	^c
Military	0	0	0	0	0	#	6	^c
Other or unspec.	18	18	21	20	21	23	21	12
N	97	135	210	331	561	720	882	4363

Less than .5%.

^a Note that column totals vary from 100%.

^b No comparable data for 1949 available.

^c Not coded.

capacity by academic institutions (Table V-8) are engaged in teaching. Projected for the total estimated population of 5750 physiologists, about 3170 physiologists are actually engaged in teaching, and approximately 1200 of these have teaching as their major activity.

The distribution of teaching physiologists by department is shown in Table V-10. While most central animal physiologists (71%) teach in departments of physiology or biology, peripheral animal physiologists are widely distributed, teaching in biochemistry, medicine, ancillary medical, or psychology departments more often than in those of physiology or biology. Plant physiologists are largely in biology, botany and applied science subjects; central bacterial physiologists, mainly (85%) in bacteriology and biology, and peripheral ones mainly (72%) in bacteriology, biology, biochemistry, and chemistry departments.

Research activities of physiologists, and the numbers involved in research, are discussed in Chapter VII.

TABLE V-10. DISTRIBUTION OF DEPARTMENTS IN WHICH PHYSIOLOGISTS HAVE TEACHING APPOINTMENTS (Q, I, 104-105; II,151).

First Department Mentioned	Central			Peripheral				Total %	N
	Animal %	Plant %	Bacterial %	Animal %	Plant %	Bacterial %	Other %		
Physiology	60	3	0	8	#	2	3	19	478
Biochemistry	#	1	2	16	3	13	11	9	226
Anatomy	2	0	1	7	#	1	2	4	100
Pharmacology	2	0	0	6	0	0	3	4	92
Bacteriology	0	0	69	1	1	40	2	5	131
Medicine; medical spe- cialties	3	0	0	10	0	1	7	6	145
Other med. and ancil. med. sci. depts.	6	1	1	10	#	3	7	6	163
Horticulture; pomol- ogy	0	7	0	#	19	1	2	3	2520
Agronomy	0	1	0	#	12	1	3	1	2520
Animal husbandry; dairy products	3	0	2	5	0	3	3	4	89
Other agriculture departments	1	5	1	2	11	3	3	3	2520
Zoology	6	1	1	6	1	2	5	5	120
Biology	11	24	16	7	11	13	11	10	257
Botany; plant pathol- ogy; plant nutrition.	0	52	2	#	29	5	3	7	168
Psychology	#	0	0	9	0	0	2	4	112
Chemistry	0	1	0	4	5	6	19	3	75
Physics; biophysics	1	0	0	2	#	1	3	1	2520
Home economics	1	1	0	3	0	1	5	2	45
Other departments	3	2	2	3	5	3	3	3	2520
No answer	1	1	3	1	3	1	3	1	2520
Total	100	100	100	100	100	100	100	100	2520
N	646	147	84	1154	278	150	61	2520	

Less than .5%.

Geographical Distribution of Employment

In making geographic tabulations, the Survey utilized the regional classification adopted by the United States Bureau of the Census (Appendix E). Since census regions do not always coincide with the geographic divisions used in other manpower studies, comparisons with published data must be made with caution.

As shown in Tables V-11 and V-12, nearly two-fifths of the physiologists are employed in the Middle Atlantic and East North Central census regions, fewer in the South Atlantic and Pacific areas. If the Delaware-Maryland-District of Columbia area were assigned, as it often is, to the Middle Atlantic States, the South Atlantic region would fall in percentage of physiologists from 16 to 9. (There were 24 respondents in Delaware, 296 in Maryland, and 91 in the District of Columbia; 311 respondents or, by projection, 391 physiologists. Also, APS members at five universities across the country rose some 20% from 1950 to 1955, while those in the D.C. area rose over 40%—49 to 86.) In comparison with all scientists, the distribution of physiologists is quite low in the Northeast, slightly higher in the total North Central area and in the South (including the Washington-Bethesda area), and nearly equal in the West. This is shown in detail in Table V-13.

TABLE V-11. PERCENTAGE OF EMPLOYED PHYSIOLOGISTS, BY REGION OF EMPLOYMENT (Q, I, 40).

Region ^a	Central			Peripheral				Total %	APS Members (1956) %
	Animal %	Plant %	Bacterial %	Animal %	Plant %	Bacterial %	Other %		
Northeast									
New England	8	4	4	8	7	6	7	7	8
Middle Atlantic	20	11	17	22	15	21	21	19	29
North Central									
E. North Central	17	15	25	19	19	26	18	19	16
W. North Central	9	7	6	8	7	7	8	8	8
South									
S. Atlantic	17	17	18	14	18	14	19	16	10
E. South Central	4	3	4	3	2	3	3	3	3
W. South Central	4	5	6	5	5	6	5	5	5
West									
Mountain	2	5	5	3	4	1	3	3	2
Pacific	10	22	12	10	16	12	11	12	9
Outside cont. U.S.									
Territories, possessions	1	4	1	#	2	#	0	1	#
Canada	6	4	1	6	2	2	2	5	4
No data	2	3	1	2	3	2	3	2	2
Total	100	100	100	100	100	100	100	100	100
N	915	352	163	1873	564	377	199	4363	1505

Less than .5%.

^a See Appendix E.

TABLE V-12. NUMBER OF EMPLOYED RESPONDENTS AND TOTAL ESTIMATED NUMBER OF PHYSIOLOGISTS, BY REGION OF EMPLOYMENT (Numerical data of Q, I, 40).

Region ^a	Central			Peripheral				N	N, Est. ^b
	Animal	Plant	Bact.	Animal	Plant	Bact.	Other		
Northeast									
New England	81	14	7	143	37	22	8	312	392
Middle Atlantic	188	37	28	403	86	78	26	846	1064
North Central									
E. North Central	156	56	41	354	105	93	22	827	1040
W. North Central	80	24	10	158	37	28	9	346	435
South									
South Atlantic	154	61	29	260	104	54	23	685	862
E. South Central	34	12	6	58	12	10	3	135	171
W. South Central	42	17	10	94	30	24	6	223	281
West									
Mountain	15	17	7	63	20	5	4	131	165
Pacific	87	76	20	185	93	44	13	578	650
Outside cont. U.S.									
Territories, possessions	5	15	1	6	10	1	0	38	48
Canada	59	14	3	111	13	9	2	211	265
No data	14	9	1	38	17	9	3	91	115
N	915	352	163	1873	564	377	119	4363	
N, estimated ^b	1151	443	205	2356	709	474	150		5488

^a See Appendix E.

^b N respondents $\times \frac{100}{79.5}$.

Distribution of sub-specialists of animal physiology follows much the pattern of the field as a whole (*Preliminary Report IV-C-3*, p. 6, Table 29); the small number of cases makes variations between most specialties of little consequence. The distribution of APS members is, however, clearly most like that of animal physiologists (Table V-11).

Employment, by geographic area, using data from successive editions of *American Men of Science*, has been consistently high in the Middle Atlantic and East North Central census regions since 1910. It has increased in the South Atlantic area due to the establishment of government research institu-

TABLE V-13. COMPARISON OF THE GEOGRAPHIC DISTRIBUTION OF RECOGNIZED SCIENTISTS (1949) WITH THAT OF EMPLOYED PHYSIOLOGISTS (1953) IN THE CONTINENTAL UNITED STATES.

Census Major Area	American Men of Science (1949) ^a		Physiologists (1953) ^b		U.S. Population (1950) %
	N	%	N	%	
Northeast	14,350	34.6	1456	29	26.2
North Central	11,040	26.6	1475	29	29.5
South	10,260	24.8	1314	26	31.4
West	5,790	14.9	815	16	12.9
Total in U.S.	41,440	100.0	5060	100	100.0

^a From ref. 84a, p. 24. Excludes 303 scientists employed outside cont. U.S.

^b Data based on Table V-12.

tions, and has steadily declined in New England, since 1906. These statements, of course, are about proportions; the actual number of physiologists has risen many fold and all sorts of institutions have expanded.

The increase in employment in the East North Central region was due to both the movement of industrial research into this area and the enormous growth of university facilities. The Middle Atlantic region has apparently balanced a loss in industrial physiologists with a gain in academic physiologists. In the Pacific region, before 1910, all physiologists were in academic institutions; but since the 1930's, the proportion in industrial and governmental work in that region has increased, as well as the proportion of all U.S. physiologists working there.

The approximate geographical distribution of physiologists, in relation to the types of employing institutions, is shown in Table V-15. The data are limited to respondents employed by one type of institution. The heavy governmental employment of physiologists in the research centers of the Washington-Bethesda area (South Atlantic region) is confirmed; and the concentration of two-thirds of all industrial employment of physiologists in the Middle Atlantic and East North Central regions is also striking. Academic employment is spread more widely, although noticeably low throughout the South.

The distribution of academic employment is compared with that of colleges and universities, and particularly those offering four-fifths of all courses in physiology, in Table V-16. Without reference to course enrollments or types of courses offered, such comparisons are very rough; nevertheless these data

TABLE V-14. GEOGRAPHIC AREA OF CURRENT EMPLOYMENT OF PHYSIOLOGISTS LISTED IN *American Men of Science*, 1906-1949; WITH COMPARATIVE DATA FOR 1953 (Project 13A) (Q, I, 40).

Census Region ^a	AMS Editions								1953	
	1906 %	1910 %	1921 %	1927 %	1933 %	1938 %	1944 %	1949 %	Central %	All %
New England	18	14	11	12	10	11	9	10	7	7
Middle Atlantic	26	25	20	20	22	22	19	25	17	19
E. North Central	11	17	20	19	18	17	17	21	18	19
W. North Central	8	11	10	9	9	9	9	9	8	8
South Atlantic	10	10	9	10	13	12	13	15	17	16
E. South Central	0	#	2	3	3	3	2	2	4	3
W. South Central	4	3	2	3	3	4	4	4	4	5
Mountain	0	0	2	2	2	2	1	3	3	3
Pacific	10	7	10	9	9	8	6	11	13	12
Canada, foreign	3	5	7	7	5	6	6	^b	7	6
Not specified	10	8	7	6	6	6	14	^b	2	2
Total	100	100	100	100	100	100	100	100	100	100
N	97	135	210	331	561	720	882	1817	1430	4363

Less than .5%.

^a See Appendix E.

^b Not included in data.

TABLE V-15. GEOGRAPHICAL DISTRIBUTION OF EMPLOYED PHYSIOLOGISTS BY TYPE OF INSTITUTION IN WHICH EMPLOYED (Preliminary Report IV-C-3, p. 2, Table 29).

Region ^a	Academic %	Industrial %	Government %
New England	8	5	3
Middle Atlantic	19	33	8
East North Central	19	33	10
West North Central.....	10	4	1
South Atlantic	12	6	45
East South Central	3	#	5
West South Central	6	2	4
Mountain	4	1	3
Pacific	13	9	7
Foreign and Canada.....	5	3	11
No data	1	4	3
Total	100	100	100
N = 3937 ^b	2867	449	621

Less than .5%.

^a See Appendix E.

^b Excluding those employed by more than one type of institution, and those employed in clinical, hospital, or private practice. See Table V-6.

TABLE V-16. GEOGRAPHICAL DISTRIBUTION OF TEACHING PHYSIOLOGISTS AND OF INSTITUTIONS OF HIGHER EDUCATION IN THE UNITED STATES, INCLUDING THOSE FROM WHICH PHYSIOLOGISTS RECEIVED BACHELORS' DEGREES (Q, II, 167; Survey Project 1, p. 3; Q, I, 137).

Region	Institutions of Higher Education						
	Teaching Physiologists ^a		All				Those of Bachelors' Degrees ^d
	N	%	N	%	Those Giving 82% of Physiology Courses		
				N	%	%	
New England	205	9	153	8	46	11	10
Middle Atlantic	482	21	296	16	69	17	18
E. North Central.....	366	20	318	17	69	17	21
W. North Central	261	11	256	13	42	10	12
South Atlantic	290	12	279	15	65	16	7
E. South Central	87	4	149	8	28	7	3
W. South Central	157	7	166	9	44	11	4
Mountain	96	4	66	4	15	3	5
Pacific	291	12	184	10	33	8	10
Outside U.S.							9
No answer							1
Total	2335 ^a	100	1847 ^b	100	411 ^c	100	4349 ^d

^a Q, II, 167. N—number of respondents for whom geographic data are given. This appears to be the number of respondents who report both teaching and research activities, or 93% of the total number of respondents who teach. The number of respondents indicating activity as teachers was 2520, or 3170 projected teaching physiologists.

^b From ref. 109a, page 10.

^c USOE categories (b), (j) and (k): i.e. liberal arts and general; liberal arts and general with one or two professional schools; and liberal arts and general with three or more professional schools.

^d Geographical distribution of institutions from which 4349 of 4571 respondents received bachelors' degrees (Q, I, 137).

show clearly that academic teaching and research throughout the South is undermanned, while in the Pacific region it is more than adequate. Since physiologists are unevenly distributed in each region, and cluster in the larger institutions with medical and other professional schools, a simple ratio of the number of physiologists to the number of institutions might give a false view of the actual situation. Nevertheless, the data in Table V-16 indicate the relative adequacy of the number of teaching physiologists in any geographic region.

INCOME OF PHYSIOLOGISTS

Professional Income, 1952

Responses to the Survey questionnaire showed a median professional income of physiological scientists in 1952 of about \$6700 a year, with the upper quartile at \$9500 and the lower quartile slightly over \$5000. The median income of animal physiologists was \$7200 a year; of plant physiologists, \$6000; and of bacterial physiologists, \$5900 (Q, II, 91). Table V-17 presents percentile data in detail for the various types of central and peripheral physiologists. Since it is based on the total number of respondents (4571) rather than on those reporting employment (4363), probably the 8% lowest income group is made up of those who did not provide data (2%) or who were unemployed, retired, or only part-time employed.

Projecting the data in Table V-17 to the total estimated 5750 physiologists, about 800 (14%) have professional incomes of \$3000 to \$4999; 1917 (33%), \$5000 to \$6999; 1610 (28%), \$7000 to \$9999; 977 (17%), \$10,000 or more. Of this highest group, roughly 800 are animal physiologists. Correlations of median income and special field within animal physiology indicate larger incomes in those with most public appeal in relation to clinical problems, such as cardiovascular-renal and mental disorders. In most special fields, the relatively small differences and the limited cases do not permit valid conclusions (*Preliminary Report*, Sec. IV-D-1, Table 34); but there are significant differences in income of physiologists in different major fields. The medians are given in Table V-17. Animal physiologists, perhaps because their work is often medically oriented and receives a major proportion of research support, have the highest median incomes, 7% above the norm; others are from 5% to 11% below. This difference must be recalled when interpreting income of any one group.

Total professional income may exceed salary level; indeed two-fifths of all scientists at the doctorate level have 'added professional income' above their regular salaries. For biologists as a whole, the estimate is 35%; for those in the \$6000 and the \$7000 brackets, 31% and 29%, respectively. In fields related to medicine (anatomy, dental medicine, pathology, physiology, phar-

TABLE V-17. PROFESSIONAL INCOME OF PHYSIOLOGISTS IN 1952 ^a (Q, I, 153; II, 93; Preliminary Report IV-D-1, p. 16).

	Central				Peripheral					All %
	Animal %	Plant %	Bacterial %	Total %	Animal %	Plant %	Bacterial %	Other %	Total %	
Less than \$3000 ^b	7	15	15	9	6	6	11	14	7	8
\$3000-\$3999	4	4	6	4	4	4	6	2	4	3
4000- 4999	10	15	11	11	10	11	11	11	10	11
5000- 5999	15	19	20	18	15	21	23	17	17	17
6000- 6999	12	16	23	14	14	20	15	19	16	16
7000- 7999	13	11	9	12	13	14	12	11	13	12
8000- 8999	11	9	5	10	8	8	7	5	8	9
9000- 9999	9	5	5	8	7	5	5	3	6	7
10,000-14,999	15	5	5	11	15	9	8	16	13	12
15,000 or over	4	1	1	3	8	2	2	2	6	5
Total	100	100	100	100	100	100	100	100	100	100
N	961	382	171	1514	1951	595	385	126	3057	4571
N, estimated	1209	480	216	1905	2454	748	404	159	3845	5750
Median income	\$7200	\$6000	\$5900	\$6500	\$7100	\$6400	\$6000	\$6500	\$6800	\$6700

^a Item 70 of the 1953 Survey questionnaire was, "What was your professional income last year?"
^b Includes respondents giving no data, reporting no professional income, unemployed, retired.

macy, pharmacology, veterinary medicine), 36% had added income; 34% and 30% respectively in the \$6000 and the \$7000 brackets. As would be expected from these figures, one-third of the physiologists employed in academic institutions reported income from more than one source (Q, I, 39).

The amount of added income is highest among engineers, geologists, and psychologists. For all scientists in 1948, the median added income was \$900; for biologists, \$740; and for those in fields related to medicine, \$720. Biologists in the \$6000 and the \$7000 range had, respectively, an extra \$790 and \$720 (84a, p. 48). Assuming \$700 annually as the median in addition to salary for one-third of all physiologists, the median total professional income would exceed the median salary income by \$200 to \$250.

Comparable data for previous years are not available, but reasonable estimates show the change in median income of physiologists. In the table below,

Year	N	Median Income	Average Annual Increment
1940	955	\$3700	
1945	955	4700	\$200
1948	1834	5600	300
1952	4571	6700	275

1940 and 1945 data are for the 955 physiologists surveyed by the Adolph Committee, 1948 data are for the 1834 physiologists listed in the 1949 *American Men of Science* survey (Survey Project 13A), and 1952 data are based on answers to Question 70 of the 1953 Survey questionnaire. Thus the median incomes of nearly comparable groups of physiologists show, from 1940 to 1953, an annual increase of \$200 to \$300.

The time trends of incomes and of purchasing power, since 1940, are shown by the following percentage figures (mainly from 83, 1956):

Income	1940 (= 100%)	% of 1940		
		1945	1950	1952
Physiologists	\$3700	125	165	180
Physicians (net)	4400	250	280	320
College teachers	3600	145	140	160 ^a
School teachers	1440	155	210	240
U.S. per capita	575	185	235	260
Price index	100	128	172	253

^a 185% on another estimate. A recent release by the National Education Association gives the average salary for 1956 as \$5240—only 150% of the 1940 figure used here. The AAUP study (43) shows a mean salary in 27 private institutions of \$4000 in 1940, \$6560 in 1956—an increase of 160%.

Physiologists have lagged in general, and especially so in comparison with physicians. In 1940, the income of the average physiologist was only 20% below that of a physician; and, assuming a family size of five and income of \$2875, it was over 20% above that of the average family. By 1952, the physician's income was more than double that of the physiologist, and the average family income, \$7975, was 20% above. Obviously this situation is not favorable to recruitment and will be especially serious in the animal area where there is direct competition of clinical medicine. The income judged as satisfactory, by physiologists at any rank and at whatever actual salary level, was, surprisingly regularly, a one-third increase.

The distribution of income of physiologists is compared to that of other professional groups in Table V-18. It should be noted that income data were furnished by all but 2% of the respondents to the Survey questionnaire (Q, I, 153), but were omitted by a high proportion of those in the comparison groups surveyed in 1951 by the National Scientific Register. The incomes of physiologists are fairly evenly distributed over the wide range between \$4000 and \$15,000. The upper quartile is estimated at \$9000 and the median at \$6700. Correcting for annual increases, the median professional income of physiologists is approximately that of geophysicists, and somewhat higher than that of all other scientific and engineering professions. The lower quartile level of \$5200, adjusted for annual differences, is roughly that of non-academic engineers, doctorate mathematicians, and geophysicists. It is also roughly that of teachers of all courses with physiologic content—\$5800 in 1954 (Survey Project 18A).

The relatively high income of physiologists is also indicated by the low proportion (3%) in the \$3000-\$3999 bracket; even Ph.D. mathematicians have double that proportion (Table V-18). Moreover, 78% of all physiologists have incomes of \$5000 or more, a higher proportion than for any comparable group; and 45% have incomes of \$7000 or over, matched only

TABLE V-18. COMPARATIVE INCOME OF SCIENTIFIC PROFESSIONS (National Science Foundation data; also Q, II, 93).^a

	Engineers in Govt. and Ind. (1953) %	Chemical Engineers (1951) %	Chemists (1951) %	Mathe- matics, Ph.D. Group (1951) %	Geologists (1951) %	Geophys- icists (1951) %
Under \$3000	0	1	4	3	2	1
3000-3999	3	15	17	7	8	9
4000-4999	21	22	20	16	21	16
5000-5999	22	20	17	21	17	17
6000-6999	15	15	13	18	11	15
7000-7999	12	9	9	12	10	12
8000-9999	14	8	9	13	11	13
10,000-14,999	10	7	7	8	11	11
15,000 or over.....	3	3	4	2	9	6
Total	100	100	100	100	100	100
N	69,060	9270	37,900	1090	4830	2190
Median	\$6200	\$5600	\$5500	\$6200	\$6200	\$6500
Lower quartile	5000 (est.)	4400	4200	5000	4700	5000
Upper quartile	8200 (est.)	7300	7400	7900	9100	8800

	Meteorologists (1951) %	Physicists (1951) %	Biologists (1951) %	Physiologists (1952) %
Under \$3000	2	2	3	8 ^b
3000-3999	17	12	16	3
4000-4999	30	16	23	11
5000-5999	25	17	21	17
6000-6999	15	16	14	16
7000-7999	7	12	9	12
8000-9999	3	13	8	16
10,000-14,999	1	9	5	12
15,000 or over.....	#	3	1	5
Total	100	100	100	100
N	2020	4760	16,800	4570
Median	\$5000	\$6100	\$5400	\$6700
Lower quartile	4200	4600	4300	5200 (est.)
Upper quartile	6100	8000	6900	9000 (est.)

Less than .5%.
^a Data are for 1951 with the exception of physiologists (1952-53) and engineers in government and industry (1953).
^b See note to Table V-17.

by geologists and geophysicists, as shown below. In 1954 an older group of psychology Ph.D.'s had incomes of: over \$15,000, 6%; \$10,000 to \$15,000, 17%; \$8000 to \$10,000, 22%; \$6000 to \$8000, 25%; \$2000 to \$6000, 12%; \$0 to \$2000, 19%.

	Physiol- ogy %	Geo- physics %	Geology %	Engi- neering ^a %	Physics %	Mathe- matics Ph.D. %	Chemis- try %	Biology %
\$5000-\$6999	33	32	28	37	33	39	39	35
\$7000 or over.....	45	42	41	38	37	35	28	24

^a Engineers employed in government and industry only.

It seems that the income status of physiologists is essentially that of highly-trained applied scientists, whose value is recognized by the amount and range of income which their profession receives. The picture is less favorable, however, when the fact is considered that nine-tenths of all physiological scientists are trained at the doctoral level (M.D. and D.V.M. degrees included) as compared with 1% to 60% in comparable scientific groups. The income at the doctoral level is shown for these same professions in Table V-19. Despite the low percentage of doctorates in engineering, chemical engineering, geophysics, and meteorology, these applied science professions demand high salaries at every level of experience. Physiology as a whole, therefore, is rather at the level of the doctoral groups within physics, chemistry, and geology; it is, however, especially at the upper quartile, considerably above the doctoral groups in biology and in mathematics.

Other biological specialties, with even four-fifths at the doctoral level, would presumably be similar to physiology at lower quartile and median; the upper quartile level would depend on the extent to which the discipline is recognized as an applied science. Thus, animal physiology is widely thought of as ancillary to medicine and 28% of central animal physiologists receive salaries of \$9000 or more, compared to 11% of central plant or

TABLE V-19. COMPARATIVE INCOME OF SCIENTIFIC PROFESSIONS AT THE PH.D. LEVEL (National Science Foundation).

	Engineering (1953)	Chemical Engineering (1951)	Chemistry (1951)	Mathematics (1951)
(a) % at Ph.D. level	0.5% ^a	7.2%	23.6%	60.5%
(b) N (Ph.D.)	2180 ^b	950	12,000	1460
(c) N (total cases)	450,800 ^c	13,300	50,900	2400
Income				
(d) Median	no data	\$7900	\$6900	\$6200
(e) Lower quartile	no data	6300	5600	5000
(f) Upper quartile	no data	11,300	9200	7900
(g) Median age at Ph.D. level	no data	37	39	41

	Geology (1951)	Geophysics (1951)	Meteorology (1951)	Physics (1951)	Biology (1951)	Physiology (1952)
(a)	17%	7.5%	3.5%	45%	40%	90% ^d
(b)	1100	230	100	2970	8450	4120
(c)	6560	2940	2820	6580	21,100	4570
(d)	\$7200	\$8100	\$6800	\$7100	\$6200	\$6700 ^e
(e)	5800	6100	5800	5700	5100	5200 ^e
(f)	9400	12,400	8300	9100	7700	9000 ^e
(g)	44	43	36	39	42	39 ^e

^a Rounded to nearest 0.5%.

^b Total of earned doctorates in engineering, 1912-50. Since 1950 over 500 engineering doctorates have been granted each year. Data from U.S. Congress Joint Committee on Atomic Energy (84).

^c Total number of engineers, census of 1950.

^d 90.2% of all physiologists have Ph.D., Sc.D., M.D., D.V.M. or other earned doctoral degrees; 80.6% have Ph.D. or Sc.D. degrees (Q, I, 130, 134).

^e Figure for all physiologists: no separate data available for Ph.D. level group.

bacterial physiologists (Table V-17). Also, median incomes of biophysicists and pharmacologists soar far above those of biologists as a whole; and the median incomes of Ph.D.'s in agriculture, pharmacology, and genetics in government employ are also high (Table V-21). Again, from data of the Association of American Medical Colleges, it was estimated that median salaries of physiologists, pharmacologists, and biochemists in medical schools ranged in 1953 from \$4000 or \$5000 for instructors (\$2500 in 1945-46) to \$8000 or \$9000 for full professors (\$6000 in 1945-46)—the salary judged proper by deans in 1953 averaged \$10,800, with departmental chairmen receiving an additional \$2000 (\$1000 in 1945-46) (*Preliminary Report X-E-1*, p. 2). Finally, biologists at the Ph.D. level employed in colleges and universities in 1951 had a median income of \$5900, with upper quartile at \$7300 and lower quartile at \$5000; while academic biologists with medical degrees received \$7600, \$10,500, and \$5700 respectively (92, pp. 50, 51).

When income is related to employing institutions, Table V-20, it is clear that the academic group lags (41% over \$7000) behind industry (57%) and government (52%). Within the \$7000-\$9999 bracket, also, the percentage of academic physiologists is significantly lower than that of the industrial and governmental groups. The high figure (24%) for the academic group with incomes below \$5000 probably reflects the instructorship level workers, but incomes at the higher levels—say for men in their fifties; \$8500 for academia, \$8800 for government, and \$12,800 for industry—indicate the comparative rewards for: teaching and pure research, which characterize academic employment; developmental research, in industry; and applied research, in government.

The estimated median income in the three types of institutions is \$6550, \$7550, and \$7150, respectively; but within each institutional group there is considerable variance with specialty. Table V-21 compares median incomes of animal, plant, and bacterial physiologists in each type of institution, with those of other doctorate level biological scientists. Again, for men in their fifties, incomes are \$9400 for animal, \$7400 for plant, and \$8000 for bac-

TABLE V-20. PERCENTAGE OF PHYSIOLOGISTS, BY TYPE OF EMPLOYING INSTITUTION, REPORTING PROFESSIONAL INCOME (*Preliminary Report IV-D-1*, p. 16).

Professional Income (1952)	Institution ^a		
	Academic %	Industrial %	Government %
Under \$5000	24	10	13
5000-6999	34	31	34
7000-9999	26	32	40
10,000 or more.....	15	25	12
No answer	1	2	1
Total	100	100	100
N = 3987 ^a	2867	449	621

^a Includes only respondents employed in one type of institution in 1953. See Table V-6.

TABLE V-21. MEDIAN PROFESSIONAL INCOMES OF PHYSIOLOGISTS (1952) AND OF BIOLOGICAL SCIENTISTS AT THE PH.D. LEVEL (1951), BY TYPE OF EMPLOYER (Q, II, 94 plus derived data).

Field of Employment	Institution			All
	Academic	Industrial	Federal Government	
Agricultural sciences	\$6100	\$7800	\$7000	\$6300
Animal sciences	6000	8300	6800	6200
Microbiology	6200	7500	6600	6500
Plant sciences	5600	7200	6400	5800
Pharmacology	7100	8800	8100	7900
Genetics	5800	^a	7100	6000
Biophysics	7300	8300	6900	7600
All fields	5900	7900	6800	6200
Physiology ^b	6550	7550	7150	6750 ^b
Animal	6800	8200	7700	7600 ^b
Plant	6200	6900	6200	6300 ^b
Bacterial	5600	6800	6500	6600 ^b

^a Too few cases to permit computation of median.

^b Medians for physiologists employed solely in one type of institution. (N = 3785, or 82.8% of 4571 respondents and 96.1% of 3937 respondents employed solely by one type of institution.) Median income of all physiologists is given in Table V-17.

terial physiologists. Even correcting for the one year difference, incomes of animal and plant physiologists in academic work exceed those of other doctorate level groups, except for pharmacologists and biophysicists; while bacterial physiologists fall low in the scale. In industry, only the animal physiologists are within the range of the other professions, and even they receive less than animal scientists in general or than biophysicists or pharmacologists. In government, where many physiologists are engaged in medically oriented research, the median level of animal physiologists is relatively high—exceeded only by that of pharmacologists, and perhaps of biophysicists when corrected for time difference in the data. Plant physiologists do better than plant scientists in general in academia, less well in industry or government; and bacterial physiologists do less well than general microbiologists throughout. All in all, this group of employed physiologists has a median income at least equal to that of other biological scientists at the Ph.D. level, with the exception of biophysicists and pharmacologists; and animal physiologists approach these two groups.

The median professional incomes of physiologists are given by type of institution and age in Table V-22 and by branch of physiology and age in Table V-23. Industry offers more attractive income at all age levels; but the percentage of physiologists in industry declines after age 40 (Table IV-16), which may indicate that the monetary advantage of industrial employment does not outweigh other attractions of academic or governmental employment. Governmental employment provides greater median income than does academic employment up to age 40; above that the difference is slight. Salaries are higher in animal than in other branches of physiology,

TABLE V-22. MEDIAN INCOMES OF PHYSIOLOGISTS, BY TYPE OF INSTITUTION AND AGE (Q, II, 95).

Age ^b	Institution ^a		
	Academic	Industrial	Government
Under 30	\$4200	\$5600	\$5000
30-39	4900	7100	6400
40-49	7800	10,000	7900
50-59	8500	12,800	8800
60 or over.....	8500	10,400	8700

^a Includes only those employed in one type of institution.
^b See Table IV-16 for number and percentage in each group.

TABLE V-23. MEDIAN INCOMES OF PHYSIOLOGISTS, BY BRANCH OF PHYSIOLOGY AND AGE (Q, II, 94).

Age ^a	Animal	Plant	Bacterial
Under 30	\$4500	\$4000	\$4000
30-39	6400	5700	6100
40-49	8500	7400	7600
50-59	9400	7400	8000
60 or over.....	7800	7600	9300 ^b

^a See Table IV-14 for number and percentage in each group.
^b See text.

up to age 60; but relatively few animal physiologists are under 30 (Table IV-14). One-fifth of the bacterial physiologists are in the lowest age group and nearly half are in their thirties; and the median income in each age group is less than that of comparable animal physiologists, slightly superior to that of plant physiologists. The high income level of bacterial physiologists over 60 is probably meaningless; it represents only 11 respondents, 2% of the group. The general decrease in income of the 60 and over group, compared to the 50-59 one, does not represent the effect of retirement.

Other analyses of income made by the Survey (*Preliminary Report*, Section IV-D-1, p. 17) show that the median income of those devoting over 60% of their time to research is \$6200, compared with \$5500 for those whose major function is teaching and \$9800 for those (10%) whose major function is administration. Even though 25% of industrial physiologists are in the top salary classification, this is not related to administration, for almost four times as many academic as industrial physiologists are administrators (Q, II, 80). Higher median salaries prevail in the Middle Atlantic and East North Central regions; due partly to a high incidence of industrial and governmental work, but also to a slightly higher general level of support given physiology in those areas. Thus, high caliber of personnel and of institutional facilities may be a major factor in concentrating physiological scientists and also in raising their salaries.

SUMMARY

The professional physiologists sampled by the Survey are distinctly research oriented. Of their total effort (man-hours), 54% goes to research, 27% to

teaching, 16% to administration; four times as many individuals have a major commitment (over 60% of time spent) to research as to teaching; and two-fifths do essentially no teaching. Among animal physiologists the emphasis on research is greater; and all groups would like even more time for this, at the expense of administration or even teaching.

Two-thirds of all physiologists are in academic institutions; the others, rather more in governmental than industrial ones. In recent decades, and especially in recent years, the portion in government has been rising—related to the strong research groups in the Washington-Bethesda area, which now accommodates nearly 8% of the entire body—and that in academia may be shrinking. Central animal physiologists more than others are concentrated in academia; peripheral bacterial physiologists, in industry. This weighting by the young bacterial group may contribute to the distinctly larger fraction of younger men in industry (two-thirds under 40) than in academia or government (half under 40).

In the academic world, two-thirds of animal physiologists, but only half of the younger bacterial group, hold tenure. Over a half century, the proportion of full professors fell from half to under a third; that of associate professors rose from 5% to 13% in 1944, when it equaled the more steady fraction of assistant professors, and since then both lower grades have nearly doubled in representation. It seems that young graduates often burst directly into professorial status, indicating a considerable demand for them.

Physiologists, as all scientists, are concentrated in the East North Central and Middle Atlantic regions, which account for two-fifths of all employment. This is more striking for the industrial than the academic group. During fifty years, the fraction in New England has been halved; that in the several Southern and the Mountain regions has increased. In comparison to the needs of existing academic institutions, however, the South is still poorly manned, while the Pacific region is supplied above average.

The professional income of physiologists is greater than the salary, for about one-third receive additional fees, averaging over \$700 a year. The salary median in 1952 was \$6700-\$7200 for animal, \$6000 for plant, and \$5900 for bacterial physiologists—and one-fourth each received over \$9500 and under \$5000. Seventeen percent, nearly all animal physiologists, had salaries over \$10,000. Between 1940 and 1952, salaries rose fairly regularly, at an average rate of \$250 each year; more recently the increments have probably been larger. A calendar correction can thus be applied to comparative data.

Physiologists compare favorably in income with engineers, chemists, geologists, biologists, and others, when the entire professional groups are considered; but this neglects a marked difference in training level. Over 90% of the physiologists have a Ph.D. or similar degree; the other groups vary

from 60% for mathematicians to under 1% for engineers. When incomes of doctorate groups are compared, physiologists outrank only mathematicians and biologists in general; although the top quartile approaches the levels of several other groups. The median income for academic physiologists was (1952) \$6550, as compared with \$7550 for those in industry (despite a younger population) and \$7100 in government; and that of investigators was \$6200, as compared with \$5500 for teachers and \$9800 for administrators. Even medical school physiologists, almost equal to practising physicians in median income in 1940, were lagging far behind them in 1952—an 80% versus a 230% increase. Biophysicists and pharmacologists commanded high pay, presumably reflecting relative shortages. The proportional rise in salary between 30 and 60 years of age is greater for academic and for animal physiologists than for the comparison groups.

These findings put the physiologists studied between the more academic teachers, as mathematicians and biologists, and the more applied industrial scientists, as engineers, geologists, and chemists; but far behind practising physicians. In balance of research and teaching and in income, especially in the upper brackets, but not in training level, which is much higher, physiologists and particularly central animal physiologists occupy an intermediate position between the pure and the applied. Each branch of physiology straddles biology, on the one foot, and medicine, agriculture, or applied microbiology, on the other. The American Physiological Society, in particular, from its inception has struggled with ambivalent attachment to the two worlds, of biological science and medical practice—a struggle reflected in the groups with which it has affiliated, in its membership, in attention to teaching, in debates on policy, and in many other ways, and to be considered further in Chapter XII.

VI

OCCUPATIONAL MOTIVATIONS, SATISFACTIONS, AND MOBILITY

WHAT MAKES A SCIENTIST?

Underlying Considerations

There is considerable evidence that people show persistent patterns of personality, intelligence, interests, and achievement throughout their lives. Such traits, a concern of psychologists and educators, also have a major bearing on the recruitment and productivity of scientists. The question, 'What makes a scientist?', remains open, but one approach is the recent socio-psychological analysis of eminent research scientists:

In the group [of 64 scientists studied] 53% of the fathers of the subjects were professional men. . . . What seems to be the operative factor here is that in practically all of these homes, whatever the occupation of the father, learning was valued for its own sake, . . . a major factor in the intellectualization of interests. . . .

Certain aspects of the data offer evidence on the basic importance of the need to achieve, or to keep independence, which is so well met by a career in research. . . . More of these men than not, as boys, pursued rather independent paths,—playing with one or a few close friends . . . [or] following their own particular interests (shifting or not) with somewhat more than the usual intensity. . . . Such interests were more often intellectual than not, except among the experimental physicists and biochemists. . . .

There is no one pattern by which they approached science as a career. The modal age at which the decision was made was during the last two undergraduate years, but in some cases it was made in early childhood or as late as the second year of graduate school. The introduction may have been through natural history interests, through gadgeteering, through interest in laboratory sciences as found in high school courses . . . or through a service motivation. When the decisive point can be determined it was usually the discovery of the possibility of . . . finding out things for oneself. For some this was understood very early . . . for others it came as a revelation of unique moment. Once it was fully understood that personal research was possible, once some research had actually been accomplished, there was never any question. . . . From then on, absorption in the vocation was so complete as seriously to limit all other activity. . . .

Many of [these research scientists] are happiest when they are working,—some only when they are working. In all these instances, other aspects—economic return, social and professional status—are of secondary importance. . . . It is of crucial importance that these men set their own problems and investigate what interests them. No one tells them what to think about, or when, or how. . . . Their limitations are only those of equipment and time, and the limitations of their own understanding. . . .

The position [of eminence] which these men have reached has not been reached easily. . . . It must be noted that their effort has usually been directed quite specifically toward the immediate problem, . . . [yet] the strength of the achievement drive which these men have shown is rarely reflected in . . . the test material.

As to why one subject chose one field of science and others chose other fields, apart from the often overlooked matter of necessary contact with the field, . . . it would appear that there are some, particularly among the experimental physicists, who seem early to have formed direct relationships with objects rather than people, not compensatorily. . . . The social scientists stand apart as having been more concerned at an earlier age about personal relations. . . . Another finding of considerable importance is the differences of imagery which are associated with the different fields of science. . . . Briefly, the biologists and experimental physicists tend strongly to dependence upon visual imagery in their thinking: the theoretical physicists and the social scientists, to dependence upon verbalization or similar symbolization in theirs. Nothing is known about the development of these modes of thinking, but it seems probable that they were developed early (they are associated with father's occupation) and played a part in the choice of a science. . . .

Theoretical physicists surpass all other groups on both verbal and spatial tests. The experimental physicists are high on the spatial and relatively low on the verbal test. Psychologists are at about the mean for this total group on all three. Anthropologists [representing the social scientists] are high on the verbal and lowest on both spatial and mathematical. . . .

The range of test intelligence . . . is also of importance. All of the evidence confirms C. S. Cox's remark: ". . . high, but not the highest intelligence, combined with the greatest degree of persistence, will achieve greater eminence than the highest degree of intelligence with somewhat less persistence." . . . There is nothing in these data to suggest that any measure from . . . tests would be nearly so adequate in predicting . . . success as the fact that they worked long hours in graduate school, many more than the course requirements, and that they preferred to work on their own. (But I do not know how many less successful scientists have worked hard and preferred independence.) . . .

Most of these subjects were fortunate enough somewhere along the line to have found a teacher who induced them to find things out for themselves, or who let them do so, or who insisted that they do so because he did not want to be bothered. Once real intellectual independence was really tasted, nothing else mattered. Certainty of his own worth is any man's greatest need. Though some of them find it only there, scientists do find this certainty in science (Roe, ref. 71, pp. 47-53).

As part of her study of research scientists, and as Project 3A of the Survey, Dr. Roe specifically compared the characteristics of 20 eminent biologists with those of 188 biologists more representative of university faculties. Within the latter group, 31 were central and 24 peripheral physiologists. Differences between these groups were not large or statistically significant; and, in general, physiologists resemble other biologists, but with somewhat greater concern for people and more personal problems. "Biologists," she reported, "are not an aggressive lot . . . but far from easy to push around. Certainly they are much more intent on pursuing their own interests than getting involved in other people's." The difference between eminent and non-eminent biologists were essentially in intensity of those factors which particularly characterize biologists—discrimination, objectivity, and independence of thought and action; both in relation to self and to interpersonal relations.

These analyses refer, of course, primarily to research scientists. Since the relation of personality to professional success is probably unique for each vocation, scientists who are eminently successful as teachers may well possess different characteristics. Knapp and Goodrich (50), for instance, in their study of the origins of American scientists, characterized the outstanding college teacher as one having verbal and histrionic expressiveness, warmth of rapport, commanding presence, and a broad education and knowledge of his subject. Likewise, the scientist who excels as an administrator would presumably have the salient characteristics of the successful business executive. What motivational factors, or intensities of attitude or perception, join with personality, intelligence, interest, and achievement patterns to produce the eminently successful scientific researcher, teacher, or administrator is by no means clear. Fortunately, much research on creativity is in progress by behavioral scientists, for this is an area of utmost importance in selecting, training, and encouraging a productive professional and scientific pool.

OCCUPATIONAL SATISFACTIONS

Attitudes of Physiologists

An 'interest in the content of the field' was given as a factor contributing to his entering the general field by 82% of the Survey questionnaire respondents (Q, I, 3); suggesting that most physiologists are such because of an interest in physiology. Sixty-two per cent of the respondents did, at one time or another, seriously consider entering another profession (Q, I, 8); and 31%, before entering their present field, were actually employed in other areas, mainly chemistry (5%), medicine (4%), and non-scientific fields (4%) (Q, I, 5-7). Both central and peripheral physiologists are thus engaged in an occupation which is basically congenial as to subject matter. Moreover, 84% of employed physiologists appear to be reasonably satisfied with their present jobs (Q, I, 71). Job satisfaction increases with age, salary level, and the desirable social and intellectual perquisites of satisfactory geographic location (Q, II, 89-90). This still leaves a goodly number, especially of the younger physiologists, who are not too happy with their situation.

Physiologists' attitudes towards working conditions were obtained from their ratings of nine specific factors in response to the question, 'How important is each of the following things to you in a job; which things do you want most in a job?' Minor differences between physiologists in the animal, plant and bacterial branches, and between central and peripheral physiologists, appear to be without statistical significance; so the results shown in Table VI-1 are representative of job attitudes of employed physiologists as a whole.

TABLE VI-1. RATINGS BY EMPLOYED PHYSIOLOGISTS OF THE IMPORTANCE OF VARIOUS JOB FACTORS (Q, I, 66-68) N = 4363.

Factors	Utmost Importance %	Very Important %	Fairly Important %	Not Too Important %	No Answer %
Freedom and authority to carry out my own ideas.....	68	24	5	#	3
Good chance to use my skills and abilities	54	35	6	#	5
Opportunity to contribute to scientific advancement	46	35	13	2	4
Good chances for advancement in my profession.....	29	42	20	4	5
Being with people who are congenial to work with.....	31	39	22	3	5
Good salary—earning enough to make a good living.....	20	49	25	2	4
Having support and recognition from my superiors	25	41	24	4	6
Security—being able to keep my job as long as I want it. . .	21	37	29	8	5
Having a job that has prestige in my profession.....	8	28	42	17	5

Less than .5%.

These data strikingly confirm Roe's test findings. Freedom and independence, and idealism of thought and action, are involved in the top three job characteristics, deemed as 'of utmost importance' or 'very important' by 92%, 89%, and 81% of the respondents. Moreover, these are the only three characteristics in the entire list where the rating of 'utmost importance' predominated. The four following characteristics, concerned with the monetary, social, and psychological conditions of the job situation, were rated as of utmost or high importance by 66% to 71% of the respondents; but the predominant rating in each was only 'very important.' This subordination of socio-economic to intellectual factors is a personality characteristic of the research scientist; but the relatively high ranking given to salary indicates also the realistic discrimination of intelligent persons. On the other hand, those committed to the clinical fields—as exemplified by 24 out of 31 groups of senior medical students considered at the AAMC Teaching Institute for Physiology, Biochemistry and Pharmacology in 1953(3)—judge that low income is a major factor in influencing medical students against taking up a teaching and research career in the basic medical sciences (Survey Project 11). Since men have regularly chosen a career in teaching and research, despite an adverse financial balance, this factor may be exaggerated as a rationalization; but it remains true that the disbalance has become much greater.

The factor of security was thought extremely or very important by 58% of the Survey respondents and fairly important by 29% more. This compares well with the attitudes of those in other occupations, being more important

to non-supervisory factory employees, less so to managerial personnel (46); security seems only moderately important for the job satisfaction of physiologists. The related, but not directly comparable, findings for psychologists deserve note (Chapter IV, Appendix). The minor emphasis on professional prestige of a job situation, in physiological opinion, may possibly be an expression of present job satisfaction; at any rate, 36% of employed respondents were very satisfied with their present jobs (Q, I, 71) and 36% believed prestige was important; while 48% were fairly satisfied with their jobs and 42% believed prestige was fairly important. The very low percentage of physiologists who regarded prestige as of utmost importance, and the relatively high percentage at the opposite end of the scale, agree with Roe's finding that eminent research scientists direct their efforts toward accomplishment rather than prestige goals.

When the attitudes of those physiologists employed in a single type of institution are compared by institutions, the patterns are similar for all, as illustrated in Table VI-2. The small differences which do exist reflect the character of the institution. Thus, 'freedom and independence' is emphasized most often by academic physiologists and least often by industrial physiologists; and 'contributions to scientific advancement', more by academic and governmental than by industrial physiologists, the latter characteristically concerned with developmental problems; while 'income' and 'recognition' are mentioned most often by industrial and least often by academic physiologists, and 'security' most by those who have tenure in academic and governmental employment. The relation between over-all job satisfaction and type of employing institution is notable; only 28% of the physiologists employed solely in government are very satisfied, as compared with 41% in industry

TABLE VI-2. RELATIONSHIP BETWEEN KIND OF INSTITUTION WHERE CURRENTLY EMPLOYED AND IMPORTANCE OF VARIOUS JOB FACTORS (Q, II, 85).

Percentage Who Regard Job Factor As 'of Utmost Importance' or 'Very Important'	Kind of Institution Where Currently Employed		
	Academic %	Industrial %	Government %
Freedom and authority to carry out my own ideas . . .	94	84	89
Good chance to use my skills and abilities	90	88	89
Opportunity to contribute to scientific advancement . .	83	76	84
Good chance for advancement in my profession	70	73	73
Being with people who are congenial to work with . .	72	72	68
Good salary—earning enough to make a good living .	68	78	73
Having support and recognition from my superiors . .	65	80	71
Security—being able to keep my job as desired	59	53	62
Having a job that has prestige in my profession . . .	36	39	39
Total	#	#	#
N, respondents employed solely in each type of institution	2867	449	621

Percentages total more than 100 because respondents indicated an importance rating for each factor.

and 36% in academic work. The proportion of fairly satisfied employees, however, is nearly the same for all: 51% of academic and governmental physiologists and 44% of industrial physiologists (Q, II, 89).

The relation between job satisfaction or dissatisfaction and various background variables, such as age, salary, type of institution, major function, and geographical region of current employment is shown in Table VI-3. Satisfaction is greater for the years past middle age, salaries above the median, and locations with research and intellectual resources. On the opposite side, youth, low salaries, exclusion from academic work, and uncongenial locations correlate with job dissatisfaction.

Institutional Preferences

Employment in an academic institution is most preferred by 78% of all employed physiologists, least preferred by only 3% (Q, I, 44, 48). There

TABLE VI-3. RELATIONSHIP BETWEEN OVER-ALL JOB SATISFACTION AND BACKGROUND VARIABLES (Q, II, 89-90).

	Very Satisfied %	Fairly Satisfied %	Neutral or Dissatisfied %	No Answer %	N
Age					
Under 30	31	47	19	3 ^a	438
30-39	33	52	13	2	1876
40-49	34	51	12	3	1182
50-59	43	44	9	4	587
60 or older.....	50	37	7	6	280
Annual salary					
Under \$5000	28	49	19	4	809
\$5000-\$6999	28	56	14	2	1490
\$7000-\$9999	39	49	9	3	1249
\$10,000 or more.....	52	37	7	4	758
Kind of institution					
Academic	36	51	11	2	2867
Industrial	41	44	13	2	449
Government	28	51	18	3	621
Major function					
Research	36	48	13	3	1893
Teaching	24	58	16	2	476
Administration	40	44	13	3	278
Geographical region					
New England	46	44	8	2	312
Pacific	42	47	9	2	518
Mountain	37	52	10	1	131
Middle Atlantic	37	48	13	2	846
South Atlantic	35	48	14	3	685
W. North Central.....	34	51	12	3	346
E. North Central	33	48	15	4	827
W. South Central.....	30	53	13	4	223
E. South Central.....	27	55	17	1	135

^a Each row totals 100%.

are few differences between groups; but peripheral bacterial physiologists prefer industrial institutions, where their specialty finds practical applications, and both central and peripheral plant physiologists prefer governmental institutions, probably because of their support of agricultural research. With unimportant differences between subgroups, 49% of the respondents indicated industrial employment as least desirable, while 36% so regarded governmental employment.

These preferences and aversions are related to the type of institution of current employment; 92% of present academic physiologists would prefer to remain in academic work; and 57% of industrial physiologists desire to remain in industry, although 34% would prefer academic employment; but only 35% of physiologists employed in government desire to remain there, and 49% of them would prefer an academic situation (Q, II, 107). On the obverse: only 1% of those now in academic work indicated dislike of it; while 52% disliked industrial employment; and 36%, governmental employment. Interestingly, work in government was least desired by physiologists currently in industry (76%), and industrial work by those in government (73%) (Q, II, 107).

Institutional preferences were also examined for respondents who had earlier worked in each type of institution. The wording did not require that only those should answer who had been in a different type of institution from the present one, but a high proportion of respondents did not answer in two categories and presumably most remained in the same type of job. The limited results, however, do tend to confirm the high preference for academic employment shown by other analyses, and indicate that previous employment in industry or in government does not influence the general

TABLE VI-4. REASONS GIVEN FOR PREFERRING ACADEMIC, INDUSTRIAL, AND GOVERNMENT INSTITUTIONS (Q, I, 45-47).

Reason ^a	Academic %	Industrial %	Government %
Freedom; independence	69	21	28
Likes nature of work; chance to use skills	41	41	48
Likes interpersonal relations—superiors, associates, subordinates	26	7	4
Prestige; respect from other people	1	3	1
Material rewards—salary, advancement, etc.	6	61	40
Funds and facilities—equipment, space, etc.	5	27	34
Organizational factors—atmosphere, goals of organi- zation, etc.	16	9	9
Other	5	8	11
Total	^b	^b	^b
Number of cases	3435 ^c	344 ^d	253 ^e

^a First three reasons mentioned.

^b Percentages total more than 100 because respondents may have mentioned more than one reason.

^{c, d, e} Includes only those respondents who indicated that they would most prefer to work in:
^c an academic institution; ^d an industrial institution; ^e a government institution.

TABLE VI-5. REASONS GIVEN FOR BEING AVERSE TO ACADEMIC, INDUSTRIAL, AND GOVERNMENT INSTITUTIONS (Q, I, 49-51).

Reason ^a	Academic %	Industrial %	Government %
Lack of freedom	5	63	66
Dislikes nature of work; no chance to use skills	42	30	18
Dislikes interpersonal relations—superiors, associates, subordinates	6	7	11
Lack of prestige or respect from other people	1	1	1
Lack of material rewards—inadequate salary, etc.	50	7	20
Lack of funds and facilities—equipment, etc.	19	3	3
Dislikes organizational factors—atmosphere, goals of organization, etc.	11	23	20
Other	4	6	8
Total	^b	^b	^b
Number of cases	114 ^c	2177 ^d	1567 ^e

^a First three reasons mentioned.
^b Percentages total more than 100 because respondents may have mentioned more than one reason.
^{c, d, e} Includes only those respondents who indicated that they would least prefer to work in:
^c an academic institution; ^d an industrial institution; ^e a government institution.

adverse reaction to these types of employment (*Preliminary Report IV-C-2*, pp. 10-12).

The reasons given by Survey questionnaire respondents for these preferences and aversions, in answer to an open-ended question, provide some insight into the beliefs and stereotypes held about academic, industrial, and governmental institutions. These data are summarized in Tables VI-4 and VI-5. The most common reason given for preferring academic institutions involves freedom and independence; that for preferring industrial institutions is material reward; and three reasons—chance to use skills, material reward, and availability of funds and facilities—are given for preferring governmental institutions. Conversely, the most common reason militating against working in both industrial and governmental institutions is lack of freedom and independence; many also dislike the organizational aspects and the particular kind of work. The few physiologists who expressed dislike of academic institutions were mainly concerned with lack of material rewards or of a chance to use skills or disliked the kind of work, perhaps reflecting individual frustrations in specific teaching or research situations.

There are no great differences between central or peripheral or between animal, plant or bacterial physiologists (3435 respondents) who indicated a preference for academic employment; except that bacterial physiologists seem to value freedom and independence more than do others—perhaps a reaction from the comparatively large proportion actually employed in industry and government. The numbers expressing a preference for work in industry (344), or government (253), or a negative preference for academia (114), are too small to permit subgroup comparisons; but among the respondents averse to industrial (2177) or governmental (1567) employment there

were variations involving the smaller subgroups (Q, I, 45-47 and 49-51).

The striking contrast between the freedom of thought and action attributed to little-organized academic institutions, and the material reward attributed to industry or government is not unique to physiological science. These responses of physiologists, which conform to the attitudes of scientists and professional personnel as a whole, support the conclusion that the greater incomes afforded by clinical and other applied science are obtained at the expense of opportunity to seek knowledge as an independent individual. This is not only true of scientists; perhaps high income and high freedom are relatively incompatible. A relevant statement was made a few years ago by a group of faculty representatives in the non-scientific disciplines:

It has often been pointed out that faculty status, even at a lower salary level than in industry or commerce, has compensations which do not readily appear at first glance. Perhaps highest among these is the incentive of satisfaction in personal accomplishment which cannot be had within the normal anonymity and impersonal atmosphere of a highly organized industry. Another is the relative freedom of action, within the scope of academic responsibility, as regards the materials and methods of teaching and research. Such incentives to productive faculty effort deserve more than perfunctory recognition in presidents' annual reports, faculty bulletins, and university publications. Individual faculty morale usually gets its highest boost through genuine and personal recognition from students, colleagues, and those charged with administrative responsibility (56a).

ATTITUDES TOWARD ACTIVITIES

The relation between major activity and over-all job satisfaction is shown below, for those physiologists who spend 60% or more of their time in research, teaching, or administration (Q, II, 89):

Major Function	Job Satisfaction				N (100%)
	Very Satisfied %	Fairly Satisfied %	Neutral or Dissatisfied %	No Answer %	
Research	36	48	13	3	1893
Teaching	24	58	16	2	476
Administration	40	44	13	3	278

Detailed analyses were made by the Survey of the environments and attitudes of physiologists engaged in research and in teaching. No comparable study was made for administration because small numbers were involved and 'administration' is difficult to define.

Research Environments of Physiologists

Of the 4570 Survey questionnaire respondents, 3980 indicated active engagement in research of some kind (Q, I, 73). Table VII-3 (later) shows the distribution of the 2610 respondents definitely known to be doing physiological research, according to the branch of identification. Of the 3980 engaged in research, 3570 respondents were employed in only one type of

institution, as indicated in detail in Chapter VII. Data based on this latter group, representing 90% of the research physiologists covered by the Survey, show characteristic differences in freedom to choose research problems, for academic (62% free), governmental (28%), and industrial (15%) institutions. At least 98% of each group answered the question (Q, II, 117). These data, and other analyses, indicate maximum opportunities for independent research in academic institutions, minimum ones in industry and government where developmental or applied research objectives prevail. On the other hand, within the limitations of the institution, government employees give more positive answers to the question, 'How much chance does your current job give you to do as good a research job as you feel you can do?' While 58% of all researchers chose 'very good' or 'good' (Q, I, 101); 65% of those working solely in government, as compared with 58% and 57%, respectively, of those in academic or industrial institutions so answered (Q, II, 138). This difference may relate to the division of research and administrative tasks in government where, for instance, only 39% of the research physiologists have some responsibility for obtaining research funds (Q, II, 124).

The amount of freedom in choosing research problems is shown later, in Table VII-5. Four-fifths of all respondents (3980) reported complete or considerable freedom; and over half (52%), complete freedom. Of the latter group, 57% are central physiologists; hardly surprising since 71% of all these are employed solely in academic institutions (Table V-5). Plant and bacterial physiologists have somewhat less freedom than do animal physiologists; probably a reflection of the greater proportion of them in industry and government.

Another index of the degree of freedom in research is the amount of supervision of research activities. Again, as shown by Table VI-6, animal physiologists are generally more free of supervision than are plant or bacterial physiologists. Table VI-7 summarizes this situation with respect to four supervisory functions enumerated in the Survey questionnaire. Variations between the different groups of physiologists are not sufficient, considering the size of the sub-groups, to be detailed (Q, I, 95-96). In general, one-half to three-quarters of the physiologists in different research groups work independently, with an over-all average of 60%. Most of these are probably in academic institutions, since comparatively few academic physiologists are engaged in research outside their university departments (see Chapter VII). It may, therefore, be inferred that the data in Table VI-7 apply primarily, although not entirely, to those working in industry and government. Any judgments on the value of research supervision to the investigators must be in relation to developmental and applied objectives in industrial and governmental institutions.

TABLE VI-6. PERCENTAGE AND NUMBER OF RESEARCH PHYSIOLOGISTS REPORTING PRESENCE OR ABSENCE OF SUPERVISION IN RESEARCH ACTIVITIES (Q, I, 94).

	Central			Peripheral				Total	
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	%	N
Present	27	49	47	37	46	51	49	39	
N	(227) ^a	(163)	(72)	(626)	(233)	(180)	(46)		1547
Absent	72	49	52	62	52	48	50	60	2383
No answer.	1	2	1	1	2	1	1	1	51
Total ..	100	100	100	100	100	100	100	100	
N	835	336	152	1710	507	347	94		3981

^a Figures in parentheses denote number of respondents reporting supervision present.

Two characteristics, 'employee-oriented' or 'consideration' or 'group-oriented', in contrast to 'production-oriented' or 'initiating-structure' or 'task-oriented', have been recognized by small-group investigators at the University of Michigan, Ohio State University, Harvard, and elsewhere as dimensions of leadership by supervisors. The data in Table VI-7 indicate the adequacy of balance of these dimensions for effective research supervision. "The employee-oriented leader is one who sees his job primarily in terms of maintaining good human relations and a smoothly running organization. The production-oriented leader is primarily concerned with the processes and techniques which contribute to high-level and efficient production" (22, p. 11). The data in Table VI-7 show that supervision is most effective when 70% of the supervised physiologists obtain funds and facilities largely through supervisory or production-oriented channels. At the same time, in view of the independent personalities of research scientists in general, a successful 'employee-oriented' supervision involves considerable freedom of choice of research methods. This freedom exists according to 77% of the respondents.

TABLE VI-7. TYPE AND EXTENT OF SUPERVISION ACTUALLY PRESENT IN RESEARCH ACTIVITIES, AS INDICATED BY RESPONDENTS (Q, I, 95-96).

Supervisory Function	Extent of Performance				Total %
	Considerable %	Some %	Little or None %	No Answer %	
Provide leadership and guidance for my research	17	46	35	2	100
Allow me freedom to do my job the way I think it should be done	77	18	4	1	100
Obtain funds and facilities necessary for my research	70	19	9	2	100
Recognize my skills and abilities . .	62	30	5	3	100

N (Respondents) = 1547

(see Table VI-6)

A wide variation in direct leadership or guidance received is indicated by physiologists. This range may reflect the presence of opposing philosophies about supervision, as well as the varied needs of different research organizations. Also, the 'productive-considerate' supervisor avoids excessive dominance but provides considerable stimulation, either directly or through group interaction; and this, properly combined with individual freedom or independence of action, becomes translated into productive research. That some combination of these three factors exists may be inferred from the response that individual skills and abilities are recognized by supervisors to a considerable extent 62% of the time, and to some extent 30%. Another study from the Survey Research Center led to the following conclusions:

The data suggest that a chief of low competence and scientific motivation is better off with a laissez-faire pattern of leadership, while a chief of high competence and motivation is better off with the participatory pattern. Finally, these findings indicate that, while the conformity of the chief to the preferences of his subordinates has the most consistent positive influence on the scientists' attitudes toward him, this leadership factor makes little difference in the motivation sense of progress of the group toward its goal—at least in this scientific organization (Baumgartel, ref. 5, p. 31).

There appears to be little difference in productivity, as evidenced by publication, between the completely independent research characteristic of academic work, and the supervised research of government and industry. This assumes, however, that in industry there is considerable restriction on publication of developmental research and that much routine research does not lend itself to publication (Q, II, 140). Nonetheless, supervision undoubtedly limits freedom to carry out ideas and to use skills and abilities, beyond the desires of research physiologists; as shown by comparing the data on supervision in Table VI-7 with those on preferences of industrial and government employees in Table VI-2. (See also further analysis of Survey data by the Survey Research Center, Chapter IV, Appendix.)

The expectations of doing good research in the current job situations, whatever the supervision, are shown in Table VI-8, covering 3980 respond-

TABLE VI-8. OPPORTUNITY TO CARRY ON EFFECTIVE RESEARCH IN CURRENT JOB SITUATION (Q, I, 101; II, 137).

	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Very good	30	28	30	29	27	21	27	18	25	27
Good	32	32	33	31	31	34	31	31	32	31
Fair	24	21	20	23	25	27	28	35	26	25
Not too good	10	12	10	11	11	12	10	10	11	11
Very poor	3	5	5	4	4	4	3	4	4	4
No answer	1	2	2	2	2	2	1	2	2	2
Total	100	100	100	100	100	100	100	100	100	100
N (Respondents) .	835	336	152	1323	1710	507	347	94	2658	3981

ents. A detailed analysis of the replies of 2190 animal physiologists (86% of the 2545 animal physiologist respondents actively engaged in research) is shown in Table VI-9. While 58% indicate a very good or a good chance of accomplishment, 40% consider their current work, for one reason or another, partially or almost entirely ineffective. Within this field, only areas with very small numbers diverge markedly from the norm; but when the two upper and the three lower groups are combined, it appears that environmental physiologists and, to a lesser degree, comparative and general physiologists and physiological psychologists regard their opportunities for effective research as very low. Specialists in circulation also appear doubtful of their effectiveness. In general, specialists in respiration and renal physiology and in biophysics appear most confident of doing effective research.

Factors which prevent maximum effectiveness in research, detailed in Table VI-10, reflect frustrations; lack of funds or equipment or full opportunity to use skills in uncongenial work. The large fraction, 55%, of respondents indicating 'dislike of work', deserves further examination. In situations where research is supervised, frustrations may also involve more subtle personal or organizational factors which appear under other headings. In general, physiologists seem to accept easily the existing interpersonal relationships; so that, while not negligible, they are not large handicaps to productivity. Between the various branches of physiology, a lack of funds or equipment was felt especially by plant and by central animal physiologists; in contrast, peripheral bacterial physiologists are in a relatively favorable situation.

Since the freedom and independence afforded physiologists in their research is generally adequate, the major environmental curbs on research

TABLE VI-9. OPPORTUNITY TO CARRY ON EFFECTIVE RESEARCH IN CURRENT JOB SITUATION: BY ANIMAL SPECIALTIES (Preliminary Report VI-E, Table 15).

Specialty	Very Good %	Good %	Fair %	Not Too Good %	Very Poor %	Other %	No Answer %	N (100%)
Metabolism	23	32	21	8	3	2	11	776
Endocrines	30	27	22	6	3	1	11	289
Circulation	23	27	22	11	2	2	13	241
Neurophysiol.	25	29	23	10		2	11	213
Growth	26	26	25	8		2	13	117
Gen. & comp.	28	20	21	13	7	3	8	102
Physiol. psychol.	25	25	11	10	9	1	19	97
Respiration	28	33	16	6	1	1	15	80
Renal physiol.	31	31	18	9	2		9	74
Biophysics	31	31	16	12	3	2	5	67
Sensory physiol.	32	26	22	10	4		6	50
G.-I.	18	33	18	9	4		18	45
Environmental	15	23	39	5	5		13	39
Total								2190
All animal physiologists. 28 (est. from Table VI-8)	31	24	11	4		2		

TABLE VI-10. FACTORS PREVENTING MAXIMUM EFFECTIVE PERFORMANCE IN RESEARCH (Q, I, 102).

First Three Reasons Mentioned	Central			Peripheral				Total %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	
Lack of freedom	5	6	11	6	4	8	5	6
Dislikes nature of work; no chance to use skills.	56	50	55	58	53	50	62	55
Dislikes interpersonal relations—superiors, associates, subordinates . . .	8	13	12	9	9	13	13	10
Lack of prestige or respect from other people	#	#	0	#	1	#	0	#
Lack of material rewards— inadequate salary, etc.	2	1	2	2	2	3	3	2
Lack of funds and facilities—equipment, etc. . .	58	57	48	49	60	37	49	52
Dislikes organizational factors—atmosphere, goals of organization, etc. . . .	1	2	3	2	2	3	1	2
Personal inadequacies—lack of ability, motivation, health, etc.	11	8	7	8	7	8	6	8
Other	6	6	7	4	5	6	1	5
Total	a	a	a	a	a	a	a	a
N (Respondents)	835	336	152	1710	507	347	94	3981

Less than .5%.

a Percentages total more than 100 because respondents may have mentioned more than one reason.

effectiveness are lack of facilities or funds and misuse of personal abilities or skills. These are discussed further in connection with the support of research activities (Chapter VIII) and the recruitment and training of physiologists (Chapter X).

Attitudes Toward Teaching

As already noted in Chapter V, between 55% and 58% of all physiologists are engaged in teaching. Their attitudes are expressed in the replies of 2520 Survey questionnaire respondents, projected to a total of 3170 physiologists. The distribution of teaching appointments in academic departments is shown in Table V-10; and the departmental distribution of courses with physiological content is given, with some reservation, in Table X-2. The attitudes of physiologists toward their teaching activities must be seen against such a background.

The physiologists (475) who spent over 60% of their time teaching were fairly, but not highly, satisfied with their over-all job situation (Q, II, 89). When all teaching physiologists are considered, however, 68% enjoy a very good or a good chance to teach with maximum effectiveness, against 22%

TABLE VI-11. OPPORTUNITY TO CARRY ON EFFECTIVE TEACHING IN CURRENT JOB SITUATION (Q, I, 118; II, 166).

	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Very good	31	33	24	31	31	26	36	23	30	30
Good	38	40	46	39	37	40	45	48	38	38
Fair	22	18	17	21	22	26	17	16	22	22
Not too good	6	5	11	6	6	5	1	11	6	6
Very poor	2	1	0	1	2	1	0	2	2	2
No answer	1	3	2	2	2	2	1	0	2	2
Total	100	100	100	100	100	100	100	100	100	100
N (Respondents) . . .	646	147	84	877	1154	278	150	61	1643	2520

with a fair and 8% with a relatively poor chance. As detailed in Table VI-11, the major variations occur in bacterial physiology and 'other' peripheral areas, where those teaching rate their situations lower than do either the animal or plant groups. Bacterial physiologists in particular and all peripheral physiologists in general tend to teach courses having 'no physiological content' (Q, II, 150), a finding that perhaps reflects a restriction of the concept of physiology to its medically-oriented relationships. Whether this relates to the lesser satisfactions is problematical.

Teaching is less attractive to physiologists than is research (Chapter V); nevertheless, of men active in both, 57% of those who feel able to do a very good research job also feel so about their teaching, and 47% able to do a good research job again feel similarly about their teaching (Table VI-12).

Analyses of the relationship between background variables and attitudes toward teaching effectiveness show no significant differences in relation to faculty rank, minor ones in relation to geographic location, and a positive correlation to major activity (Q, II, 167). Physiologists in the East South Central region (Kentucky, Tennessee, Alabama, Mississippi) report least opportunity to do good or very good teaching; which may reflect inadequacy of facilities, inadequately prepared students, or training of the teachers. Of

TABLE VI-12. RELATIONSHIP BETWEEN OPPORTUNITY FOR EFFECTIVE TEACHING AND OPPORTUNITY FOR EFFECTIVE RESEARCH (Q, II, 171).

How Much Chance to Do a Good Research Job?	How Much Chance to Do a Good Teaching Job?				N ^a
	Very Good %	Good %	Fair, or Not Too Good %	No Answer %	
Very good	57	23	18	2	727
Good	27	47	24	2	717
Fair, or not too good	18	39	41	2	1004
Poor or no answer ^a					72
Total					2520

^a No correlations made of respondents reporting poor opportunity. The estimated number of these is about 24; the estimated number not answering these questions, or not actively engaged in research, is about 50.

the physiologists throughout the nation whose major function is teaching, 58% indicated that they can do a good or very good teaching job in their present situations; of those whose major function is research, 78% so reported, but of the primary administrators, only 39%. The high correlation between research and teaching opportunities may, of course, involve such spurious factors, separating the more satisfied and less satisfied groups, as differences in institutional teaching standards, in level of students taught, and in the personal leadership-achievement values of the teacher. Such contributory factors are not evaluated.

Other analyses relating background factors to attitudes toward teaching effectiveness showed that: those physiologists satisfied with their laboratory equipment, space, materials, and assistance were also more likely to anticipate effective teaching than were those who felt a need for improved facilities, especially if the need was great (Q, II, 168); but expected teaching effectiveness did not clearly relate to teaching methods (Q, II, 169-170). Further analysis of stress put on lectures, laboratory work, seminars or discussion, and demonstrations and visual-aids might reveal conditions which make for teaching effectiveness. Interviews with members of physiology departments (Survey Project 8B) showed, as the main teaching objectives, a desire to instill concepts of scholarship, to teach the methods and values of intellectual curiosity, and to show how inquiry can most effectively be carried out.

OCCUPATIONAL MOBILITY OF PHYSIOLOGISTS

Professional Promotion

Physiologists with medical training are most likely to be employed in academic institutions and those without doctoral degrees, in industry or government; but those with doctoral degrees are distributed in like proportion in all fields, although numerically concentrated in academic work (Q, II, 81). Fifty per cent of all physiologists, as shown in Table VI-13, have been

TABLE VI-13. NUMBER OF YEARS OF EMPLOYMENT OF PHYSIOLOGISTS IN PRESENT INSTITUTION (Q, I, 42).

Years	Central			Peripheral				Total %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	
Less than 1.....	7	11	18	9	6	14	14	9
1-2	12	15	22	15	14	18	21	15
3-5	23	27	27	27	23	34	21	26
6-10	30	20	18	23	22	17	16	23
11-15	9	5	5	9	9	6	12	8
16-20	6	5	5	5	8	4	4	6
Over 20	13	15	4	11	16	6	12	12
No answer	#	2	1	1	2	1	0	1
Total	100	100	100	100	100	100	100	100
N (Respondents)	915	352	163	1873	564	377	119	4363

Less than .5%.

TABLE VI-14. FACTORS BELIEVED TO BE ACTUALLY EFFECTIVE AND FACTORS WHICH SHOULD BE EFFECTIVE IN DETERMINING JOB PROMOTIONS (Q, I, 60-64; II, 100-101).^a

	How Much Does This Count? %	How Much Should This Count? %		How Much Does This Count? %	How Much Should This Count? %
Length of Service			Administrative Abilities		
To a considerable extent.	22	11	To a considerable extent.	23	25
To some extent.....	46	63	To some extent.....	36	47
To little or no extent...	20	16	To little or no extent...	29	19
No answer.....	12	10	No answer.....	12	9
Quality of Research Done			Ability to Obtain Research Funds		
To a considerable extent.	49	84	To a considerable extent.	11	4
To some extent.....	32	11	To some extent.....	24	28
To little or no extent...	12	1	To little or no extent...	50	56
No answer.....	7	4	No answer.....	15	12
No. Research Publications			Other Job Offers		
To a considerable extent.	29	10	To a considerable extent.	21	2
To some extent.....	40	55	To some extent.....	31	20
To little or no extent...	20	26	To little or no extent...	32	64
No answer.....	11	9	No answer.....	16	14
Teaching Abilities			'Whom You Know'		
To a considerable extent.	17	47	To a considerable extent.	15	1
To some extent.....	33	26	To some extent.....	30	6
To little or no extent...	37	17	To little or no extent...	42	82
No answer.....	13	10	No answer.....	13	11

^a N = 4363 employed physiologists.

employed in their present institutions only five years or less, 23% from six to ten years, and 26% over ten years. Length of service is believed by 68% of physiologists to count some or considerably in determining professional advancement, and 74% believe it should count that much (Table VI-14). This table also shows discrepancies between the actual and the desirable relation between promotion and research quality (underweighted), research publication (overweighted), teaching ability (underweighted), and job offers and personal contacts (both overweighted).

The perceived and the desired weightings of criteria for promotion are shown by type of employment in Table VI-15. The desirable situation is

TABLE VI-15. PERCENTAGE OF RESPONDENTS, BY TYPE OF INSTITUTION IN WHICH EMPLOYED, REPORTING ACTUAL AND DESIRABLE MAXIMA CRITERIA FOR PROMOTION (Q, II, 102, 103).

Criteria for Promotion Reported	Academic N = 2867		Industrial N = 449		Governmental N = 621	
	Act. %	Desir. %	Act. %	Desir. %	Act. %	Desir. %
Operative 'to a Considerable Extent'						
Length of service.....	22	11	26	12	33	10
Quality of research done.....	47	83	61	87	48	90
No. research publications.....	34	10	6	6	27	13
Teaching abilities.....	24	65	3	8	1	8
Administrative abilities.....	16	20	50	53	32	29
Ability to obtain research funds..	12	3	4	4	5	3
Other job offers.....	26	2	8	2	15	1
'Whom you know'.....	14	1	16	2	17	1

strikingly similar for the three groups except for a natural weighting of teaching by the academic group and of administration by the industrial one. Discrepancies between the ideal and the perceived situation are in the same direction but not of the same intensity in the different cases: length of service seems overemphasized to all, but doubly so in governmental as compared to academic institutions; number of publications is judged greatly overemphasized in academia, not at all in industry; quality of research comes closest in industry to receiving the high emphasis judged desirable by all groups; ability to raise funds and receiving job offers are especially overemphasized in academic institutions. It would be important to know whether the perceived high weighting given research quality in industry reflects a difference of standards or is a real situation. As between teaching and research in academic promotions: half the medical school faculty judged the two of equal weight, one-third judged research and one-eighth teaching as more important; but chairmen emphasized research more, over half, and deans placed teaching first (3).

The factors which seem to operate in gaining professional promotion are relevant to the fact that 12% of all employed physiologists have been in their present institutions over 20 years, and another 14% have been there over 10 (Table VI-13). In academic institutions, quality of research and its publication are recognized as the prime factors, but other job offers have apparently played almost as great a part in obtaining promotions as has length of service or teaching ability. In industry and government, quality of research (and, in government, its publication) and administrative ability have been the major factors, with length of service and personal relations also exerting considerable influence. In government, length of service has more weighting than elsewhere; and job offers, more than in industry but considerably less than in academia.

Job Stability and Mobility

A 1948 study of a small sample of Ph.D. scientists revealed certain mobilities, despite a general employment stability of the group. By middle age, most had had experience in teaching, research, and administration or similar function; had worked for more than one type of employer; and had held positions in two or more states. Moreover, half had transferred from one scientific specialty to another (85, p. 5). Since 36% of the physiologists here surveyed entered the profession over 16 years ago, and another 36% entered during the preceding ten years, physiology appears to be a rather stable profession (Q, II, 27). Half the physiologists now employed have been with their present institutions from three to ten years; one-fourth for longer periods (Table VI-13). Contributing to this stability is the job-tenure (not necessarily job-continuity) of most government employees and of the 58% of physiologists (full and part time) in academic institutions (Q, I, 37).

The presence of tenure, age over 50, and salary level from \$7000 to \$10,000, tend to be stabilizing and are reflected in job-satisfaction (Q, II, 89). On the other hand, physiologists do move to new localities to advance their economic or professional interests, particularly earlier in their careers. This is also indicated by the different geographic distributions of those institutions which gave physiologists their baccalaureates, doctorates, and present positions—as already summarized in Table IV-17. The Survey did not obtain data on job mobility by type of employment or specialty, but the fact that 37% of the physiologists surveyed pursued no other field than their present one perhaps indicates a relative stability of the physiological profession. Central physiologists had a slightly lower score in this regard (Q, I, 31, 32). Geographical mobility in general was discussed in Chapter IV.

Job Demand and Job Availability

Project 13J of the Survey analyzed the records of the Placement Service maintained by the Federation of American Societies for Experimental Biology mainly for animal physiologists (*Preliminary Report IV-D-3*). During the period 1949-54 there were 316 applicants, 49% in the 20-29 and 42% in the 30-39 age groups. About three-fourths had the Ph.D., 8% were M.D.'s, and 7% had both degrees; 11% were not doctorates. About 40% of these applicants had received their doctorates in animal or human physiology, 3% in plant physiology, 3% in biophysics or physics, 5% in biochemistry, 16% in botany or zoology, and 11% in clinical or veterinary medicine; the remainder spread among other fields. Most applicants did not specify any particular field of interest; over half indicated their present field of interest as either physiology or animal physiology; and smaller groups specified general and comparative physiology (9%), endocrine physiology (8%), or metabolism and nutrition (6%)

The largest single group of applicants (29%) held the title of research assistant or fellow; 11% were teaching assistants; 10%, research associates; 11%, instructors; 7%, assistant professors; 4%, associate professors; and 2%, professors. The remaining quarter was divided between military service, graduate study, and miscellaneous positions. The FASEB Placement Service thus serves mainly those just completing their training or who hold interim positions; but a limited turnover also occurs in the lower echelons of regular academic employment.

Teaching jobs were desired by 43% of this group of applicants, jobs combining teaching and research by a fourth, and research jobs in academic institutions by a sixth; a total of 83% desiring jobs in academic institutions. Only 8% specified jobs in industry. Despite the lower salaries in academic institutions, this environment is much preferred by most applicants and the opportunity to teach apparently is inviting.

For the total group of applicants, salaries desired ranged from \$2000 to over \$10,000 a year, the median being approximately \$5600 a year. This is \$400 above the lower quartile income of Ph.D. physiologists (Table V-19); practically equal to the median for physiologists concerned mostly with teaching (\$5500). The median desired salary for animal physiologists in the 20-29 age bracket was \$4500; in the 30-39 bracket, \$6400. The income desired by applicants, mostly seeking academic positions in animal physiology, is thus in reasonable accord with academic salaries. Applicants in the lower age brackets apparently desire and expect to do considerable teaching.

Most applicants were located in the South Atlantic (31%) and the East South Central regions (22%); more than 10% each, in the West South Central, the East North Central regions, and outside the United States. Of all applicants, 28% desired to shift to another area; mostly the Middle Atlantic region, often the Pacific and South Atlantic regions. The latter, with a high concentration of government research projects, has become a desired locus for physiologists. Turnover is probably high because undesirable features overshadow attractive ones or because a large fraction of the appointments are temporary or because the Washington location of the Placement Service invites extra use by those in the Washington-Bethesda area.

Of 29 positions available, listed in September, 1953, most were in research; a few involved both research and teaching. Almost all professional ranks were included, but research associates were most in demand. These vacancies show that in-training positions (research assistant) yield candidates for professional positions (research associate); the parallel situation for teaching, involving teaching assistants and instructors, is less clear. Positions were scattered over almost all regions, but the South Atlantic and East South Central ones supplied the largest relative numbers of both applicants and jobs. This suggests a turn-over problem in these regions.

Salaries offered ranged from \$2000 to \$10,000 a year, with the median offered, \$4700; as compared to that desired, \$5600. The \$4700 offered compares well with medians in academic institutions, \$4200 for the 20-29 and \$4900 for the 30-39 age ranges (Table V-22). Fields of interest were specified in 22 of the 29 available positions, with neurophysiology indicated in 6, isotopes and radiation in 4. Nine other fields were specified; but it is not clear by comparison with the applicants' descriptions of their specialties, whether or where the supply is adequate to the demand.

Data obtained by Survey Project 11, in connection with the 1953 Teaching Institute organized by the Association of American Medical Colleges, showed 11 vacancies, mainly at lower levels, among 403 faculty positions in physiology departments of 76 medical schools. Approximately two-thirds of the 287 faculty members polled on the question thought it would be advantageous to advertise professional vacancies in medical journals, as is customary in Great Britain.

Summary

Many stereotypes seem to gain support from these findings: achievement depends more on perspiration than on inspiration; New England is the hub of most-satisfied physiologists (with the climatic Pacific a good second); noble motives of advancing science and of functioning fully and freely dominate the job choices of these scientists, who prefer freedom to fortune and who find it in academic research. Some caution is needed in accepting self-assigned nobility, as in questionnaire responses, however sincere the responders; and the greater fraction of very satisfied men in industry than in academia or government (smallest), or in administration than in research or teaching (smallest)—an order that fairly parallels salary levels—suggests that physiologists are not immune to the more ordinary human desiderata.

Actually, both from intense psychological study of a small elite group of scientists (Roe, ref. 71) and a related one of physiologists and from the questionnaire responses of the large Survey population, certain rather characteristic attitudes emerge. Four-fifths of the physiologists were attracted to the field by its subject matter—after one-third of all had tried and a second third had strongly considered another profession—and six-sevenths are reasonably well content in their positions. (The discontented tend to be in the young and low-salary brackets.) A good job is judged by half to two-thirds of all physiologists as offering freedom of action, an opportunity to use abilities, and the chance of contributing to scientific advance; whereas only 20% to 30% judge salary advancement, security, appreciation, or a congenial group as of major importance. Since medical students give a 'low salary' as their main reason for eschewing physiology or an academic career, either physiologists have a biased image of themselves or they are a biased population by positive self-selection. Yet the emphasis on freedom by industrial physiologists is similar to that by academic ones and, despite the relative lack of freedom in industry, 41% of the industrial group are very satisfied (85% fairly or very satisfied) in comparison with 36% (87%) in the academic one.

An academic post is most preferred by four-fifths of all physiologists and one in industry is least preferred by half. Yet two-thirds of government physiologists want out, as against half of those in industry (and 5% in academia); and a smaller fraction is very satisfied (28%, compare above) or fairly or very satisfied (79%). The extent to which dissatisfaction with government employ is related to loyalty-security measures must remain conjectural. The most satisfactory aspect of the job is freedom for the academic (70% so judge), income for the industrial (60%), and effective use of skills (50%) for the governmental employee; the least satisfactory is inadequate income in academia (50%), freedom in industry (65%) and government (65%). This dilemma faces wider segments of humanity than physiologists. Perhaps it is a general law of human nature that people (or organizations) are more willing

to pay for immediate and particular service than for long-range and general gains; so an individual must choose to give service and gain wealth or to retain freedom and accept penury.

As shown in Chapter V, and supported further by an analysis of jobs wanted, research is much preferred to teaching by the physiologists surveyed, and administration is least favored. Yet 41% of those primarily in administration are very satisfied (86% very or fairly satisfied), as compared with 37% (87%) in research and 25% (75%) in teaching. A larger proportion of those involved feels in a position to do good teaching (68%) than good research (58%; 65% for those in government) and there is a high correlation between good conditions for research and for teaching. This may well reflect general institutional strength—at least, it is less common to find a good research and poor teaching situation than the reverse and in academic institutions research is more a luxury item than is teaching. Also, conditions are least satisfactory in the East South Central than in other regions. Limiting factors on research are mainly in opportunity to use abilities (55%) and in funds and facilities (50%); although two-fifths of the investigators are under supervision, less than a fifth feel their freedom seriously infringed.

Physiologists seem fairly stable in their employment, even though half have been in their present jobs less than five years, and only 12% over twenty, while two-thirds have been in physiology for over sixteen years. This accords with a good level of job satisfaction. Nevertheless, there are interesting discrepancies between the weightings of different factors affecting satisfactory service and promotion, as perceived to exist and as judged desirable. For all groups, quality of research was seen by half as being weighty, while six-sevenths judged that it should be so; number of publications, length of service, job offers, teaching or administrative ability were judged to be important factors by 20% to 30%, fewer thought they should be important—except for teaching.

The academic group more than others felt that emphasis is given to teaching (24%) and believed strongly that it should be given (65%); the industrial group, also understandably, felt more strongly that administration is (50%) and should be (53%) heavily weighted. The number of publications is judged more important for promotion in academic (34%) than in other groups (6%-10%), as is the offer of another job (26% vs. 8% in industry and 15% in government). Even more surprising is the judgment of three-fifths of industrial physiologists, as compared with less than half of those in academia or government, that quality of research is important in securing promotions. Perhaps standards of research quality are lower in industry, perhaps emphasis on teaching somewhat undercuts that on research in the academic world, where, in addition, personal bibliographies and outside invitations may be of especial importance; but perhaps also there are real discrepancies between the realities and the stereotypes concerning them.

VII

RESEARCH ACTIVITIES AND PROGRAMS

RESEARCH AS A MAJOR ACTIVITY

Enumerating Research Physiologists

The number of physiologists engaged in research may be estimated on various bases. As indicated in Chapter V (Table V-2), over half of the total professional effort of physiologists is spent on research. As another basis, 43% of the employed respondents to the Survey questionnaire spent six-tenths or more of their time in some type of research (Table VII-1). A third basis is the proportion of those actively engaged in research who work in physiological or non-physiological fields (Table VII-3). Still another is that 87% of all physiologists (3980 respondents, or an estimated actual number of 5010) are actively engaged in research. Of these, approximately 73% are employed in academic institutions, 11% in industry, and 16% in government (Q, II, 117).

Despite clustering at the zero, quarter, and half points on the time-scale, the numerical data in Table VII-1 allow relatively accurate comparisons between the major groups of physiologists, and also between physiologists and other professions. There is little difference between central and peripheral groups (Table VII-1), but animal physiologists are less likely to spend all or a major part of their time in research than are either plant or bacterial physiologists. As shown in Table VII-2, twice the proportion—though about the same total number—in the plant and bacterial as in the animal groups is working entirely on research projects. Approximately 40% of animal, 50% of plant, and 52% of bacterial physiologists spend 60% or more of their time in research.

Although data made on differing bases must be compared with caution, research is the major effort of 43% of the physiological profession, but of only one-third of all biological scientists (92, p. 40). For subgroups of biologists, research emphasis is as follows: 25% of those employed in the agricultural sciences; 38%, in microbiology; 41%, in plant sciences; 35%, in pharmacology; 42%, in genetics; and 56%, in biophysics. There is, of course, a significant difference in educational background, and therefore in research potentiality, of physiologists (81% with a Ph.D. or D.Sc. degree

TABLE VII-1. NUMBER AND PERCENTAGE OF EMPLOYED PHYSIOLOGISTS ENGAGED IN RESEARCH (Q, I, 52 corrected).

% of Time in Research	Central				Peripheral					Total
	Animal	Plant	Bact.	Total	Animal	Plant	Bact.	Other	Total	
<i>A. No. Respondents^a</i>										
0-9 ^b	74	16	9	99	163	52	23	18	256	355
10-19	56	31	10	97	145	39	19	4	207	304
20-29	106	30	15	151	205	59	34	11	309	460
30-39	89	15	9	113	160	30	20	9	219	332
40-49	84	22	13	119	139	30	27	6	202	321
50-59 ^b	153	54	22	229	286	73	50	16	425	654
60-69	93	19	5	117	144	36	23	9	212	329
70-79	82	31	9	122	155	59	43	6	263	385
80-89	63	20	17	100	124	44	25	8	201	301
90-99	49	35	21	105	145	50	43	11	249	354
100	63	76	30	169	187	84	64	20	355	524
No data	3	3	3	9	20	8	6	1	35	44
Total ^a	915	352	163	1430	1873	564	377	119	2933	4363 ^a
Est. N physiologists	1151	443	205	1799	2356	709	474	150	3689	5488
<i>B. % of Respondents</i>										
0-9 ^b	8	5	6	6.9	9	9	6	15	8.7	8.1
10-19	6	9	6	6.8	8	7	5	3	7.0	7.0
20-29	12	9	9	10.6	11	11	9	9	10.5	10.5
30-39	10	4	6	7.9	9	5	5	8	7.4	7.6
40-49	9	6	8	8.3	7	5	7	5	6.9	7.4
50-59	17	15	13	16.0	14	13	13	13	14.5	15.0
60-69	10	5	3	8.2	8	6	6	8	7.2	7.6
70-79	9	9	6	8.5	8	11	11	5	9.0	8.8
80-89	7	6	10	7.0	7	8	7	7	6.8	6.9
90-99	5	10	13	7.4	8	9	11	9	8.5	8.1
100	7	21	18	11.8	10	15	18	17	12.4	12.0
No data	#	1	2	0.6	1	1	2	1	1.1	1.0
Total	100	100	100	100	100	100	100	100	100	100

Less than .5%.

^a 208 of 4571 respondents were retired or unemployed.

^b Clustering at 0 and 50% respectively.

TABLE VII-2. RESEARCH ACTIVITY OF PRINCIPAL GROUPS OF PHYSIOLOGISTS (Derived from Table VII-1).

Proportion of Time in Research, %	Branch of Physiology					
	Animal		Plant		Bact.	
	N ^a	%	N ^a	%	N ^a	%
60-99	855	31	294	32	186	34
100	250	9	160	17	94	17
Total major time.....	1155	40	454	50	280	52
Total N ^a (4228).....	2778	100	910	100	540	100

^a Number of respondents. For approximate total of employed physiologists multiply by 5/4.

plus 9% with an M.D.) and of biologists in general (40%) (*ibid.*, p. 10); and the definition of major function may also not apply equally to the two groups. Even so, physiologists clearly rank high in the proportion principally engaged in research.

The vitality of a scientific profession is measured not only by the productivity of its members; the fraction not engaged in research is also important. Table VII-3 is based on 3980 responses (87% of the total). About one-third are from central physiologists, in harmony with the proportion of these in the total estimated population. Besides about 400 counted as engaged in non-physiological research—a partial measure of those in peripheral physiological research—some 160 gave no adequate replies and another 590 engaged in research so slightly that they did not answer the section of the Survey questionnaire specifically addressed only to those 'active' in research. On the basis of the firm data, about one-sixth of 800, whose area of research could not be classified satisfactorily, can reasonably be excluded from active physiological research. Thus, a total of 1180, or 26%, of the 4570 physiologists surveyed are not at all active in physiological research (although half of these do some kind); conversely, certainly 2610, or 57%, are definitely active in such research, and the figure would be 71% if five-sixths of the indeterminate group were included. Within the known physiological research group in Table VII-3, animal physiologists constitute 69% of all physiologists active in some type of research; plant physiologists, 61%, and bacterial physiologists, 58%. Compared to the total number of respondents in each field, the figures are 61%, 53%, and 52%, respectively.

Organized Research Activity

The organization of research outside of university departments was investigated by the Survey. Wording of the question excluded university depart-

TABLE VII-3. PERCENTAGE OF RESEARCH PHYSIOLOGISTS ENGAGED IN PHYSIOLOGICAL AND NON-PHYSIOLOGICAL RESEARCH PROBLEMS (Q, I, 73).

Major Research Classification (First Research Problem Mentioned)	Central			Peripheral				Total	N ^b
	Animal	Plant	Bact.	Animal	Plant	Bact.	Other		
Physiological, N ^a	657	243	104	1118	273	184	35		2614
	%	%	%	%	%	%	%	%	
Physiological	79	73	68	65	53	53	38	66	
Non-physiological	4	8	9	10	20	13	22	10	400 ^c
Cannot determine	13	14	18	22	21	29	33	20	800 ^c
No answer	4	5	5	3	6	5	7	4	167 ^c
Total	100	100	100	100	100	100	100	100	
N (Respondents)	835	336	152	1710	507	347	94		3981 ^b

^a Numerical data from Q, I, 77. No other data given.
^b 590 respondents, not actively engaged in research, did not answer this section of the Survey questionnaire.
^c Estimated.

ments but unfortunately did not insure uniformity in characterizing a 'research organization'; so disparities in the data make the findings only tentative. About 1800 research physiologists (1430 respondents) are working in research organizations outside university departments (Q, I, 82), 36% of all research physiologists. Animal, plant, and bacterial physiologists working in research organizations represent, respectively, 33%, 41%, and 45% of their groups. Other data, based on 90% of all research physiologists, account for only 1190 respondents in these research organizations (Q, II, 117); but those engaged in clinical or private employment, and possibly also those who reported multiple employment, are apparently excluded (Table V-6). The proportion of those in academic institutions engaged in non-departmental research seems to be about 15%, while workers in 'research organizations' are 73% and 88% of those in industry and government, respectively.

Of the 1430 respondents, 34% are associated with research organizations having twenty or fewer professional personnel; on the basis of the 1190 respondents, this proportion is only 24%. Nearly half (46%) of the former group, however, report over fifty professional persons in their research organizations; and 26% reported six levels of professional staff; 12%, five; 18%, four; 26%, three; 12%, two; and only 2% a single level; with 4% giving no data (Q, I, 84). There were no essential differences between central or peripheral physiologists or between those in any branch of physiology.

Pure and Applied Research

In any discussion of physiological research it is necessary to make some arbitrary judgment as to what research is physiological and what is non-physiological. Such qualitative judgments will vary with circumstances and can lead to discrepancies in the data obtained; Table VII-3 is thus only suggestive. Animal physiologists, both central and peripheral, seem less likely to engage in research as a principal activity than do plant or bacterial physiologists, but more likely to concentrate their efforts on physiological problems. This may result from the historic orientation of animal physiologists as ancillary to medicine, while the orientation of other physiologists is more diffused.

The Survey, further, attempted to determine whether the orientation of physiological research was primarily toward the pure or the applied, recognizing that the variables of definition and of judgment (based on brief questionnaire statements or on titles of papers or theses) make the data rather subjective. Table VII-4 is based on 2615 cases; constituting 66% of the 3980 respondents actively engaged in research and 57% of all respondents. The first three classifications in Table VII-4, representing 'pure' research, account for almost 70% of physiologic research; but different figures appear in other Survey projects—7, 12A and 14A—based on different materials and interpretations (*Preliminary Report VI-A*, pp. 5-7). The range is from 17%

TABLE VII-4. ORIENTATION OF PRIMARY RESEARCH PROBLEMS AS INDICATED BY PHYSIOLOGISTS ENGAGED IN RESEARCH OF A PHYSIOLOGICAL NATURE (Q, I, 81).

Orientation	Central			Peripheral				Total ^a %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	
Gen. scientific; educational; acad. (pure) science....	74	75	81	63	60	70	65	68
Theoretical biol. (incl. bi- ometry)	0	1	0	0	0	0	0	#
Psychobiol.; sociol.; anthro- pol.	#	0	0	2	#	0	0	1
Medicine; dentistry; publ. health and indust. hy- giene	15	0	6	17	2	12	11	12
Technology (environmental physiol.; human engineer- ing; military physiol.); commercial; indust.	4	2	2	3	1	2	6	3
Agric. sciences (veterinary medicine; animal hus- bandry; soil sciences; hor- ticult.)	2	16	3	8	29	5	9	9
No answer; cannot code...	5	6	8	7	8	11	9	7
Total	100	100	100	100	100	100	100	100
N (Respondents) ^a	657	243	104	1118	273	184	35	2614 ^a

Less than .5%.

^a Includes only those known to be engaged in physiological research. See Table VII-3.

pure research estimated from a study of doctoral dissertation titles and 20%, from an analysis of medically-oriented projects registered with the Biological Sciences Information Exchange, to 95% from a longitudinal study of papers published in three physiological journals. The last figure is undoubtedly high because of selective acceptance of such papers by the editors. Obviously, improved methods are needed for identifying 'pure', 'applied', or 'developmental' aspects of research projects; for such analysis must bear on the amount of support which is or should be afforded.

The orientation of research is determined not only by the academic school or department or the type of governmental or industrial laboratory in which research is done, but also by the prevailing amount of freedom in choosing research problems. It is not surprising, in view of the discussion of institutional freedom and job satisfaction in Chapter VI, that 62% of academic research physiologists, 28% of those in government, and 15% of those in industry, report 'complete' freedom in choosing their current research problem (Q, II, 117). Table VII-5 details the research freedom for the various branches of physiology. Only half of all research physiologists feel that they have complete freedom of choice; and comparison of percentages here with those of Table V-5 relates degree of research freedom to those orientations—toward pure, applied or developmental research problems—which characterize

TABLE VII-5. DEGREE OF FREEDOM OF CHOICE OF CURRENT RESEARCH PROBLEM REPORTED BY RESEARCH PHYSIOLOGISTS (Q, I, 99; II, 116).

	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Complete	65	42	49	57	56	38	39	38	48	52
A great deal	24	31	23	26	26	40	26	31	29	28
Some	6	13	16	9	9	11	17	16	11	10
Not much	3	5	6	4	5	4	9	12	6	5
None at all	1	7	5	3	3	4	8	2	4	3
No answer	1	2	1	1	1	3	1	1	2	2
Total	100	100	100	100	100	100	100	100	100	100
N (Respondents) . .	835	336	152	1323	1710	507	347	94	2658	3981 ^a

^a 590 respondents, not actively engaged in research, did not answer this section of the Survey questionnaire.

academic, governmental, or industrial institutions. Still, 80% of the research physiologists represented by the Survey report a high degree of freedom in their work; only 8% little or none.

RESEARCH METHOD AND CONTENT

Experimental Variables

An evaluation of the methods and content of physiological research indicates that, unlike the situation in more amorphous disciplines, there has been no need for formal professional standards. Physiology is so largely an experimental science that observations lead regularly to testable hypotheses, and testing is largely by laboratory experimentation; so the total problem, even if taking years to investigate, is completed in a sequence of phases, each published for prompt professional consideration. The development of each concept thus becomes almost a continuous process, subject to all possible influences. Theory as such does not yet hold the place in physiological science that it does in developing the basic concepts of physics, chemistry, or mathematics, or in analyzing the relatively uncontrolled and complex variables of the social sciences. The problems of physiological research lie, rather, in the control and measurement of a reasonably clear set of variables. It was hoped that a multidimensional analysis of research projects would yield valuable relationships. A code (Appendix D) was accordingly developed so that each investigation could be rated as to experimental material (structural level, as cell, organ, individual, etc.; and taxonomic position); imposed variable; and observed response. Many analyses possible with these data have not been attempted, unfortunately, and the more obvious correlations are not too interesting; but some results follow.

The emphases on various experimental procedures in physiological research, as judged by analyses of three sources of data, are shown in Table VII-6.

These data are inherently different, and have also been compiled under different interpretations; yet they are reasonably comparable. (Failure to specify any experimental variable does not indicate that none was used.) The Survey also tried to utilize data from the medically-oriented projects registered with the Biological Sciences Information Exchange (BSIE); but duplication in coding made it impossible to assign satisfactory percentages to the occurrence of these variables (*Preliminary Report VI-B-1*).

Table VII-6 shows that in 35% to 40% of the physiological research reports studied, the independent variable is not expressly introduced by the experimenter but is physiologically endogenous or otherwise inherent within the situation—as when the influence of age or diurnal or oestrus cycle or sex or species on some other property is examined. The frequency with which an endogenous variable is used is perhaps a fair index of the still largely descriptive nature of physiology. It was hoped that a time trend in the published literature would indicate increased analytical experimentation, but this study was not completed. An endogenous variable is currently used by a higher percentage of animal physiologists and of central bacterial physiologists than of any other group, but the differences are not significant (Q, I, 74-75).

Pharmacological variables are used in 18% to 25% of the physiological reports studied, the higher percentage appearing in the fifty-year sample of journal literature. Pharmacological and physiological variables show inverse use, their sum is fairly constant over the years. Perhaps before the rise of other tools, drugs were used relatively more; perhaps today researches empha-

TABLE VII-6. PERCENTAGE DISTRIBUTION OF EXPERIMENTAL VARIABLES IN PHYSIOLOGICAL RESEARCH, AS REPORTED FROM THREE SOURCES (Q, I, 74-75; Survey Projects 7, 12A).

Experimental Variable ^c	Current Research Reported by Survey Respondents (Q, I, 74-75) ^a %	Papers in Physiological Journals, 1900-50 (Proj. 12A) %	Research Represented by Ph.D. Dissertations (Proj. 7) ^b %
Physiological-endogenous	35	36	40
Metabolic-nutritional	25	9	13
Pharmacological	18	25	23
Biological	4	2	9
Physical-chemical	2	7	2
Electrical energy	2	6	1
Radiant energy	10	5	4
Mechanical energy	2	2	3
Natural-psychological	2	1	5
Combinations or other	#	1	#
Not specified	^a	6	^b
Total	100	100	100
N	1280 ^a	1595	982 ^b

Less than .5%.

^a No answer to this question was given by approximately 51%, or 1334 of the 2614 respondents engaged in physiological research (Q, I, 75).

^b Variables not specified in 557 or approximately 35% of 1591 theses plus 52 entries not accounted for (Proj. 7, Table 4).

^c See Appendix D (Physiological Research Code).

sizing drug action are largely siphoned into pharmacological journals—but recently drug use is on the increase. At least, the pharmacological variable is used least by the animal physiologists; even though nearly all physiologists who now identify themselves with pharmacology as a subject field, even to small extent, are animal physiologists (Q, I, 2).

TABLE VII-7. TIME TRENDS OVER 50 YEARS OF ARTICLES PUBLISHED IN *American Journal of Physiology*, *Journal of Cellular and Comparative Physiology*, *Journal of Neurophysiology*^{a-b} (Survey Project 12A).

	1904 and 1909	1914 and 1919	1924 and 1929	1934 and 1939	1944 and 1949
Number of papers.....	84	113	462	568	368
<i>A. Research Content</i>					
	%	%	%	%	%
Experimental variable					
Energy	8	11	10	15	19
Physico-chemical	16	3	2	5	8
Pharmacological	33	22	19	24	28
Physiological	23	48	43	35	30
Nutrition	9	15	7	5	6
Other, uncertain	11	1	19	16	9
Structural level					
Cell and below.....	7	3	2	9	9
Tissue	23	16	9	10	16
Organ and system.....	27	20	21	31	35
Organism	40	55	52	44	40
Other, uncertain	3	6	16	6	#
Organism type					
Non-metazoa	4	1	3	6	7
Invertebrates	20	8	2	7	5
Cold blooded	10	3	6	13	10
Warm blooded	43	63	63	57	67
Man	17	22	11	10	11
Uncertain	6	3	15	7	#
Functional response					
Growth and metabolism.....	15	15	18	23	25
Receptor and effector.....	42	46	30	41	48
Circulation	5	24	16	13	11
Ingestion and excretion.....	18	12	18	12	11
Other, uncertain	20	3	18	11	5
<i>B. Origin and Support</i>					
Department					
Physiology	40	52	41	36	35
Pharmacology	9	10	6	2	4
Medical	7	7	9	8	10
Zoology-biology	4	9	8	14	13
Biochemistry	21	3	3	4	3
Anatomy	1	#	3	3	3
Other, uncertain	18	19	30	33	32

(Continued next page)

TABLE VII-7.—*Continued*

	1904 and 1909	1914 and 1919	1924 and 1929	1934 and 1939	1944 and 1949
<i>B. Origin and Support</i>					
	%	%	%	%	%
School					
Medicine	17	26	31	45	43
Pharmacy	8	14	6	1	2
Arts, Literature, Science.....	#	#	#	1	5
Graduate	#	#	1	2	#
Other, uncertain	75	60	62	51	50
Institution					
College or Univ., public.....	19	11	14	21	23
College or Univ., private.....	51	62	60	57	54
Clinic or hospital, private.....	2	2	8	7	5
Govt. laboratory or clinic.....	6	13	4	1	5
Foreign	3	6	8	4	8
Other, uncertain	19	6	6	10	5
Support					
Intramural (incl. unspecified)..	95	99	92	74	56
Government	#	#	5	6	17
Foundations	5	#	2	17	19
Societies	#	1	1	3	8

Less than .5%.

^a The small numbers, occasional founding of a new specialty journal, changes in editorial policy, and the like, make these figures only roughly suggestive. The trends judged significant are mentioned in the text. Over the decades, space allotment has remained surprisingly constant between methods (23%), results (26%), discussion (23%), and tables and figures (28%).

^b Articles sampled for one year at five-year intervals. Figures in % (each column totals 100%).

The metabolic or nutritional variable was used in one-quarter of the projects listed by Survey respondents, but only in 9% of the published articles sampled over fifty years and in 13% of the samples of doctoral theses. It is most favored by peripheral plant physiologists, least by central animal physiologists (Q, I, 75). (Much of this research, however, is concerned with metabolic responses to other experimental variables.) Biological variables (sera, vaccines, etc.) are used today largely by peripheral bacterial physiologists; they are prominent also in the medically-oriented research projects listed with the BSIE. The current use of radiant energy as an experimental variable is double that of earlier reports or theses, undoubtedly reflecting the rapid growth of the atomic energy field. Physical and chemical variables were used more widely in journal reports of past physiological research than at present; again, this may simply reflect the separation of biochemical journals. It is also interesting that nearly half of the physiologists replying to the Survey questionnaire recognized an inadequate training in physics, chemistry, and biochemistry (Q, II, 74); but this probably reflects rising standards rather than falling competence. The relatively infrequent use of electrical, mechanical, or psychological variables is somewhat surprising in view of the importance of electrical stimulation in neuromuscular physiology; perhaps the greater frequency of the electric variable in published articles reflects this. Use of energy as a variable is clearly increasing (Table V-10).

Interaction between variables in physiological experiments occurs frequently but is rarely well understood and even more rarely given adequate consideration, largely because of inadequate control of ill-defined or ill-considered experimental variables. Some often given inadequate attention are: effects of anesthesia, abnormal animal postures (circulation), surgical trauma (C.N.S.), parameters of electric stimuli, etc.

Structural Level

Table VII-8 presents a similar analysis of the structural levels studied in physiological research. Between 33% and 46% of physiological investigations are directed to the whole organism, from 12% to 20% are concerned with organ systems, and only 6% to 10% with single organs. Research on tissue constitutes 6% to 15% of the total, and on cells from 3% to 12%, with little attention to smaller units. The shift from organism to organ to tissue to cell, indicated by comparing current and published work and by time trends (Table VII-7), is expected; the emphasis on groups of organisms in Ph.D. theses is not understood.

Research in plant physiology is most consistently (62% to 65%) on the whole organisms common to this field. In bacterial physiology, research was judged to involve organisms only when a plant or animal served as host (bacteria alone were considered as 'cells') and such studies account for about 20% of current work in the bacterial area. Among animal physiologists reporting research activity, smaller proportions of central (29%) than of peripheral (41%) workers deal with the whole animal or human organism in their current research (Q, I, 78).

TABLE VII-8. PERCENTAGE DISTRIBUTION OF STRUCTURAL LEVELS USED IN PHYSIOLOGICAL RESEARCH, AS REPORTED FROM THREE SOURCES (Q, I, 78; Survey Projects 7, 12A).

Structural Level ^a	Current Research Reported by Survey Respondents (Q, I, 78) %	Papers in Physiolog- ical Journals, 1900-50 (Proj. 12A) %	Research Repre- sented by Ph.D. Dissertations (Proj. 7) %
Molecular	#	1	0
Cellular particulates	2	#	1
Cell	12	5	3
Tissue	6	15	12
Organ	7	6	10
Organ system	18	20	12
Organism	40	46	33
Group of organisms	#	1	16
Other	#	1	0
Unspecified	15	5	13
Total	100	100	100
N	2614	1595	1592

Less than .5%.

^a See Appendix D (Physiological Research Code).

Organs and organ systems are more developed in animal than in other forms of life and animal physiologists carry out most of their research at these structural levels. Bacterial research is naturally largely at the cellular level. Four per cent of all animal physiologists indicate specialization in general or comparative physiology (Q, I, 78) and 6% of their research is directed to the cell. At still lower levels, research workers are probably self-classified as biochemists.

Type of Organism

The types of organisms utilized in physiological research are exhibited in Table VII-9. Warm-blooded vertebrates other than man represent about half (48% when the low value for these is averaged in); human subjects, about one-tenth. Why the percentage is much lower for current work than for published results is not clear; perhaps it depends on interpretation of the Survey question. The general level may relate to the fraction of physiologists with an M.D. degree—16% of all, 28% of central animal, and 21% of peripheral animal physiologists (Q, I, 133). The earlier emphasis on lower forms and the steady decline in human experimentation (Table VII-7) may well reflect changes in publication outlets—e.g. the *Journal of Applied Physiology*. The emphasis on various organisms by animal, plant, and bacterial physiologists is that which is to be expected in terms of their interests; but data can be compared only when similarly based. Thus, for example, over 15% of current work and Ph.D. theses utilizes vascular plants (comparable to

TABLE VII-9. PERCENTAGE DISTRIBUTION OF TYPES OF ORGANISMS USED IN PHYSIOLOGICAL RESEARCH, AS REPORTED FROM THREE SOURCES (Q, I, 76-77; Survey Projects 7, 12A).

Type of Organism ^a	Current Research Reported by Survey Respondents (Q, I, 76-77) %	Papers in Physiologi- cal Journals, 1900-50 (Proj. 12A) %	Research Represented by Ph.D. Dissertations (Proj. 7) %
Viruses, rickettsiae	#	#	1
Unicellular	10	2	9
Molds, fungi	1	#	4
Plants, autotrophic nonvascular (larger algae)	#	#	#
Plants, vascular	15	1	17
Metazoa, invertebrate	2	8	4
Vertebrate, poikilothermous	2	8	2
Vertebrate, homeothermous	52	59	31
Vertebrate, human	4	14	13
Model or analogy, pathology.....	#	1	8
Combination	#	2	0
Unspecified	14	5	11
Total	100	100	100
N	2614	1595	1592

Less than .5%.

^a See Appendix D (Physiological Research Code).

the 20% of physiologists in the plant group); only 1% of published articles are concerned with plants because the journals sampled do not represent this area.

Type of Functional Response

When the functional responses are examined, the figures on published articles are especially skewed by the particular journals examined, circulation and neurophysiology at the expense of metabolism and growth (and unspecified) (Table VII-7). As shown in Table VII-10, metabolism is studied by 34% of research physiologists and appears in 42% of the Ph.D. dissertations sampled; growth ranks next with 12% and 13%, respectively; and neurophysiology (including sensory, motor, and adaptation categories) is about the same, with 15% and 11%. In questionnaire responses (Q, I, 79), plant physiologists were most involved in research on growth, but plant physiology is little represented in the journal literature sampled. Circulation research, a primary interest of central animal physiologists (but not so much as metabolism), is less represented in the sample of Ph.D. dissertations than in current work—discounting the still greater figure for the literature—but again the meaning is obscure.

There are interesting discrepancies (Table VII-11) between the emphases in research reported by Survey respondents or in publications and the amount of support available from the Office of Naval Research. Whether a sampling bias is involved, or a coding deviation, is hard to say.

TABLE VII-10. PERCENTAGE DISTRIBUTION OF FUNCTIONAL RESPONSES STUDIED IN PHYSIOLOGICAL RESEARCH, AS REPORTED FROM THREE SOURCES (Q, I, 79-80; Survey Projects 7, 12A).

Functional Responses ^a	Current Research Reported by Survey Respondents (Q, I, 79-80) %	Papers in Physiologi- cal Journals, 1900-50 (Proj. 12A) %	Research Repre- sented by Ph.D. Dissertations (Proj. 7) %
General properties of protoplasm...	#	1	2
Growth	12	6	13
Metabolism	34	13	42
Reception-sensation	7	17	7
Motor activity	3	25	1
General adaptation	5	1	3
Circulation	7	14	2
Ingestion	1	6	#
Excretion	2	8	#
Others	2	2	2
Unspecified	27	7	28
Total	100	100	100
N	2614	1595	1592

Less than .5%.

^a See Appendix D (Physiological Research Code).

TABLE VII-11. COMPARISON OF RESEARCH EMPHASIS AND RESEARCH SUPPORT IN VARIOUS CATEGORIES.

	% of ONR Funds	% from Tables VII-6 to VII-10
Experimental variable		
Biological	23	5
Mechanical energy	17	2
Radiant energy	16	6
Physiological	11	37
Structural level		
Organ	24	8
Tissue	23	11
Molecular	21	1
Organism	10	40
Type of organism		
Human	25	9
Warm blooded (non-human).....	22	47
Functional response		
Metabolism	23	30
Adaptation	18	3
Department		
Dentistry	22	
Biology	23	13
Medical	15	9
Physiology	9	35

Measurement in Physiological Research

Perhaps more rewarding than the other breakdowns, an attempt was made to judge the sophistication and precision of physiological research over a half century. The precision in most phases is actually rather poor comparatively, especially on the more physical and chemical problems. Adequate measurements at these levels are, however, now being attained by some workers in biochemistry and metabolism, bioelectric phenomena, and cellular structure. Of course, precise tools of measurement and analysis are hardly applicable to phenomena now describable only in terms of gross observation; and Table VII-6 shows the extent to which such experimental variables dominate physiological research. The functional responses examined (Table VII-10) are, however, more often susceptible to precise measurement; yet precision is little used (Table VII-12). Apparently the training of physiologists does not encourage the full exploitation of the phenomena they study.

Basic Techniques and Concepts

The use of statistical, mathematical, chemical, and physical concepts in experimental situations in physiology should indicate the competence of physiologists in these basic scientific areas and their confidence in employing such skills. The data in Table VII-12—like Table VII-7 derived from samplings, at five-year intervals, of the *American Journal of Physiology*, the *Journal of Cellular and Comparative Physiology*, and the *Journal of Neuro-*

TABLE VII-12. SOPHISTICATION IN THE USE OF STATISTICS, MATHEMATICS, PHYSICS, AND CHEMISTRY FOR METHOD AND ANALYSIS, IN PHYSIOLOGICAL RESEARCH PAPERS, 1900-50 * (Survey Project 12A; Preliminary Report IV-G-2, pp. 14ff).

	1904-09	1914-19	1924-29	1934-39	1944-49
(a) <i>In Method</i>					
A. Statistics					
Not present; not applicable.....		1		1	#
Applicable; not present	5			2	#
Applicable; slightly present	33	4	#	4	5
Applicable; some specificity	45	35	25	31	34
Applicable; good specificity	17	54	53	53	57
Applicable; excellent specificity		4	7	3	3
Unspecified		2	15	6	#
N	84	113	462	568	368
B. Mathematics					
Not present; not applicable.....	98	91	78	79	79
Applicable; not present				#	
Applicable; slightly present	1	4	5	8	9
Applicable; some specificity	1	4	2	6	8
Applicable; good specificity		1	#	1	4
Applicable; excellent specificity			#		
Unspecified			15	5	
N	84	113	462	568	368
C. Physics					
Not present; not applicable.....	73	11	8	20	10
Applicable; not present				1	#
Applicable; slightly present	14	54	49	31	29
Applicable; some specificity	11	28	22	28	38
Applicable; good specificity	2	7	5	13	21
Applicable; excellent specificity			1	1	1
Unspecified			15	5	
N	84	113	462	568	368
D. Chemistry					
Not present; not applicable.....	21	23	22	28	31
Applicable; not present				#	
Applicable; slightly present	21	30	22	19	14
Applicable; some specificity	51	45	36	35	39
Applicable; good specificity	7	2	5	11	14
Applicable; excellent specificity				#	#
Unspecified			15	5	
N	84	113	462	568	368

(b) *In Analysis*

A. Statistics					
Not present; not applicable.....	2		#	3	#
Applicable; not present	14	1		4	4
Applicable; slightly present	76	84	69	62	64
Applicable; some specificity	8	9	14	23	25
Applicable; good specificity		4	2	2	6
Applicable; excellent specificity		1			1
Unspecified		1	15	6	
N	84	113	462	568	368

(Continued next page)

TABLE VII-12.—*Continued*

	1904-09	1914-19	1924-29	1934-39	1944-49
(b) <i>In Analysis</i>					
B. Mathematics					
Not present; not applicable.....	98	85	70	70	70
Applicable; not present				#	3
Applicable; slightly present		12	11	13	10
Applicable; some specificity	1	3	3	7	12
Applicable; good specificity	1		1	4	4
Applicable; excellent specificity			#	1	1
Unspecified			15	5	
N	84	113	462	568	368
C. Physics					
Not present; not applicable.....	54	6	3	11	8
Applicable; not present				#	1
Applicable; slightly present	38	63	40	34	23
Applicable; some specificity	8	24	27	28	35
Applicable; good specificity		6	12	17	25
Applicable; excellent specificity		1	2	3	8
Unspecified			15	5	
N	84	113	462	568	368
D. Chemistry					
Not present; not applicable.....	20	34	21	27	33
Applicable; not present	16	11	5	4	9
Applicable; slightly present	32	17	21	14	15
Applicable; some specificity	24	33	26	32	23
Applicable; good specificity	8	5	11	16	19
Applicable; excellent specificity			#	#	1
Unspecified			15	5	
N	84	113	462	568	368

Less than .5%.

‡ Figures in % (each column totals 100%).

physiology (Survey Project 12A)—may be taken as some measure of the sophistication of physiologists (mainly animal) in performing and interpreting their research.

Statistical concepts, judged almost always applicable both in methodology and analysis, have been actually used with increasing effectiveness. Almost all papers published in the years sampled utilized some statistical techniques in their experimental design, and to a fairly constant and respectable extent over the past thirty years. The application of statistical techniques to analysis of data has also remained relatively constant in quantity but has markedly improved in quality over a period of forty years. If statistics are used frequently and appropriately in planning experiments, it may also be inferred that their use is better intentioned than carried through; for adequate analysis, although improved, is still largely lacking. More general mathematical concepts and techniques, initially hardly applicable, are used in the last decade in 20% to 30% of the papers and with increasing effectiveness, and in analysis even more than in design. Really adequate use of mathematics,

however, has increased very slightly and remains insignificant percentage-wise, despite an increased need for mathematical treatment.

The use of physical concepts has increased markedly, both in planning research and analyzing results; and the quality, or sophistication, of their use has risen to a higher point than for statistical, mathematical, or chemical concepts. There is indication, however, that physiological investigations are not planned with physical concepts in mind so much as that the results of experiments are couched in physical terms. The gradual but persistent decline in use of chemical concepts, both in planning and interpreting physiological research, undoubtedly results from diversion of reports into appropriate biochemical publications, corresponding with the rise of biochemistry as a distinct profession. Despite this splintering, chemical concepts still find a significant place in physiological research, both in methodology and in analysis, and there is here also a continued improvement in the quality, or sophistication, of application.

The findings of the Survey as to the use of the techniques and concepts of statistics, mathematics, physics, and chemistry in physiological research indicate a general rise in the level of sophistication in all these areas, and also an increase in the applicability of mathematical and physical concepts in physiological research. With the relatively recent development of combined departments of physiology and biophysics and the establishment of separate laboratories of biophysics in a number of academic and research institutions, there is every indication that biophysics is taking the same course that earlier led biochemistry to professional separation.

DISTRIBUTION OF RESEARCH ACTIVITIES

Geographical Distribution

The geographical distribution of research activities, as judged from Survey Projects 7, 12A, and 14A and the Survey questionnaire, is succinctly presented in Table VII-13. Additional material, based on Survey Project 12C, is given in Table VII-14. It is obvious, on all counts, that physiological research activity has consistently been greatest in the East North Central and Middle Atlantic regions, followed by the West North Central area and New England. The Pacific area appears to be coming up; indeed, on the basis of the more recent material, it has arrived. Lacking university facilities in the past and still inadequately supplied with institutions stimulating to research activity, the South and also the sparsely populated Mountain region are far below the national average. In the South Atlantic region, the discrepancy between data from various sources is partly due to the concentration of medically-oriented research in the Washington-Bethesda area—particularly reflected in the dollar value of research grants. It should be remembered that the grants registered

TABLE VII-13. REGIONAL DISTRIBUTION OF PHYSIOLOGICAL RESEARCH ACTIVITY, AS ESTIMATED ON FIVE BASES.

Region ^a	(A)		(B)		(C)		(D)		(E)	
	N	%	N	%	\$	%	N ^b	%	N ^b	%
Northeast										
New England ...	261	16	619	16	7.5	17.0	109	7	368	10
Mid. Atlantic ...	309	19	931	23	10.6	23.8	331	21	700	19
North Central										
E. North Cent. ...	329	21	639	16	10.5	23.6	508	32	1060	29
W. North Cent. ...	197	13	322	8	2.7	6.1	209	13	478	13
South										
South Atlantic ..	157	10	442	11	4.1	9.2	88	6	257	7
E. South Cent. ...	39	2	103	3	.8	1.8	12	1	15	#
W. South Cent. ...	32	2	169	4	1.4	3.2	41	3	74	2
West										
Mountain	15	1	106	3	1.5	3.4	20	1	35	1
Pacific	89	6	383	10	4.0	9.0	207	13	405	11
Outside cont. U.S. ...	107	7	247	6	1.3	2.9	52	3	147	7
No data, unspecified.	51	3							35	1
Total		100		100		100		100		100
N	1596		3961		\$44.4		1557		3683	

(A) Geographic distribution of papers published in *Am. J. Physiol.*, *J. Cell. & Comp. Physiol.* and *J. Neurophysiol.*, 1904-9, 1914-19, 1924-29, 1934-39, 1944-49 (Proj. 12A). See Table VII-15.
 (B) Number of grants in physiological fields listed with the Biological Sciences Information Exchange, June 1952 (Proj. 14A, Table 2).
 (C) Dollar value (in millions) of BSIE grants (Proj. 14A, Table 2).
 (D) Number of Ph.D. theses judged physiological in content, 1939-40, 1944-45, 1950-51, 1951-52 (Proj. 7, Table 2). See Table VII-16.
 (E) Physiologists having Ph.D. or Sc.D. degrees, by region of institution granting degree (Q, I, 141).
 # Less than .5%.
^a For census regions see Appendix E.
^b Estimated N based on percentage data.

TABLE VII-14. CITATIONS OF PAPERS OF PHYSIOLOGISTS BY REGIONS (Survey Project 12c).

Region	Members ^a	Citations ^b	Citations/Member
Northeast	784	4088	5.2
New England	316	1362	4.3
Middle Atlantic	468	2726	5.8
North Central	636	4318	6.8
East North Central	436	3251	7.5
West North Central	200	1067	5.3
South	548	2166	3.9
South Atlantic	376	1650	4.4 ^c
East South Central	67	196	2.7
West South Central	105	320	3.0
West	374	2463	6.6
Mountain	71	225	3.2
Pacific	303	2238	7.4
Hawaii	19	54	2.8
Total	2,361	13,089	5.5
Canada	70	260	3.7

^a Total members of American Physiological Society, American Society of Plant Physiology, and Society of General Physiology.
^b Citations in six *Annual Review* series for 1950, 1951, and 1952.
^c Includes Washington-Bethesda area.

with the Biological Sciences Information Exchange (BSIE) are largely medically oriented.

Detailed data from Survey Projects 12A and 7, on which portions of the data in Table VII-15 are based, illustrate longitudinal trends in the geographical distribution of research. For instance, on the basis of sampling three physiological journals over five decades, New England and the Middle Atlantic region appear to have reached their relative heights during the 1930's, with 21% and 24%, respectively, of the papers published. The East North Central region has varied considerably, while the maximum of the West North Central and the Pacific region was in the 1920's. On the other hand, while the three southern regions have all advanced over the years, with the South Atlantic region benefiting from the gradual concentration of research in one area, they are still relatively unproductive. The detailed data are given in Table VII-15. A study of Ph.D. dissertations for the period 1940-1952, Table VII-16, confirms the leadership of the East North Central and Middle Atlantic regions in physiological research.

Departmental Distribution

The distribution of physiological research activity, by types of institution and department, was determined by a sampling of the journal literature in physiology (Project 12A) and of doctoral dissertation titles (Project 7), and

TABLE VII-15. GEOGRAPHICAL DISTRIBUTION OF PAPERS PUBLISHED IN *American Journal of Physiology*, *Journal of Cellular and Comparative Physiology*, AND *Journal of Neurophysiology*, 1900-50^a (Survey Project 12A; Preliminary Report VI-C, p. 4).

Region	1904-09 ^a		1914-19		1924-29		1934-39		1944-49		Average (1900-50)	
	N	%	N	%	N	%	N	%	N	%	N	%
Northeast												
New Engl.	14	17	12	11	66	14	120	21	49	13	261	16
Mid. Atlant.	16	19	21	19	59	13	135	24	78	21	309	19
North Cent.												
E. North Cent.	27	32	26	23	111	24	91	16	74	20	329	21
W. North Cent.	6	7	11	10	76	16	65	11	39	11	197	13
South												
South Atlant.	3	4	22	20	39	9	52	9	41	11	157	10
E. South Cent.			2	1	16	3	15	3	6	2	39	2
W. South Cent.			2	1	9	2	10	2	11	3	32	2
West												
Mountain					3	#	3	#	9	2	15	1
Pacific	5	6	5	4	36	8	23	4	20	6	89	6
Territories					1	#			1	##		
N. America	1	1			27	6	9	2	14	4		
S. America									4	1		
Europe	1	1	2	1	8	2	6	1	8	2		
Asia			6	6	3	#	5	1	7	2		
Australia & Oceania.									4	1		
Unspecified	11	13	4	4	8	2	34	5	4	1	51	3
Total		100		100		100		100		100		100
N	84		113		462		568		369		1596	

Less than 1%.

^a Two sample years in each decade; e.g. 1904 and 1909 for the decade 1900-10.

TABLE VII-16. PERCENTAGE OF PH.D. DISSERTATIONS IN PHYSIOLOGICAL SCIENCE, BY REGION OF INSTITUTION GRANTING DEGREE, 1940-1952 (Survey Project 7).

	1939-40 %	1944-45 %	1950-51 %	1951-52 %	Est. Av. %
Northeast					
New England	9	3	8	6	7
Middle Atlantic	23	30	23	18	21
North Central					
East North Central	31	24	34	32	32
West North Central	17	8	11	14	13
South					
South Atlantic	6	6	6	5	6
East South Central	0	0	1	1	1
West South Central	1	5	1	4	3
West					
Mountain	1	1	1	2	1
Pacific	10	18	12	14	13
Canada	2	5	3	4	3
Total	100	100	100	100	100
N	293	146	555	598	1592

by the replies to the Survey questionnaire regarding the departmental affiliation of the supervisor of the respondent's doctoral thesis. The comparative results of these studies are given in Table VII-17. Since 58% of the research grants listed with the Biological Sciences Information Exchange were made to medical schools, and 14% to hospitals, data from that source are not comparable in this instance. In published research the preclinical departments outstrip the non-medical and clinical ones by nearly four to one, and they also produce three times as many doctoral dissertations as do non-medical departments. On the other hand, questionnaire responses indicated that the

TABLE VII-17. PERCENTAGE OF PHYSIOLOGICAL RESEARCH ACTIVITY, BY TYPE OF DEPARTMENT (Survey Projects 7, 12A; Q, I, 129-130).

Departments	Papers in Physiol. Journals, 1900-50 ^b		Ph.D. Dissertations ^c		Thesis Supervisors of Ph.D. Physiologists ^d	
	N	%	Est. N ^a	%	Est. N ^a	%
Non-medical (1)	257	16	353	22	1436	39
Preclinical (2)	946	59	1015	64	1610	41
Med., med. ancillary (3).	238	15	50	3	112	3
Agric., agric. ancil. (4).	35	2	173	11	405	11
Other	51	3			110	3
Not specified or no data.	74	5			110	3
Total		100		100		100
N	1601		1591		3683	

^a Estimated N's are based on percentage data.

^b (Project 12A); see Table VII-18.

^c (Project 7); see Table VII-19.

^d (Based on Q, I, 129-30); see Table VII-20.

(1) Includes departments of Biology, Zoology, Chemistry, Biophysics, Psychology, etc.

(2) Includes Physiology, Biochemistry, Anatomy, Pharmacology, Bacteriology, Pathology.

(3) Schools of Dentistry, Pharmacy, Public Health, Veterinary Medicine, Nursing, etc.

(4) Horticulture, Animal Husbandry, etc.

doctoral supervisors were about equally divided between preclinical and non-medical departments. The discrepancy may depend on a time difference, the dissertation study sampling a recent period while the Survey respondents received their degrees over a wide span of years; at least, in recent decades, the non-medical departments have doubled their relative contribution of published research papers in physiology (Table VII-18). Also, zoology-biology contributions have risen, those from pharmacology have fallen (Table VII-7). It is difficult to make valid comparisons with the physiological research activities of medically and agriculturally oriented physiologists, since the journals to which these groups normally contribute were not sampled by the Survey. As might be expected, supervisors of doctoral research in bacterial physiology were largely in preclinical departments; in plant physiology predominantly in non-medical ones (Tables VII-19 and VII-20).

TABLE VII-18. PERCENTAGE OF PAPERS PUBLISHED IN *American Journal of Physiology*, *Journal of Cellular and Comparative Physiology*, AND *Journal of Neurophysiology*, BY DEPARTMENTAL SOURCE, 1900-50 (Survey Project 12A; Preliminary Report VI-C, p. 12, Table 4).

Type of Dept.	1904-09		1914-19		1924-29		1934-39		1944-49		Total Average	
	N	%	N	%	N	%	N	%	N	%	N	%
Non-Medical											257	16.1
Zoology			9	8	19	4	41	7	16	5		
Biology	3	4	1	1	18	4	38	7	30	8		
Biophys., psychol.					8	2	5	1	3	1		
Chemistry	4	5			5	1	6	1	1	#		
Others			2	2	8	2	19	4	21	6		
Preclinical											946	59.2
Physiology	33	40	58	52	189	41	204	36	130	35		
Biochemistry	16	20	4	3	14	3	22	4	11	3		
Anatomy	1	10			17	3	18	3	12	3		
Pharmacology	8	9	11	10	30	6	11	2	14	4		
Bact. pathol.	1	1	2	2	4	1	14	2	3	1		
Others			3	3	43	9	37	6	36	9		
Medicine, Med.											238	14.9
Ancillary												
Medicine	6	7	9	7	44	9	47	8	39	10		
Surgery					10	2	13	2	8	2		
Pediat., obst.-gynec.					1	#	4	1	5	1		
Optometry			1	1			4	1	1	#		
Psychiatry	2	2					18	2	13	4		
Dentistry					4	1						
Publ. health, nursing					2	#	3	1	4	1		
Agricult. and Agriculture Related											35	2.1
Horticulture, agronomy			5	4	2	#	14	2	4	1		
Animal husbandry, dairy products			1	1	6	2	2	#				
Others					1	#						
All others			6	5	26	6	14	2	5	2	51	3.1
Unspecified	10	11	1	1	11	2	45	7	7	2	74	4.6
Total		100		100		100		100		100		100
N		84		113		462 ^a		579 ^a		363		1601

Less than 1%.
^a Corrected totals.

TABLE VII-19. DISTRIBUTION OF PH.D. DISSERTATIONS IN PHYSIOLOGICAL SCIENCES, BY DEPARTMENTAL CATEGORIES (Survey Project 7, Table 3).

Department	1939-40 %	1944-45 %	1950-51 %	1951-52 %	Average %
Non-medical ^a	29	19	17	23	22.2
Preclinical ^b	63	69	66	62	63.8
Med., med. ancillary	1	1	5	3	3.1
Agric. sciences	7	11	12	12	10.9
Total	100	100	100	100	100
N	293	145	555	598	1591

^a Includes Departments of Psychology, Zoology, Genetics, Entomology, Botany.

^b Includes Departments of Physiology, Anatomy, Biochemistry, Bacteriology and Microbiology, Pharmacology.

Time trends are also apparent in the schools and institutions from which papers, published in the journals sampled, originate; and in the sources of funds that support them (Table VII-7). Contributions from medical schools have increased, from under 20% to over 40%, and those from liberal arts colleges also seem to be increasing recently; but the large uncertain fraction makes any conclusion dangerous. Academic institutions contribute three-fourths of the papers; with a steady shift, after the first decade, from private to public ones. Also present is a rise over the decades in research support from government, foundations, and societies—as judged by acknowledgments in the published articles. The rise of general physiology in zoology and biology departments of liberal arts schools, and the increased dependence of academic institutions on extra-mural funds for research support are thus shown by the published articles.

It was not possible to obtain data on research sponsored by the U.S. Department of Agriculture, so no study of the contribution to physiological research by agricultural departments, as a complement to that of medical departments, could be made. The interests of plant physiologists are thus, unfortunately, further slighted in this report. There is need for fully-correlated studies on

TABLE VII-20. DISTRIBUTION OF DEPARTMENTAL AFFILIATIONS OF THESIS SUPERVISORS OF PHYSIOLOGISTS HAVING PH.D. OR SC.D. DEGREES (Preliminary Report VI-C-1, Table 4C-2; based on Q, I, 129-230).

Department	Central			Peripheral				Total %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	
Non-medical ^a	35	71	12	39	46	26	36	39
Preclinical ^b	49	16	74	44	14	64	41	41
Med., med. ancil.	4	#	1	3	#	2	2	3
Agric., agric. ancil.	4	9	5	7	33	5	12	11
Others	4	1	1	4	3	2	7	3
No answer	4	3	7	3	4	1	2	3
Total	100	100	100	100	100	100	100	100
N	750	307	138	1565	520	298	105	3683

Less than .5%.

^{a, b} See notes to Table VII-19.

the distribution of research grants in the physiological sciences, in terms of both basic and applied research and with medical, agricultural, and biological orientations. The present trend toward supporting applied and developmental research, in all fields of science, is discussed in Chapter VIII. In the absence of adequate data regarding physiological research in agricultural and ancillary departments, the research contributions of all types of physiologists whose work is oriented to that sector of life science cannot be fully appreciated.

SUMMARY

Research is the primary concern of professional physiologists. Over half their total effort is so directed; nearly 90% do some research and over 40% spend over 60% of their time on it, ranging from one-fourth in agriculture to over half in biophysics, and a third more than for biologists in general. A third of the research effort is outside of university departments, higher in the bacterial area, and about half of this is carried out in organizations with fifty or more professional persons and four or more levels of authority. Four-fifths of all workers have a high degree of freedom in choosing and pursuing their research problems—complete freedom is reported by roughly 60% of academic, 30% of government, and 15% of industrial researchers—even though only one-fifth of current projects (BSIE) or recent theses were judged to represent 'pure' research.

Research is a 'smokeless industry' and its essential product is published articles. The spoor of physiology is, thus, its journal literature; and examination of this over the decades should reveal the course traveled. The original plan for an extensive and comparative literature analysis was not fully executed and, since such a study still seems desirable for finding trends in the discipline, this document is here included as Appendix H. The limited study, sampling three journals over fifty years, considered primarily: the independent or experimental variable used by the investigator; the material to which it was applied, identified both as to level of complexity, from molecule to group, and as to taxonomic position; the dependent variable or functional response of the living system; and the precision and sophistication of experiment and analysis, as indicated by the use of the resources of mathematics and physical science.

In nearly two-fifths of the papers sampled, the experimenter did not manipulate his material but used an 'endogenous' variable, such as age, and described some accompanying change. About one-fifth of the experiments involved drug administration, more in past decades than at present (radiation is now used increasingly); and metabolism or nutrition entered into a fourth of the investigations, at least in part as an independent variable. Electrical and other physical or chemical variables were used surprisingly little. The

response observed involved metabolism in two-fifths of all reports; growth, in one-eighth; and some neurophysiological behavior also in one-eighth.

About half the experiments involved homeotherms (mainly sub-human mammals); 10% were on man (16% of physiologists are M.D.'s); and 15% were on vascular plants (20% of physiologists are in the plant area). Plant physiologists are more likely ($2/3$) to study the whole organism than are animal physiologists ($1/3$), especially the central ones. Even one-fifth of bacterial physiologists work at the level of the multi-cellular organism, being concerned with host-parasite interactions. Considered together, physiologists study whole organisms two-fifths of the time; organs and organ systems, one-fourth of the time; and cells and tissues, one-fifth of the time. More recent effort is clearly moving toward the cellular level; and it is significant that 6% of physiological papers fall in the cell category while only 4% of the investigators call themselves general physiologists.

Over the half-century, statistics were judged applicable in nearly all cases, mathematics only rarely at first. There has been an encouraging increase over time in the skill with which statistics have been used in designing and analyzing experiments, although analysis lags, and in the use of mathematics in theoretical interpretation. Chemistry, despite the separation of biochemistry, has had a large and improving role in physiological experimentation; and the use of physics has increased considerably, in techniques more than in conceptualization. Indeed, the indications are clear that biophysics is ready to follow the course of biochemistry as a separate entity. Despite these gains, the use of the basic tools of mathematics and the physical sciences is meager and reflects the feeling of physiologists, half of whom regard their training in physics, chemistry, and biochemistry as inadequate.

The stream of physiological research is fullest in the East North Central and the Middle Atlantic sections of the country; shallow in the South and Mountain sections. This order holds, despite some quantitative changes over time, for number of published articles, number or financial support of current projects, and total doctoral theses or those of the present population of physiologists. Departmentwise, the preclinical departments dominate the picture, with non-medical ones next and the clinical and agricultural groups lower. About three-fifths of all published articles and Ph.D. theses in the physiological area emanate from preclinical departments and two-fifths of the supervisors of doctoral research are in these. Physiological publications, in the journals sampled, are rising from liberal arts colleges and zoology-biology departments, and from public compared to private universities. They are supported increasingly by extra-mural funds.

VIII

RESEARCH FACILITIES AND SUPPORT

CONDITIONS OF RESEARCH

Availability of Equipment

The availability of laboratory materials and equipment is a major determinant of both the amount and kind of research undertaken and the precision with which it is accomplished. A good supply is important not only in the actual prosecution of scientific research; but also in supporting the feeling of freedom to act, so valuable to morale. Yet a majority of the physiologists questioned by the Survey indicated that some or much improvement was needed in their research facilities. Over half (55%) expressed satisfaction with their living materials and other supplies, but about the same proportion felt that some or much improvement was needed in their laboratory equipment (56%) or in their technical facilities (53%). These data, given in detail in Table VIII-1, are fairly representative for all types of physiologists, although central animal physiologists tended to be less satisfied with their living materials and plant physiologists, with other supplies (Q, I, 91-93). These reactions may partly reflect the effectiveness of commercial supply houses in anticipating and meeting the demands of physiologists.

TABLE VIII-1. ADEQUACY OF RESEARCH FACILITIES AS EXPRESSED BY PHYSIOLOGISTS ACTIVE IN RESEARCH (Q, II, 130 based on Q, I, 91-93).

	Satisfactory As It Is Now %	Some Improvement Needed %	Much Improvement Needed %	No Ans. %	Total %
Living material—plants or animals	55	28	8	9	100
Supplies other than living material	55	33	6	6	100
Laboratory equipment	42	44	12	2	100
Technical facilities—histological photographic, etc.	42	37	16	5	100
Repair and replacement facilities	38	40	18	4	100
Laboratory space	36	34	27	3	100
Storage facilities	33	35	27	5	100
Research assistance	27	39	30	4	100
N					3981

Physiologists working in industry and governmental institutions are more likely (over half) to be satisfied with their laboratory equipment (55%) and space (45%) than are those in academic ones (37%, 33%) (Table VIII-2). Quite obviously the material resources of universities and colleges do not compare with those of industry nor of government agencies, once an appropriation is secured; academic workers are, however, unquestionably better off than before extensive grant funds became available. In these data, of course, adequacy is largely a subjective judgment, relative to possible extremes of need or desire, and it is interesting that laboratory equipment, space and living materials for teaching purposes are perceived as only slightly less adequate than those for research (Q, I, 110-113). Academic physiologists expressed a need for improvement in research personnel, presumably in number mainly, more than did those in government or industry. The situation is similar to that revealed in 1945 by the Adolph Committee—over 80% of their sample expressed satisfaction with research (and teaching) conditions in general, but only one-fourth had adequate technical help. These physiologists also do not as often possess the material resources necessary to attract

TABLE VIII-2. RELATION BETWEEN EXPRESSED ADEQUACY OF RESEARCH FACILITIES AND TYPE OF INSTITUTION IN WHICH EMPLOYED (Q, II, 131).

	Type of Institution		
	Academic %	Industrial %	Government %
Laboratory equipment			
Satisfactory as it is now	37	53	57
Some improvement needed	47	36	36
Much improvement needed	15	9	9
No answer	1	2	2
Total	100	100	100
Living material			
Satisfactory as it is now	53	60	60
Some improvement needed	31	20	24
Much improvement needed	8	6	7
No answer	8	14	9
Total	100	100	100
Laboratory space			
Satisfactory as it is now	33	44	45
Some improvement needed	33	37	36
Much improvement needed	31	15	16
No answer	3	4	3
Total	100	100	100
Research assistance			
Satisfactory as it is now	26	37	24
Some improvement needed	39	44	41
Much improvement needed	32	16	32
No answer	3	3	3
Total	100	100	100
N	2611	406	552

the optimal research personnel for their programs. To the extent that discontinuity, as of short-term grants, rather than poor salaries or equipment is responsible for this difficulty, a continuing fund to underwrite salaries of trained research technicians who could be shifted from one research project to another would help.

The supply of commercial equipment for research and teaching was investigated in Project 9 of the Survey, by questionnaires distributed to companies exhibiting at a meeting of the Federation of American Societies for Experimental Biology. Of 84 firms responding, three supply physiologists exclusively, ten others are chiefly concerned with the area of physiology, and four-fifths are interested in design and manufacture as well as in distribution of relevant equipment. With so many companies supplying physiologists and able to help in developing apparatus, quality and variety should be favorable; and, in fact, the demands of research scientists do influence the production of equipment and supplies to a large extent. There is no consistent company effort, however, to check on the performance characteristics of their products, although those primarily supplying physiologists are most likely to do so; so investigators must take the initiative in suggesting design improvement. Items in increasing demand are the ones which have sold most consistently over a long period; so presumably the volume of physiological research is generally on the increase but with little change in basic procedures. In most consistent demand are instruments for measurement, for introducing variation (including drugs) and recording effects, and special equipment of all types (*Preliminary Report VIII-B*).

Supply of Experimental Animals

The procurement of animals for physiological research presents two problems not present for plants or bacteria; the uncertain sources of supply and consequent variance in cost and quality, and opposition to the use of animals for research by some who perceive para-human qualities in pets, particularly dogs and cats. Table VIII-3 shows the rat to be most used by physiologists in research, frogs for teaching, and dogs and rats equally when both teaching and research are involved. These questionnaire reports agree reasonably well with the analysis of published research (Table VII-7): warm bloods were used 72% and 67%, respectively; cold bloods, 6% and 10%. Relatively inexpensive animals, such as frogs, are favored when large numbers are used by unskilled manipulators, presumably in general college courses. The extent to which the cost or quality of various laboratory animals presents a problem to physiologists is shown in Table VIII-4. Results of the questionnaire to physiological supply houses (Project 9) showed that five companies supplying animals breed their own stock to guarantee quality; and that white mice, white rats, and guinea pigs are the animals most frequently sold. Replies to

TABLE VIII-3. USE OF ANIMALS IN PHYSIOLOGICAL RESEARCH AND TEACHING^a
(Preliminary Report VII-C, p. 3; based on Q, I, 65 and II, 155).

	Research %	Teaching %	Teaching & Research %
Use of Animals ^b	34	4	28
Rats	36	17	26
Dogs	14	6	27
Mice	11	7	5
Rabbits	8	13	5
Cats	4	3	5
Monkeys	3		2
Guinea pigs	3	4	2
Frogs	1	27	6
Turtles	1	1	
Other	3	4	2
No answer	18	17	20
Total	100	100	100
N	1458	159	1248

^a Only animals first mentioned by respondents have been analyzed and tabulated; second, third, etc., animal choices are not represented.

^b 33% used no animals; 1% did not answer; total 100%. N = 4363.

the questionnaire to physiologists indicate that turtles, monkeys, frogs, rabbits, and guinea pigs are most often obtained from dealers, but that an appreciable proportion of workers breed their own mice, rats, and guinea pigs. Dogs are obtained from pounds and from dealers in almost equal numbers; cats, mostly from dealers (Q, II, 156). With animals from pounds, quality is the main problem; with those from dealers, the problem of quality remains serious but cost is a higher factor; while for those who bred locally—mostly mice and rats—cost is much less of a problem and quality is more readily attained. These data, condensed in Table VIII-5, apply to both teaching and research use: 28% of the physiologists reporting used animals in both teaching and research; 34% used them in research alone; and only 4%, in teaching alone (Table VIII-3).

Important advances in the animal supply may be expected from the work of the Institute of Laboratory Animal Resources of the National Academy—

TABLE VIII-4. EXTENT TO WHICH COST AND QUALITY OF ANIMALS ARE PROBLEMS
IN THEIR USE IN PHYSIOLOGICAL RESEARCH AND TEACHING (Q, II, 155).

Animals	Cost %	Quality %	N
Monkeys	64	56	161
Dogs	39	53	862
Cats	39	51	345
Guinea pigs	32	37	303
Mice	21	37	564
Rats	24	30	1412
Rabbits	30	29	676
Frogs	13	30	295
Turtles	16	20	75

TABLE VIII-5. RELATION BETWEEN SOURCES AND COST AND QUALITY OF ANIMALS USED IN PHYSIOLOGICAL RESEARCH AND TEACHING (Preliminary Report VII-C, p. 10).

	Source of Animals					
	Pound		Dealer		Breed Own	
	Cost %	Qual. %	Cost %	Qual. %	Cost %	Qual. %
Problem	25	45	33	42	18	30
Not a problem	74	54	66	56	81	65
No answer	1	1	1	2	1	5
Total	100	100	100	100	100	100
N	218	218	1220	1220	414	414

Research Council. Various committees are working on: genetic, parasite, and nutrition standards of animals; a handbook of breeders and evaluation of their materials; collection of animals in nature, especially monkeys; courses for animal caretakers at the technician level; and other helpful matters.

Legal and Regulatory Limitations

One important factor in the procurement of animals, particularly dogs and cats, is the existence of antivivisection laws and other regulations limiting the use of animals for experimental purposes. Certainly, with the U.S. dog population increasing at four times the human rate and with two-thirds of households including one or more dogs, there is no dearth of animals (60a). The National Society for Medical Research provided the Survey with a conspectus of state laws restricting or regulating animal experimentation. These vary greatly from state to state and also are often in conflict with city regulations; so it is not possible to assess fully the effect of antivivisection laws on research. Nevertheless, a direct relationship was found between the cost of animals and the legal status of animal experimentation. In states permitting vivisection, only 34% of the respondents using dogs and cats (458) found that costs were a problem; in states with antivivisection laws, 62% of the respondents (88) found costs high (*Preliminary Report VII-C, p. 11*).

According to foreign physiologists attending the International Physiological Congress held in Montreal in September, 1953, attitudes toward and restrictions on animal experimentation vary widely about the world. In Mexico, Japan, and Yugoslavia there are no legal restrictions on animal experimentation, and in Japan there are no social objections either, so animals can be obtained without difficulty. Likewise in Mexico, advertisements for animals do not evoke any criticism. In Italy, where no antivivisectionists are active, the purpose of each experiment and the anesthetic used must be recorded but there are no restrictions; in Argentina, despite some antivivisectionist groups, animal experimentation is not hampered; and in Switzerland it is tacitly understood that experiments on warm-blooded animals are done under anesthesia, and the antivivisectionist movement does not seriously hamper animal

use. There is, however, some difficulty in obtaining large animals there and many institutes breed their own stock. In Austria and Germany restrictive Nazi laws survive but are dead letters. German professors supervise animal experiments which require special training and facilities. In Austria a permissive law on animal experimentation is being considered, but no difficulties in procurement now exist and the general public shows understanding.

In Denmark and Sweden specific national laws recognize and regulate the use of animals for experimental purposes. Antivivisectionists in Sweden were very active several years ago—they no longer have an effective status—and there, in contrast to Denmark, animal costs are high and dogs, especially, cannot be obtained in adequate quantity. Some institutes breed their own animals, and it has been suggested that some state-supported organization plan the breeding and maintenance of experimental animals. Licensing and record keeping have also raised some problems for animal experimenters in both countries.

Great Britain probably has the most restrictive legislation concerning animal use of any of the countries considered. The antivivisectionist movement is quite strong in the United Kingdom, as is the general prejudice against working on animals. Some laboratories find it impossible to breed and maintain their own animals in the face of local restrictions, and it is often difficult to plan experimental work which involves using many animals. A special national license is issued to investigators, however, which permits them to use live animals for experimental purposes. All laboratories are open for inspection by a representative of the Home Office; and any public charge by an element of the lay public regarding mistreatment of animals by physiologists is thus a libel against the government, which will defend against such charges or suits. A Research Defense Society (analogous to the National Society for Medical Research in the United States) promotes the experimental use of animals, counteracts the antivivisectionist activity, and is attempting to improve the supply of animals. The national licensing procedure has tightened physiological experimentation in the view of some, but other workers have been so frustrated that they have had to visit other countries in order to do necessary experiments, including the testing on animals of new operations for humans.

In the United States the use of animals for experimental purposes is hampered by some restraining legislation and by activities of antivivisectionist groups. Due primarily to the National Society for Medical Research—an organization supported by many scientific and medical organizations, including the American Physiological Society—supportive legislation, recognizing the need of animal experimentation, is being enacted in more states and cities. The Animal Care Panel of the American Physiological Society has also helped by recommending standards and rules for the use and care of animals and circulating them to all laboratories known to use laboratory animals.

TABLE VIII-7. PERCENTAGE OF RESEARCH PHYSIOLOGISTS INDICATING ONE OR MORE SOURCES OF EXTRAMURAL RESEARCH FUNDS (Q, I, 86; II, 115).

	Central				Peripheral					Total %	% of Grants ^b
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %		
Govt., non-military ..	66	58	68	65	65	56	61	60	62	63	39.4
Govt., military	33	15	21	28	26	14	33	18	24	25	15.6
Foundation	39	27	27	35	44	21	33	42	39	38	23.8
Indust., commerc.	26	45	33	30	31	50	39	36	35	34	21.3
Total	#	#	#	#	#	#	#	#	#	#	100
N	562	162	84	808	1043	232	181	45	1501	2309 ^a	
Est. total physiologists.										2904	

Percentages total more than 100 because respondents may have indicated that their research funds come from more than one source.

^a Does not include 1550 respondents who indicated their only source of research funds is allocation of funds from within their institution, or 122 respondents who did not answer that question.

^b 160% of respondents reported a source of funds in some category, = 3694.

military agencies, less than 0.5% from industrial or commercial sources, and 29% from private foundations or societies (Survey Project 14A, Table 5). The sources of research support underlying the published research, sampled over a fifty-year period, could be estimated on the reasonable assumption that the large proportion of papers not specifying the source were supported intramurally (Table VII-7). Over half had local support; nearly one-fifth each, government and foundation; and a tenth, society support—by the 1940's.

If the data in Table VIII-6 are used as a guide, about 2900 physiologists—equivalent to the 2309 Survey respondents—receive some or all of their

TABLE VIII-8. GOVERNMENT AND FOUNDATION SUPPORT OF SCIENTIFIC RESEARCH AND DEVELOPMENT, 1953/54.^a

A. By Amount ^b			
	Basic	Applied	Total
Federal government (1954)			
Military (Dept. of Defense)	\$ 20	\$1263	\$1283
Non-military (all other)	96	383	479
43 Foundations (1953)	17	9	26
Total	\$133	\$1655	\$1788
B. By Use ^c			
Military	1.6	98.4	100%
Non-military	20.1	79.9	100%
Foundation	64.7	35.3	100%
C. By Source ^c			
Military	15.0	76.3	71.8
Non-military	72.4	23.1	26.8
Foundation	12.6	0.6	1.5
Total	100%	100%	100%

^a Sources: Refs. 100, p. 27; 102, p. 15. The government data represent actual expenditures. The two years 1953/1954 are the nearest years for which comparable data were available at the time of preparing this report.

^b Dollar figures in millions.

^c Percentages.

research support from outside their own institutions. Table VIII-7 shows the sources of this support, about 39% from non-military funds, and 24% from foundations. In contrast to the very scant industrial support indicated in the medically-oriented projects registered with BSIE, 21% of the research physiologists say they receive some support from industry. No analysis was made in relation to academic, governmental or industrial employment.

A study (89) of medical research in 74 major medical schools considers the funds (\$66.3 million) and the faculty (4607 full-time equivalent men). Clinical areas account for 48% of the funds and 47% of the faculty; pre-clinical ones, for 52% and 53%, respectively. Likewise, as between an administrative location in or out of the medical school, funds and faculty are 68% and 67%, respectively, inside and 32% and 33% outside. Clearly the distribution is equitable between preclinical and clinical areas and between medical and other university units; and the average support per man is \$14,500—in excellent agreement with the \$14,000 estimate of an average Public Health Service Grant (see below). (In comparison, the average funds per man for teaching assistance and supplies, in all departments giving courses with physiological content in 1954, were \$2600—or \$7000 if remodeling costs are included. These figures, derived from Survey Project 18H, are based on reports from chairmen of 71 large universities and involve only 200 faculty members.)

In the medical research area, which includes most central animal physiologists and is 70% basic in orientation, one-third of the funds is intramural unbudgeted and another eighth is budgeted; so about 60% of the funds is extramural (89). Of this portion, 55% comes from government (0.7% from non-military agencies), 29% from foundations, 11% from industry, and 5% from other sources. The proportions in Table VIII-6, from questionnaire responses of physiologists, are: 55% government, 29% foundations, and 21% industry. Extramural support acknowledged in physiological articles published in the 1940's (Table VII-7) was 39% to government, 43% foundations, and 18% other sources—a strong independent verification, despite the different base of data, of the rapid recent rise of government support in the field of physiological research.

A summary of research support by government and by the major foundations making grants in the natural and social sciences, in Table VIII-8, shows that over-all (in contrast to the medical area) applied and developmental research is mainly supported by the Department of Defense. It is not generally possible to determine how much of the research and development funds of other agencies is related to military needs, nor how much of the military budget finally appears in the form of research contracts or grants through non-military or other agencies; also considerable basic work is probably buried in government-supported work with applied goals. However, it

TABLE VIII-9. COMPARATIVE AMOUNTS OF GOVERNMENT AND FOUNDATION SUPPORT OF SCIENTIFIC RESEARCH AND DEVELOPMENT, 1953/1954.^{a, b}

Source of Funds	Life Sciences				Phys. Sci.	Soc. Sci.	Total
	Biol.	Med.	Agric.	Total			
For basic science research							
Military ^c	\$0.8	\$ 1.2	\$0	\$ 2.0	\$18.0	\$0	\$20.0
Non-military ^d	8.7	17.4	4.6	30.6	64.5	0.9	96.1
Foundation ^e	3.5	3.8	0.7	7.8	1.8	6.9	16.8
For applied and developmental research							
Military	\$30.2	\$25.1	\$ 0	\$ 55.3	\$1199.0	\$8.7	\$1263.0
Non-military	26.4	52.7	28.3	107.4	245.6	6.1	382.8
Foundation	0.2	3.9	0.4	4.5	0.5	4.1	9.2
Total							
Military	\$30.9	\$26.3	\$ 0	\$ 57.3	\$1216.9	\$ 8.7	\$1282.9
Non-military	30.0	70.1	32.9	138.1	310.1	13.0	478.9
Foundation	3.7	7.7	1.0	12.3	2.4	11.0	25.9

^a Refs. 100, pp. 27-31; 102; p. 15. Additional data derived.

^b Dollar figures in millions. Totals will not add due to rounding.

^c Department of Defense. Military-related expenditures of other departments are not shown.

^d All other departments and agencies.

^e 43 of the 77 large foundations supported scientific research in 1953.

seems that little of the military research and development budget is overtly directed to basic research, and only about 20% of the funds of non-military government agencies, in comparison with nearly 65% of foundation funds. Table VIII-9 provides a further analysis of these expenditures by area of science. The ratio of non-military government support to foundation support of basic research in the physical sciences is 35 to 1, while in the life sciences it is only 4 to 1. In applied and developmental research this ratio is 450 to 1 in the physical sciences as against about 24 to 1 in the life sciences. Foundation support, of course, is largely for medical research, as is the rapidly rising support from the National Institutes of Health. For medically-oriented research (Table VIII-10), government military grants are often \$50,000 or more, but 55% are between \$5000 and \$20,000, and 75% of the non-military grants are in that range. Most industrial and foundation support,

TABLE VIII-10. SOURCE AND AMOUNT OF FUNDS OF PHYSIOLOGICAL RESEARCH PROJECTS (PRINCIPALLY MEDICALLY ORIENTED) REGISTERED WITH THE BIOLOGICAL SCIENCES INFORMATION EXCHANGE, 1952 (Preliminary Report VI-F, p. 12; Survey Project 14A).

Grant Amount	Government		Private Industry %	Foundations and Societies %
	Non-Mil. %	Military %		
Less than \$1000	2	1	13	12
\$1000-\$4999	6	1	56	12
\$5000-\$9999	41	14	19	51
\$10,000-\$19,999	34	41		16
\$20,000-\$24,999	8	10		3
\$25,000-\$49,999	4	7	6	1
\$50,000 or more	5	26	6	5
Total	100	100	100	100
N	2351	272	16	1277

on the other hand, is in relatively small amounts and presumably given to individual experimenters for specific research projects.

Amount and Adequacy of Support

Responses to the Survey questionnaire showed the median fund for a research project was close to \$10,000. Research grants by the U.S. Public Health Service averaged \$11,000 in 1955 (ref. 115; fellowships averaged \$3700, corrected); and over the eight years from 1945 to 1953, \$100,000 was given for 7,000 grants, an average of \$14,000 (17). Table VIII-11 shows the support for different branches of physiology and the relation between this and the judged adequacy. The proportion of physiologists reporting adequate funds rises, with the amount of funds available, to a plateau near the median and then actually decreases some at top levels. Presumably the sum of \$10,000 for current expenses is about what most physiologists care to spend effectively as individual investigators. With more money, except for equipment and apparatus, the individual recipient may project more experiments than he can adequately supervise or interpret. Other limitations, as of time or space, may also put a ceiling on the support required.

The funds available for the research projects current at the time of the Survey seemed very adequate to 28% of the respondents and adequate to another 50%, with only 16% reporting funds inadequate and another 4% reporting them very inadequate. There was little deviation from the norm, except that plant physiologists were less likely to report very adequate support (Q, I, 88; II, 122). Comparing animal and plant groups, funds were judged very adequate by 30% and 21%, respectively; 58% and 29% must seek funds; and 26% and 45% have industrial grants. This latter difference probably reflects the dubious policy of the Department of Agriculture of not making extramural grants. Those reporting inadequate support were, not surprisingly, for the most part engaged in projects receiving only small funds (Table VIII-11).

TABLE VIII-11. PERCENTAGE OF PHYSIOLOGISTS REPORTING TOTAL AMOUNTS AND ADEQUACY OF FUNDS AVAILABLE FOR RESEARCH PROJECTS IN WHICH THEY WERE ENGAGED, 1952 (Q, I, 87; II, 122, 126).

Project Total	Central				Peripheral					Total %	Total N	% Reporting Adequate Funds
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %			
Less than \$1000..	13	14	20	14	11	12	11	9	11	12	487	47
\$1000-\$4999 ...	17	28	19	20	18	25	18	19	19	19	777	69
\$5000-\$9999 ...	19	20	16	20	16	18	16	12	16	17	695	83
\$10,000-\$19,999 ..	17	12	14	15	16	16	14	20	16	16	623	87
\$20,000-\$29,999 ...	10	4	5	8	10	9	7	2	9	9	351	87
\$30,000-\$39,999 ..	4	2	2	3	5	4	5	5	5	4	177	94
\$40,000-\$49,999 ..	3	1	3	2	4	1	2	1	3	3	108	90
\$50,000 or more...	10	8	8	9	12	9	15	10	12	11	431	90
No answer	7	11	13	9	8	6	12	22	9	9	332	
Total	100	100	100	100	100	100	100	100	100	100		
N	835	336	152	1323	1710	507	347	94	2658		3981	3759

Funds for physiological research seem, for most investigators, adequately underwritten; it is appropriate to question whether the programs themselves are adequate for the financial support they enjoy and whether distribution is optimal. The Survey data are general and it would be advisable to explore in detail differences in the needs of research workers in various fields of physiology. Academic, governmental, and industrial situations differ greatly, as do basic research and that which is primarily applied or developmental with a medical or agricultural orientation; and there is considerable variation in methods of securing research support and in the bases on which funds are made available. Only by a detailed analysis can the future requirements of physiological research be adequately determined.

From 1940 to 1953, total research and development funds rose from 0.1 to 1.9 billion dollars(83). In terms of 1953 dollars, the increase was from 0.22 billion in 1940, through a peak of 2.6 in 1945, to 1.9 in 1953. Life sciences received a tenth of the R&D funds in 1953, divided between biology (63 million), medicine (84 million), and agriculture (36 million). The fraction for pure research is estimated to be 27 million(101). Over the same period the number of scientists about doubled (92,000 to 190,000; ref. 93), so the purchasing power per scientist has increased over four-fold. The figure may be lower for all life sciences, but animal physiologists have probably experienced a change of this order.

Some indication of the use of these funds in the medical research area is available from a study by Endicott and Allen(17). In 1948 some 370 published papers mentioned support by a Public Health grant, and in 1951, 935 papers. Grants made totaled 0.8 million in 1946, 3.4 in 1947, 10.9 in 1949, and 13.0 in 1950. If a lag of one year between grant and publication is assumed, the cost per article published in 1948 was \$9200, and in 1951, \$13,900; for a two-year lag, the figures are, \$2000 and \$11,700. Discounting the aberrant 1946 figure, a research article cost about \$9000 in 1947 and about \$13,000 in 1950.

Academic physiologists are less likely than any other group to find their research funds adequate—74%, as compared to 82% of those in government and 86% in industry—and 75% of the investigators have some responsibility for obtaining their own funds; 35% find this fairly or very difficult (Q, II, 124-125). At the other end of the spectrum, industrial physiologists most frequently obtain large funds, most often adequate, with the least difficulty, and with a modicum of responsibility. Academic physiologists thus sacrifice both income and easy research support in order to obtain that independence of thought and action, so largely limited to academia, from which can flower scientific creativity.

SUMMARY

The wherewithal for research is reasonably adequate, as judged by investigators in physiology. Over half are fully satisfied with supplies, including living material (animal physiologists have more trouble here); two-fifths, with laboratory equipment and special technical facilities; one-third, with space; a fourth, with assistants. In no category (including funds) did as many as a third of the respondents feel that much improvement (compared to some or none) is needed. In academia, as usual, the resources are less bountiful than in government or industry. Many commercial firms develop as well as supply physiological apparatus and largely welcome guidance from investigators.

Two-thirds of all physiologists use animals; only a small percentage for teaching alone—presumably in general courses, where the frog is favored. For research alone, the rat is most used; for research and teaching, dogs and rats. Rodents are bred commercially and in many laboratories; dogs are obtained equally from pounds and from dealers—the latter with higher price and quality. Price of dogs is a serious problem twice as often in states with restrictive laws as in those without; legal strictures on animal experimentation in most other countries are minimal, in a few they are so severe that men go abroad for important investigations. Since humane standards obtain in countries or states without as well as with antivivisection activity, the main effect of this is to make research more expensive and inconvenient, not to curtail use of animals or to improve their care.

Funds for research are entirely intramural for two-fifths of the projects, partly so for a like fraction. Outside funds, as reported by Survey respondents, come from non-military (2/5ths) and military (1/7th) government agencies, foundations (1/4th), and industry (1/5th). Industrial support is rarely reported to the Biological Sciences Information Exchange, so figures on its projects are, respectively, 62%, 9%, 29%, and 0.5%. Applied and developmental research is more supported by the Department of Defense; basic projects, two-thirds by foundations. Actually, considerable fundamental work is embodied in many researches supported by the military.

In the medically-oriented area, \$10,000 is the median support; government grants or contracts are mostly over \$5,000; those of foundations and industry, largely below. Four-fifths of all investigators, fewer plant physiologists, find their support adequate (perhaps a large enough fraction from the taxpayer's viewpoint); and adequacy of support does not closely parallel total amount. Over half of the projects in biophysics or environmental physiology are over \$10,000, less than a fourth of those in general and comparative physiology; yet only 3% of the workers in biophysics, 24% of the environmental, and 18% of the general physiologists feel their support is inadequate. In fact, a small fall in percentage adequacy occurs at the top levels of support.

It seems clear, on all counts, that today space and technical assistance are the main limiting factors for physiological investigators; indeed, the natural growth of the discipline and the relatively rapid increase in available funds, largely from government, have put a severe premium on buildings and on trained personnel—perhaps even on really competent scientists. These needs are beginning to receive attention from granting agencies.

The academic physiologist not only has more meager funds (and facilities) than his colleagues in government or industry; he must also, three-fourths of the time, scrounge for them himself—an activity distasteful and difficult to half of those who do it. With lower salaries and support but more freedom, the academic group is most active in research. Perhaps spiritual largesse with material strictures is indeed conducive to creativity, and the academic laboratory is the scientist's equivalent of the artist's garret.

IX

PROFESSIONAL COMMUNICATION: PUBLICATIONS AND SOCIETIES

PUBLICATION OF RESEARCH BY PHYSIOLOGISTS

Amount of Publication

Physiologists interviewed in the course of the Survey, queried on research publication, commonly responded that its aim is to inform others of the results of experiments. Underlying this intent to communicate were varying purposes: 'to add to knowledge', 'to establish a reputation', 'because it is expected', or, a cynical hope, that it might 'add to the height of the literature rather than to its breadth' (*Preliminary Report IV-H-2*, p. 17). Thus the goal of the research physiologist's effort is to present results and interpretations to other scientists for their criticism, acceptance and, perhaps, their stimulation. Acceptance is gratifying and provides psychological reinforcement for further research; effective and high productivity encourages further investigation and further communication of results and ideas.

Physiologists in research responded to the Survey questionnaire on the number of research papers published in the past three years (roughly 1950 to 1952), either as author or co-author. Table IX-1 shows that 10%, mostly

TABLE IX-1. PERCENTAGE OF RESEARCH PHYSIOLOGISTS PUBLISHING PAPERS AS AUTHOR OR CO-AUTHOR DURING A THREE-YEAR PERIOD (Q, I, 100; II, 139 corrected).

No. Papers	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
0	5	12	11	7	7	10	13	14	9	8
1-2	14	21	21	17	16	21	24	21	18	18
3-4	22	22	24	22	24	24	23	25	24	23
5-6	17	18	15	18	17	17	12	16	16	17
7-8	8	7	8	8	8	6	8	4	7	8
9-10	11	6	9	10	10	7	9	9	9	9
11-12	6	3	3	5	4	4	3	3	4	4
13-14	2	2	1	1	1	1	1	1	1	1
15 or more..	13	5	6	10	11	7	6	5	10	10
No answer ..	2	4	2	2	2	3	1	2	2	2
Total ..	100	100	100	100	100	100	100	100	100	100
N	835	336	152	1323	1710	507	347	94	2658	3981

animal physiologists who include many graduate students in their societies, published 15 or more papers during that period, while 8%, mostly plant or bacterial physiologists, published nothing. No correlations were made within this group; but possibly the non-publishers were largely employed in industry or government or had just entered on a career or were committed to teaching. Two-fifths each published one to four and five to fourteen papers, animal physiologists again falling more into the higher group.

The average publications of 4000 responding physiologists are 5.6 for three years or 1.7 per man per year. This is in good agreement with the average *Annual Review* (see below) citations (4300 a year for 2480 men) of 1.7 per man per year; but, since the number of men cited is substantially smaller than those publishing and since multiple citations of a paper are frequent, many published articles have not had attention in these reviews. Incidentally, even at 1.7 papers per man, 4000 physiologists would fill perhaps 100 volumes a year; so, besides multiple authorship, which may well cut the number to a half or a third, some of the publications reported by respondents must be brief abstracts or ephemeral materials.

On the other hand, it has been estimated(35) that over 20,000 (or 26,000; 52) journals dealing with biology (including metabolism) existed in the early fifties—say 7000 for physiological science and 2000 for physiology—as compared with 100,000 in all science(64); and, extrapolating Rothschuh's figures(72) to 1952, some 220,000 pages of original material in physiology were published that year—an average of 100 pages per physiology journal or 10 pages per biology periodical. If U.S. science constitutes a fourth of world science, and so published 55,000 pages in 1952, this would allow 7000 articles, averaging eight pages, or 1.7 per investigator.

The relation between amount of publication and some personal variables was also examined by the Survey. (See Chapter IV, Appendix.) As shown in Table IX-2, there is a curvilinear relationship between age of author and number of papers published, publication rate increasing rapidly to a peak in the forties and then remaining on a slightly lower plateau until it falls sharply after the sixties. Psychological studies indicate that an intensive research effort during their twenties is characteristic of eminently successful scientists; and, to the extent that such men gain their doctorates earlier, this is borne out by Survey Project 3D (*Preliminary Report IV-H-4*, Table 134). Little pre-doctoral research appears in professional journals in physiology, as is often the case in some other disciplines and, of course, a considerable time-lag is common between the submission and publication of a paper. Because of the wide age groupings, the data in Table IX-2 are not decisive concerning the psychological findings; they do indicate, however, a continuing period of growth in productivity, as evidenced by publication, during the early years of a career.

TABLE IX-2. RELATIONSHIP BETWEEN NUMBER OF RESEARCH PAPERS PUBLISHED IN A THREE-YEAR PERIOD AND PERSONAL AND EMPLOYMENT BACKGROUND VARIABLES (Q, II, 141).

Variables	Number of Papers			N
	5 or More %	0-4 %	Total %	
Age				
Under 30	29	71	100	417
30-39	47	53	100	1737
40-49	60	40	100	1021
50-59	54	46	100	476
60-69	56	44	100	185
70 or older.....	34	66	100	32
Annual salary				
Under \$5000	24	76	100	711
\$5000-\$6999	41	59	100	1362
\$7000-\$9999	63	37	100	1135
\$10,000 or over.....	73	27	100	638
Type of institution				
Academic	53	47	100	2555
Industrial	27	73	100	398
Government	52	48	100	543
Major function				
Research	50	50	100	1833
Teaching	22	78	100	329
Admin.	40	60	100	164
Undergraduate grade average				
A	61	39	100	485
A-	56	44	100	1023
B+	50	50	100	1177
B	40	60	100	686
B- or lower.....	38	62	100	419

The salary level above the third salary quartile (\$9000) also has a direct relationship to the number of papers published. The Survey data do not show the amount of co-authorship, common in joint or supervised research and in organized projects. To the extent that high salary represents professional success, the higher publication volume of those earning over \$10,000, as compared to those earning less, may indicate merely that success follows publication volume, that more work is done through others, that the investigator has more opportunity for research, or even that editors are more likely to accept the work of successful scientists. Holding salary level and type of institution constant reveals a direct relationship between amount of publication and degree of freedom of choice in research (Q, II, 144, 145); and the few papers published by industrial physiologists may reflect not only the character of developmental research, but also the limited freedom of research direction in industry. The higher output of primary administrators than teachers suggests publication with junior associates. Undergraduate grade-average also parallels publication level. Perhaps this is related to the concentration of high-grade men in academic institutions; nine times as many

physiologists who had A or A— rankings are in academic institutions as in industry, and six times as many as in government (Q, II, 80).

Similar correlations between the amount of research publication and conditions under which research is undertaken are shown in Table IX-3. There is a direct relation between publication and the amount and adequacy of research funds. Those who have complete responsibility for obtaining research funds tend to publish more than those who have no responsibility; although, again, leadership of a group, entailing such factors as co-authorship, responsibility to publish results, and independence of action, may be involved. Among those partially responsible for obtaining their research funds, publication is most likely if support was not difficult to obtain. Here also, cause and effect may be confused; also such factors as classified projects in government-sponsored research may prevent normal publication of results. Finally, absence of freedom in choosing research problems is clearly related to less publication; but at the other end of the scale, great or complete freedom is not so different from some freedom. The number of physiologists with no

TABLE IX-3. RELATIONSHIP BETWEEN NUMBER OF RESEARCH PAPERS PUBLISHED IN A THREE-YEAR PERIOD AND VARIABLES IN RESEARCH CONDITIONS (Q, II, 142-143).

Variables	No. Papers			N
	5 or More %	0-4 %	Total %	
Amount of research funds				
Less than \$1000.....	21	79	100	467
\$1000-\$4999	38	62	100	762
\$5000-\$9999	54	46	100	681
\$10,000-\$19,999	64	36	100	612
\$20,000 or more.....	65	35	100	1047
Adequacy of research funds				
Very adequate	53	47	100	1084
Adequate	52	48	100	1934
Inadequate	45	55	100	633
Very inadequate	31	69	100	156
Responsibility for obtaining funds				
Complete	64	36	100	883
Major	59	41	100	860
A little	48	52	100	841
None	35	65	100	1206
Difficulty of obtaining funds ^a				
Very difficult	40	60	100	171
Fairly difficult	52	48	100	707
Not too difficult	62	38	100	1269
Not difficult at all.....	64	36	100	321
Amount of freedom in choosing problem				
Complete	57	43	100	2044
A great deal	51	49	100	1090
Some	36	64	100	407
Not much	25	75	100	196
None	18	82	100	134

^a Among those who have some responsibility for obtaining their research funds.

freedom is, however, relatively low. All these data are general; fuller investigation of interrelations suggested by Tables IX-2 and IX-3 would require segregation of sub-groups. Rich material remains in the Survey cards; and since many other factors may be operating, general conclusions now must be made with caution.

Significance of Publication

As a measure of the quality or significance of research published by physiologists, Survey Project 12C studied the citations in *Annual Reviews* of papers by members of the American Physiological Society, the Society of General Physiologists, and the American Society of Plant Physiologists. *Annual Reviews* for 1950, 1951, and 1952 were analyzed in the fields of Physiology, Plant Physiology, Medicine, Psychology, Physical Chemistry, Biochemistry, and Microbiology. The *Annual Review of Nuclear Science*, which first appeared in 1952, was analyzed for only one year. Tabulation did not eliminate multiple citations to the same paper, so the data include such duplications.

As shown below, members of the APS, the largest society, received a greater total of citations; citations per member was highest for members of the SGP, with the smallest membership. There is some overlap in members: five physiologists belong to all three societies, 26 to both SGP and ASPP, and 79 to APS and SGP, but only one belongs to APS and ASPP. Thus, 94% of the membership of APS and 97% of ASPP, but only 43% of that of SGP, is unshared. The data below include multiple memberships. It is interesting that four persons who belong to both SGP and ASPP were among the ten highest in each society in number of citations.

CITATIONS IN ANNUAL REVIEWS, BY SOCIETY MEMBERSHIP (Data from Survey Project 12C).

Society	Total Members	Total Citations	Average Citations per Member
APS	1310	7492	6
SGP	192	2049	11
ASPP	979	3313	3

Table IX-4 presents, for the three societies, the frequency of citation ranges—corresponding roughly to high, medium, low, and no citations—and for each range, the number and percentage of members and the average number of citations. The high range for each society is that of the ten (or more in case of ties) members within it who received most citations in the eight *Annual Reviews*. The SGP has the largest proportion of members receiving 16 or more citations, and one-fourth of its members are in the middle and high ranges, in contrast to only 9% of APS members and 5% of ASPP

TABLE IX-4. DISTRIBUTION OF ANNUAL REVIEW CITATIONS, BY SOCIETY MEMBERSHIP (Survey Project 12C).

Citation Range	Number Members	% of Membership	Total Number Citations	Average Number Citations
American Physiological Society				
39-75	11	1	583	53
16-38	100	8	2161	22
1-15	893	68	4748	5
0	306	23	0	
Society of General Physiologists				
38-81	11	6	601	55
16-37	36	19	833	23
1-15	111	58	615	6
0	34	17	0	
American Society of Plant Physiologists				
34-133	12	1	692	53
16-33	42	4	955	23
1-15	410	42	1666	4
0	515	52	0	

members. The top of the high range is greatest for ASPP members, 133 citations as compared to 81 for APS and 75 for SGP members; but the ASPP also has by far the largest proportion of members (over half) receiving no citations.

The number and proportion of total citations, and the number and proportion of members represented, is shown for each of the three societies in Table IX-5. Aside from the weighting of the other groups in their appropriate review areas, the proportion of SGP members represented in the several area reviews is regularly higher than that of other society members. Presumably the work of general physiologists is of interest in a greater variety of fields than is that of more specialized animal or plant physiologists—an objective justification of the term 'general'.

USE OF PUBLICATIONS BY PHYSIOLOGISTS

Keeping Abreast of Research

The problem of maintaining contact with current research faces all scientists. Rothschild (72) reports an increase of original publication in physiology (within his definition) from 46,000 pages in 1920 to 192,000 in 1950, and calculates that several years of full-time reading would be required for one year's output. (The number of physiologists has increased some six- to eight-fold in this 30-year period, if the U.S. figures can be generalized; so the four-fold rise in pages shows a real tightening in presentation.) Progressive specialization and selectivity in reading original articles,

TABLE IX-5. REPRESENTATION OF MEMBERSHIP IN THREE PHYSIOLOGICAL SOCIETIES IN *Annual Review* CITATIONS, 1950-52 (Survey Project 12C).

Annual Reviews 1950-52	Total No. Citations (Nearest 100)	Citations for Soc. Members (Nearest 10)	% of Total Citations by Soc. Members	No. Members Cited	% of Membership Represented
American Physiological Society (Membership, 1310)					
Physiology	24,700	4480	18.1	853	65.1
Medicine	17,500	1280	7.3	439	33.5
Biochemistry	29,400	1040	3.5	306	23.4
Psychology	7,300	370	5.1	132	10.0
Microbiology	14,400	210	1.5	87	6.6
Plant physiology	10,200	100	0.9	60	4.6
Physical chemistry	12,200	30	0.2	16	1.2
Nuclear science (1952).....	5,300	130	2.4	70	5.3
Society of General Physiologists (Membership, 192)					
Physiology	24,700	440	1.4	111	57.8
Plant physiology	7,300	710	9.7	76	39.6
Biochemistry	29,400	480	1.6	74	38.5
Microbiology	14,400	250	1.7	51	26.6
Medicine	17,500	60	0.3	29	15.1
Physical chemistry	12,200	90	0.7	25	13.0
Psychology	7,300	30	0.4	12	6.2
Nuclear science (1952).....	5,300	50	0.8	28	14.6
American Society of Plant Physiologists (Membership, 979)					
Plant physiology	10,200	2470	24.2	398	40.7
Microbiology	14,400	280	1.9	95	9.7
Biochemistry	29,300	320	1.1	91	9.3
Physiology	24,700	90	0.4	55	5.6
Physical chemistry	12,200	110	0.9	33	3.4
Medicine	17,500	30	0.2	18	1.8
Psychology	7,300	10	0.2	7	0.7
Nuclear science (1952).....	5,300	90	1.7	50	5.1

and increased use of indexing, abstracting, and reviewing to supplement the primary literature, are the current solutions to this problem. Some indication of the character of the primary literature of physiology is given in Tables IX-6, 7, 8, and 9. The strong position of the United States, largely by virtue of size, is evident; as is the provincialism of each nation, least in Britain, in its professional reading. American physiologists are more clinically oriented than are European ones, as judged by 28% versus 17% of references to medical journals. A recent report by Morgan (56) considers the use of periodical literature by physiologists.

However great the problem may be, most physiologists seem to feel comfortable about keeping abreast of their specialized literature. On the basis of 99% responses to the Survey questionnaire, 11% of all physiologists consider that they keep up 'very well', 66% 'fairly well', 20% 'not too well',

TABLE IX-6. JOURNALS MOST FREQUENTLY CITED IN *Annual Review of Physiology*, 1948-49, IN ORDER OF FREQUENCY OF CITATION (Survey Project 12A).

	No.	%
1. American Journal of Physiology.....	595	7.5
2. Proceedings, Society Experimental Biology and Medicine...	311	3.9
3. Endocrinology	191	2.4
4. Journal of Biological Chemistry.....	187	2.4
5. Journal of Neurophysiology	170	2.1
6. Journal of Physiology	162	2.0
7. Science	158	2.0
8. Journal of Clinical Investigation.....	155	2.0
9. Anatomical Record	148	1.9
10. Nature	147	1.9
11. Journal of Pharmacology and Experimental Therapeutics..	108	1.4
12. American Heart Journal.....	92	1.2
13. American Journal of Medical Sciences.....	89	1.1
14. Journal of Laboratory and Clinical Medicine.....	87	1.1
15. Journal of American Medical Association.....	85	1.1
16. Lancet	73	1.0
17. Journal of General Physiology.....	62	.8
18. Journal of Cellular and Comparative Physiology.....	60	.8
19. Biochemical Journal	60	.8
20. Archives of Neurology and Psychiatry.....	51	.7
Total	3083	39.0
Total under 50.....	4825	61.0
Grand total	7908	100.0

and 2% 'not well at all' (Q, I, 31). Reasons for unsatisfactory coverage, in answer to an open-ended question responded to by 84%, were: limitation of time (48%), too many or too widely scattered publications or too extensive a field (30%), time lag in publication (8%), and lack of access to publications or inadequate library facilities (11%). Five percent admitted insufficient motivation, too broad interests, or poor training in the methods of covering current literature (Q, I, 32-33).

In addition, 4% to 8% criticized either the material published or the indexing and abstracting facilities, and a like number felt isolated, either because of location or of inability to attend scientific meetings. The latter factor will be discussed later in this chapter. Certainly abstracting journals should be used by otherwise isolated workers; a survey of *Biological Abstracts* in 1953 showed that most users, equally for all groups, considered its coverage satisfactory (87%) and its indexing adequate (85%). (Perhaps 'satisfactory' was relative to limited expectations based upon present realities.) At the time this questionnaire was sent out, the abstract indexes were four years behind, so it is not surprising that 59% of their total respondents (including non-users) indicated an unsatisfactory situation. Complaints were above average from physiologists (69%), plant physiologists (68%), and biochemists (70%). Although most users (54%) felt that there was too great a lag between publication of the original article and the abstract, the

TABLE IX-7. JOURNALS MOST FREQUENTLY CITED IN THE *American Journal of Physiology*, 1948-49, IN ORDER OF FREQUENCY OF CITATION (Survey Project 12A).

	No.	%
1. American Journal of Physiology.....	1691	21.2
2. Journal of Biological Chemistry.....	717	9.0
3. Proceedings, Society Experimental Biology and Medicine...	363	4.6
4. Journal of Clinical Investigation.....	323	4.1
5. Journal of Physiology	299	3.8
6. Endocrinology	189	2.4
7. Federation Proceedings	176	2.2
8. Journal of Pharmacology and Experimental Therapeutics..	122	1.5
9. Journal of Neurophysiology.....	112	1.4
10. Science	106	1.3
11. Journal of Experimental Medicine.....	104	1.3
12. Journal of Laboratory and Clinical Medicine.....	95	1.2
13. Physiological Reviews	94	1.2
14. American Heart Journal.....	93	1.2
15. Journal of the American Medical Association.....	86	1.1
16. Pflüger's Archiv.	79	1.0
17. Journal of Cellular and Comparative Physiology.....	76	1.0
18. Biochemical Journal	71	.9
19. Comptes Rendue Société de Biologie	69	.9
20. Archives of Internal Medicine.....	63	.8
21. American Journal of the Medical Sciences.....	60	.8
22. Journal of Nutrition.....	53	.7
23. Archiv. für Experimentelle Pathologie.....	53	.7
24. Journal of General Physiology.....	52	.7
25. Lancet	49	.6
26. Archives of Pathology.....	48	.6
27. Bulletin Johns Hopkins Hospital.....	46	.6
28. Biochemische Zeitschrift	46	.6
29. Acta Physiologica Scandinavica.....	45	.6
30. Archives of Neurology and Psychiatry.....	38	.5
31. Proceedings of the Royal Society, London.....	36	.5
32. Nature	36	.5
33. Anatomical Record	35	.4
34. Quarterly Journal of Experimental Physiology.....	33	.4
35. Zeitschrift für Physiologische Chemie	32	.4
36. Archives of Biochemistry.....	31	.4
37. Archives of Surgery	28	.4
38. Surgery, Gynecology and Obstetrics.....	27	.3
39. Annals of Surgery	26	.3
Total	5734	72.0
Total below 25.....	2240	28.0
Grand total	7974	100.0

TABLE IX-8. JOURNALS REFERRED TO MOST FREQUENTLY IN THREE NATIONAL JOURNALS^a IN ORDER OF FREQUENCY OF CITATION, 1938-39 (Survey Project 12A).

	No.
1. American Journal of Physiology.....	2424
2. Journal of Physiology	1625
3. Pflüger's Archiv.	1071
4. Journal of Biological Chemistry.....	694
5. Proceedings, Society for Experimental Biology and Medicine	427
6. Comptes Rendue Société de Biologie.....	340
7. Biochemische Zeitschrift	271
8. Royal Society of London—Proceedings B.....	249
9. Archiv. für Experimental Pathologie.....	240
10. Biochemical Journal	211
11. Klinische Wochenschrift	150
12. Zeitschrift für Biologie.....	127
13. Archives Internationales de Physiologie.....	96
14. Skandinavisches Archiv. für Physiologie.....	91
15. Journal of General Physiology.....	89

^a American Journal of Physiology, Journal of Physiology, Pflüger's Archiv.

actual lag, except for foreign journals, was less than generally supposed (Glass, 35).

With respect to the use of abstracts (and professional journals) the Survey questionnaire did not cover content, timeliness, or availability; nor the extent to which physiologists use various abstracting journals, either in connection with specific research programs or for keeping generally current; so the opinions shown in Table IX-10 are over-all impressions. The data do show that physiologists depend on journals considerably more than on abstracts or on reviewing publications to keep abreast in their field, and that comparatively few make much use of monographs for this purpose. Journals seem most satisfactory of the printed media, and all of these rate better than the verbal communication techniques. Further analysis of the Survey cards could show which types of respondents hold which opinions and so reveal such relations as that between judged adequacy and amount of use.

Abstracting journals have been shown to cover a maximum of 30% of the

TABLE IX-9. CITATIONS OF FOUR NATIONS IN THREE NATIONAL JOURNALS, 1938-39 (Survey Project 12A).

Journals Cited	Am. J. Physiol. %	J. Physiol. %	Pflüger's Arch. %	All ^a %
American	71	31	10	37
British	16	48	14	25
German	9	13	70	31
French	4	8	6	6
Total citations	7284	3674	2809	
% of citations in journals listed..	80.5	63.5	74.7	

^a Each journal given equal weight. Since no French journal was analyzed, this nation is under-represented here. Of the journals most cited, the percentage in the clinical area is, U.S., 28% (both *Am. J. Physiol.* and *Ann. Rev. Physiol.*; for 1948-49, the values are 30% and 34%); Great Britain, 18%; Germany, 17%.

TABLE IX-10. PERCENTAGE OF PHYSIOLOGISTS USING VARIOUS MEDIA OF COMMUNICATION TO KEEP ABREAST OF THEIR FIELDS OF SPECIALIZATION, AND PERCEIVED ADEQUACIES OF THESE MEDIA (Q, I, 27-30).

	Journal %	Abstr. %	Ann. Rev. %	Monogr. %	Soc. Meet. %	Seminar, Conf. %
<i>Use</i>						
Considerable	86	41	31	20	25	21
Some	12	41	46	44	47	41
Little or none	1	13	16	26	22	30
No answer	1	5	7	10	6	8
Total	100	100	100	100	100	100
N = 4571						
<i>Adequacy</i>						
Satisfactory as is now . . .	59	48	48	40	30	28
Some improvement needed.	33	32	32	32	47	38
Much improvement needed.	5	12	10	11	14	20
No answer	3	8	10	17	9	14
Total	100	100	100	100	100	100
N = 4571						

published papers in physiology, so it is not surprising that they appear deficient to their users. Much can certainly be spared; the average citations per paper falls with the number published by an author—from 1.5 for one paper, through 0.9 at five, to 0.6 at 30 (from Survey Project 12C). The study of psychologists also showed that many prolific publishers were not highly regarded by colleagues (Clark, *op. cit.*). Even though much of the omitted material consists of trivial and repetitive publications, the fact remains that not all significant material is retrievable by the use of abstracts, reviews, and indices as currently prepared. A major overhaul is due for mechanisms of handling information.

Communication in Scientific Meetings

Scientific gatherings provide a means of intimate communication not possible by the written word. Whether as society meetings, at which members present the results of original investigations; as symposia, with or without an audience; or as seminars, at varying levels, the function of such gatherings is to communicate new facts and viewpoints. The value set upon meetings and seminars as a means of keeping up to date is indicated by the questionnaire responses summarized in Table IX-6. Meetings are used extensively by about one-fourth, and at least some by three-fourths of the profession. Seminars or conferences rate lower, with nearly a third of the profession taking little part in them. Again, further correlations on the existing cards could show the relation between participation and the judgment as to value in keeping up with current advances.

Most physiologists interviewed in the course of the Survey stated that societies, and specifically the American Physiological Society, should provide a means of communicating ideas and information—by 'talking with people in the field', 'presenting and hearing papers', and 'getting new ideas' (Survey Project 8B). Most felt that the Society provided such communication adequately through the scientific sessions; although occasional comments about 'low scientific content' or meetings in 'remote places' showed minor discontent. Papers should be presented, most felt, to communicate and share research results with other scientists; with a corollary possibility of getting honest criticism. Less common reasons for being on the program were such personal ones as: 'building a reputation', 'getting identified with the field', 'obtaining recognition', 'satisfying institutional responsibilities', 'getting before the public', and 'getting expenses paid to the meetings'. It is interesting that one proposition put to the Council of the American Physiological Society as early as 1911 was that "Reading of the papers should be dispensed with and the sessions should proceed directly to the discussion based on the printed abstracts." Often broached, since then, such a procedure has been tried only recently.

Opportunities for Attending Meetings

Opportunities for physiologists to attend meetings are favorable. Only a third of the Survey respondents reported that they must present a paper in order to have expenses paid (Q, I, 23), and 96% indicated some travel aid by their institutions. Only 7% of physiologists in industrial institutions must present papers to have expenses paid, and only 22% of those who are either administrators or who have salaries of \$10,000 or more a year (Q, II, 74).

Presumably administrators, who also more often belong to many societies than do other classes of physiologists, must especially be in the research stream to find personnel, pick up ideas, and otherwise foster programs of research consistent with current trends. Investigators, who would more often contribute to the program, must also more often present a paper in order to get there; but a third of them and of teachers, all of whom need to keep up in their fields, may have to stay home. However, the fact that well over half of all physiologists can have expenses to meetings paid, without being required to present a paper, indicates that institutions, agencies, and foundations are making an important contribution to the continuing education and scientific advancement of scientists.

MEMBERSHIP IN PHYSIOLOGICAL SOCIETIES

Society Characteristics

There are seven professional organizations concerned with physiology in the United States and Canada. Four of these are independent professional

societies: the American Physiological Society (APS), the American Society of Plant Physiologists (ASPP), the Society of General Physiologists (SGP), and the Canadian Physiological Society (CPS). Three are established physiological divisions or sections of larger biological societies: the physiological section of the Botanical Society of America (BSA), the division of physiology of the Society of American Bacteriologists (SAB), and the division of experimental psychology (including the formerly separate division of physiological psychology) of the American Psychological Association (APA).

Table IX-11 compares (for 1952-53) some characteristics of these organizations. The Society of General Physiologists, oriented towards a broad scientific approach, is smallest, but the only one containing both animal and plant physiologists in appreciable numbers; APS and ASPP rarely have members in common. This may indicate little community of interest in content or may result from different histories; certainly at the level of application, the agricultural orientation of the ASPP and the medical one of the APS lead to a serious diversity of subject matter. A similar chemical versus medical orienta-

TABLE IX-11. DATES OF FOUNDING, RANK IN MEMBERSHIP AND OVERLAPPING MEMBERSHIP OF PHYSIOLOGICAL SOCIETIES AND SECTIONS (Data from membership directories and rosters, for 1952-53).

	Physiological Societies							
	APS		ASPP		CPS		SGP	
Date of founding	1887		1924		1936		1946	
Total membership	1310		979		331		192	
Ranking among 43 biological societies	10th		18th				33rd	
Membership Overlap	N	%	N	%	N	%	N	%
APS only	1173	89						
ASPP only			947	97				
CPS only					279	84		
SGP only							82	42
APS & ASPP	1		1					
APS & CPS	52	4			52	16		
APS & SGP	79	6					79	41
ASPP & SGP			26	2			26	14
APS, ASPP, SGP	5	1	5	1			5	3
Total	1310	100	979	100	331	100	192	100
	Physiological Divisions and Sections							
	BSA		SAB ^a			APA		
Date of founding								
Whole society	1907					1892		
Physiology section			1952					
Population								
Total	1894		3800			11,000		
Division or section	490		359			172		
Section as % of total	26%		11%			2%		

Less than .5%.

^a Self-classified first competencies in physiology with societies.

tion led to the formation of the American Society of Biological Chemists, to serve the growing concerns of biochemistry. The American Society for Pharmacology and Experimental Therapeutics had a converse origin from the APS, becoming even more clinical. The APS has consistently retained a medical orientation, despite earnest efforts of its council, especially in recent years, to broaden its base well beyond the medical field.

The membership growth curve of the APS, erratic in the early years, rose considerably in the first two decades of this century and then settled to a fairly constant 5% to 10% increment each year, the present rate. The ASPP, starting with a fairly vigorous rate, has also settled to a growth of the same order as the APS. The more recent SAB is growing erratically but at a rate larger than for the APS or the ASPP, and the proportion of contributed papers of physiological content is rising. (See Chapter IV and Table IV-10 for other comparisons.)

A detailed survey of the growth and development of physiological societies is available in *Preliminary Report VIII-A*. (See also Chapter XII.)

Extent of Membership

Almost all physiologists surveyed belong to at least one professional society; a majority, to three or more. As shown in Table IX-12, greater proportions of animal and plant than of bacterial physiologists are in the multiple category; the latter being served by fewer professional associations. The relation between society membership and such background variables as age, salary, type of institutional employment, and major function is developed in Table IX-13. Older physiologists and those at higher salary levels tend to belong to more professional associations than do the younger, struggling members of the profession: 87% of the physiologists over 40 years old are members of three or more societies, but 40% of those with such member-

TABLE IX-12. PERCENTAGE OF PHYSIOLOGISTS BELONGING TO PROFESSIONAL SOCIETIES, NOT INCLUDING HONORARY SOCIETIES (Q, I, 12; II, 43).

No. Societies	Central				Peripheral				Total %	
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %		
None	6	3	4	5	5	3	6	10	5	5
One	10	10	24	12	11	9	22	16	12	12
Two	17	25	28	20	17	18	21	24	18	19
Three to five	46	46	38	45	41	53	39	34	43	43
More than five	21	15	6	18	26	17	12	16	22	21
Unspecified ^a	#	0	0	#	#	#	0	0	#	#
No answer	#	1	0	#	#	#	0	0	#	#
Total	100	100	100	100	100	100	100	100	100	100
N	961	382	171	1514	1951	595	385	126	3057	4571

Less than .5%.

^a Not in questionnaire; added to code.

TABLE IX-13. RELATIONSHIP BETWEEN NUMBER OF PROFESSIONAL SOCIETY MEMBERSHIPS AND VARIOUS BACKGROUND VARIABLES (Q, II, 44).

	Number of Societies				N
	0-2 %	3 or more %	No Ans. %	Total %	
Age					
Under 30	71	29	#	100	481
30-39	46	54	#	100	1911
40-49	21	78	1	100	1194
50-59	16	83	1	100	596
60 or older.....	17	82	1	100	358
					<hr/> 4540
Annual salary					
Less than \$5000.....	62	37	1	100	927
\$5000-\$6999	43	57	#	100	1509
\$7000-\$9999	23	77	#	100	1267
\$10,000 or over.....	8	91	1	100	773
					<hr/> 4476
Kind of institution					
Academic	33	67	#	100	2867
Government	40	60	#	100	621
Industrial	42	67	1	100	449
					<hr/> 3937
Major function					
Research	44	56	#	100	1893
Teaching	38	62	#	100	476
Administration	23	76	1	100	278
					<hr/> 2647

Less than .5%.

ship are under 40; and 87% of physiologists earning \$7000 or more a year—a little over the median—belong to three or more societies. The data relating employment and function to society membership are based on a much smaller sample, since only physiologists employed solely by one type of institution and those spending 60% or more of their time on one function are included. They show a slightly greater tendency for physiologists in academia to belong to multiple societies than for those in government or industry. Likewise, administrative physiologists are more likely than those mainly in research or teaching to belong to three or more societies. Further interrelationships could be studied by running correlations on the Survey data.

In general, membership in the society of primary identification has been held by 26% of all physiologists from 3 to 5 years, by 25% from 6 to 10, and by 14% from 11 to 15. Only 4% have held membership for less than one year, and 8% from 1 to 2; while 8% have belonged for 16 to 20 years, and 14% for over 20. Only within these senior groups are there any notable differences, which reflect the relative ages of physiological fields (Q, I, 18).

Primary Professional Affiliations

No single physiological society contains a large proportion of the physiologists studied by the Survey; the total population is heterogeneous and includes those in various branches and specialties of physiology and also those identified with physiology only peripherally. In general, as shown by society membership, physiologists have identified themselves with type of organism; the various physiological societies or sections having derived from mother organizations which are organism-oriented. Thus the ASPP relates to the Botanical Society of America and, administratively, plant physiologists are found in botany departments or botanical laboratories. Bacterial physiologists are likewise organized as a section of the SAB and are usually found in bacteriology departments or laboratories. The same types of association also characterize mammalian physiologists, including medically-oriented ones, physiological psychologists, and general or cellular physiologists. No single society can claim to represent the interests of a majority of the physiological population, largely because of historical development and contemporary habits.

Table IX-14 presents the primary, or first-choice, professional associations

TABLE IX-14. PERCENTAGE OF PHYSIOLOGISTS INDICATING PRIMARY AFFILIATION WITH A PROFESSIONAL SOCIETY (Q, I, 16-17).

	Central			Peripheral				Total %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	
Am. Physiol. Soc.	50	1	0	8	#	1	4	14
Am. Soc. Plant Physiol.	0	71	0	#	13	#	0	8
Soc. Gen. Physiol.	1	1	1	#	#	0	2	#
Botanical Soc. America.	#	6	0	#	9	#	1	2
Soc. Am. Bacteriol.	#	1	86	1	1	54	4	8
Am. Psychol. Assoc.	1	0	0	8	0	0	5	4
Am. Inst. Nutrition.	1	0	0	4	#	0	0	2
Am. Soc. Biol. Chem.	#	0	4	10	2	7	6	5
Am. Soc. Zool.	4	0	0	3	0	0	2	2
Am. Soc. Pharmacol. & Exper. Therap.	1	0	0	4	0	0	0	2
Am. Phytopathol. Assoc.	0	1	0	#	6	1	2	1
Am. Soc. Hortic. Sci.	0	6	0	#	19	1	1	3
Am. Soc. Agronomy.	0	1	0	#	10	#	1	1
Am. Chem. Soc.	2	1	2	16	11	17	34	11
Am. Assoc. Adv. Sci.	3	1	1	1	1	1	4	2
Am. Soc. Clin. Invest.	1	0	0	2	0	0	0	1
Others (American)	23	4	4	34	23	12	29	27
Foreign societies	6	1	1	3	1	0	1	2
More than one society—primary one uncertain	2	2	0	2	3	2	1	2
No answer	5	3	1	4	1	4	3	3
Total	100	100	100	100	100	100	100	100
N	899	369	165	1855	574	361	114	4337 ^a

Less than .5%.

^a Does not include 234 respondents who did not indicate membership in any professional society.

of the central and peripheral groups of animal, plant, and bacterial physiologists. Of the central groups, 50% of animal physiologists belong to the APS; 71% of plant physiologists, to the ASPP; and 86% of bacterial physiologists, to the SAB. Although 4% of central animal physiologists specialize in general or comparative physiology (Q, II, 38), only 1% of them belong to SGP, the actual number being equalled by central plant and bacterial physiologists. Despite a small membership, the SGP represents wide physiological interests which cut across the usual organism-oriented lines. The data in Table IX-14 also show that other organizations supporting distinct physiological sections—the Botanical Society of America (Section on Physiology) and the Division of Experimental Psychology of the American Psychological Association—can claim the primary allegiance of only an insignificant proportion of physiologists. Data were not correlated by the Survey to show the extent to which Canadian physiologists regard the Canadian Physiological Society as their primary professional association.

The wide spread of primary society memberships among central animal physiologists is in contrast to the close identification of bacterial physiologists with a single society. The oldest and largest branch of physiology, with the major administrative recognition in academic institutions, thus has the least professional homogeneity; whereas the smallest group, the newest and least developed branch of physiology whose personnel is employed over a wider range of institutions, has the greatest professional unity. The underlying chemical basis of physiological methods and concepts is illustrated by the primary association of many peripheral physiologists with the American Chemical Society or with the American Society of Biological Chemists. These data as to primary professional affiliation thus reaffirm the essential unity of physiology while revealing its diversity of field and of interest.

APS and ASPP Membership

Since half the central animal physiologists consider the American Physiological Society their primary professional organization, and nearly three-quarters of the central plant physiologists similarly regard the American Society of Plant Physiologists, it is worth examining the extent to which the total memberships of those societies regard them as primary. As shown in Table IX-15, this is about half, 55% for the APS and 47% for the ASPP. In both instances, around 80% of the central physiologists who are members regard these societies as their primary affiliation, while between 71% and 80% of the peripheral physiologist members look to other societies. This may reflect the influence of physiology in other fields and the attraction of physiological societies to other workers as a forum for presenting their physiological research; or, a less charitable view, membership may provide respectability to investigations otherwise difficult to assign. In any event, the

TABLE IX-15. PERCENTAGE OF SURVEY RESPONDENTS WHO ARE APS OR ASPP MEMBERS WHO IDENTIFY THOSE SOCIETIES AS THEIR PRIMARY PROFESSIONAL AFFILIATION (Q, II, 49).

Primary Prof. Affiliation	Central		Peripheral		Total	
	APS %	ASPP %	APS %	ASPP %	%	N
APS	78		29		55	
Other than APS.....	22		71		45	
N	540		451			991
ASPP		82		20	47	
Other than ASPP.....		18		80	53	
N		306		383		689

major physiological societies contain a sizeable proportion of peripheral physiologists; whether a greater one than for other professional societies of wide scope, has not been determined.

The extent to which those in various subfields of animal physiology regard the APS as their primary professional association is shown in Table IX-16. Neurophysiology, circulatory physiology, and renal physiology—systematic physiological specialties—contain the largest proportions of workers who identify with the APS. The specialties whose members affiliate primarily with societies other than the APS are the non-systemic, younger groups—including metabolic or nutritional physiology, growth physiology, and physiological psychology. Thus, 53% of the neurophysiologists, 52% of the circulatory physiologists, and 52% of the renal physiologists regard the APS as their primary society; whereas only 9% of the metabolic physiologists, 7% of the growth physiologists, and 6% of the physiological psychologists do so. Endocrinologists also feel less centered (18%) in the APS. In the animal

TABLE IX-16. PERCENTAGE OF ANIMAL PHYSIOLOGISTS, BY FIELD OF SPECIALIZATION, IDENTIFYING APS OR OTHER SOCIETIES AS PRIMARY PROFESSIONAL AFFILIATION (Q, II, 50).

Field of Specialization	Primary Professional Affiliation				N
	APS %	Other Soc. %	No Ans. %	Total %	
Neurophysiology	53	44	3	100	204
Circulatory	52	44	4	100	225
Renal	52	45	3	100	67
Respiratory	49	46	5	100	76
Environmental	49	48	3	100	38
Gastrointestinal	41	57	2	100	44
Biophysical	26	69	5	100	64
General or comparative.....	20	71	9	100	97
Endocrine	18	78	4	100	277
Sensory	14	86	0	100	77
Metabolic or nutritional.....	9	88	3	100	725
Growth	7	89	4	100	114
Physiological psychology	6	93	1	100	97

specialties, the APS apparently fails to serve the primary professional needs of many physiological areas of interest, especially the more recent and expanding ones, just as static concepts of physiology fail to provide room for these new specialties—to be considered later.

Desire to Join Professional Societies

Of the 4570 respondents to the Survey questionnaire, 54% had no desire to join additional professional societies and 5% did not answer the question. For the remaining 1860, 41% of the total, there was little differentiation between groups, except that proportionally more central bacterial physiologists and slightly fewer peripheral plant physiologists wished additional memberships (Q, I, 13; II, 53). Younger physiologists tended toward enlarging their professional associations; the proportions of those not answering and of those not desiring further memberships rose with age. Likewise, as also expected, those already belonging to three or more societies felt little urge to join additional ones, while 58% of those who belonged to none, 55% to only one, and 49% to two, desired further professional group contacts (Q, II, 54). The societies of first choice, of the 1860 respondents wishing further membership, are shown in Table IX-17. Further affiliation was desired by 41% of all animal physiologists, 39% of central and 32% of peripheral plant physiologists, and 57% and 43%, respectively, of central and peripheral bacterial physiologists.

Central and, even more, peripheral animal physiologists give a wide variety of societies as their first choice; but 48% of the central ones, as compared with 15% of peripheral ones, desired to join the APS. Of the latter, 27% would prefer to join the American Society of Biological Chemists, in which 10% of all peripheral animal physiologists have their primary affiliation (Table IX-14). Plant physiologists show wide variation; the American Chemical Society, the ASPP, and the Botanical Society of America are most preferred by the central group, the first two by the peripheral one. Since a large majority of bacterial physiologists already belong to the SAB, the major choices of this group are the American Society of Biological Chemists and the American Chemical Society; but 40% of the central group and nearly half of the peripheral one name a variety of other choices.

The background variables of animal and plant physiologists who wish to join APS and ASPP, respectively, are compared with those of present members in Table IX-18. ('All others' in the table does not mean those who would not like to join APS or ASPP, as implied in the original presentation, but merely includes the remaining animal or plant physiologists.) As compared with present APS members in the same area, animal physiologists who would like to join are equally likely to be in academic or other institutions; are more likely to be central than peripheral; and are younger, in lower salary

TABLE IX-17. SOCIETIES INDICATED AS FIRST CHOICE OF PHYSIOLOGISTS DESIRING ADDITIONAL SOCIETY MEMBERSHIP (Q, I, 14-15 with additions).

Percentage Who Would Like To Join (First Society Mentioned)	Central			Peripheral				Total %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	
Am. Physiol. Soc.....	48	1	1	15	2	1	2	17
Am. Soc. Plant Physiol...	0	13	0	0	12	0	0	2
Soc. Gen. Physiol.....	2	2	1	2	0	0	0	1
Botanical Soc. of America.	0	15	0	#	7	1	0	2
Soc. Am. Bacteriol.....	#	3	6	#	2	6	2	2
Am. Psychol. Assoc.....	1	1	0	#	0	0	0	#
Am. Inst. Nutrition....	2	0	0	6	1	1	4	3
Am. Soc. Biol. Chem....	1	5	35	27	9	28	31	19
Am. Soc. Zool.....	2	0	1	2	0	0	0	1
Am. Soc. Pharmacol. & Exper. Therap.	1	0	0	2	0	0	4	1
Am. Phytopathol. Assoc..	0	2	0	0	2	0	0	#
Am. Soc. Horticult. Sci...	0	5	0	0	5	0	0	1
Am. Soc. Agronomy.....	0	6	0	0	4	0	0	1
Am. Chem. Soc.....	1	16	22	4	15	16	12	8
Am. Assoc. Adv. Sci.....	2	7	8	3	6	8	12	4
Am. Soc. Clin. Invest...	5	0	0	2	0	0	0	2
Others (American)	28	11	20	30	25	29	27	28
Foreign societies	2	5	3	1	3	3	2	2
No answer	5	8	3	6	7	7	4	6
Total	100	100	100	100	100	100	100	100
N	395	150	97	808	193	167	49	1859*
Total respondents (Table IV-1)	961	382	171	1951	595	385	126	4571
% of total.....	41	39	57	41	30	32	38	

Less than .5%.

* Does not include 2481 respondents who indicated that they were not interested in joining any additional professional societies, or 231 respondents who did not answer that question.

brackets, belong to fewer professional societies, have published less; and teaching, much more than research, is likely to be their main function. Fewer had high grade averages; a greater proportion, medium ones.

A similar comparison between those who are and those who would like to be ASPP members shows negligible differences in central or peripheral identification, number of research papers published, major function, or grade averages. Those who would like to join are, however, younger and almost entirely within the lower salary group (reflecting the generally lower salaries of plant physiologists), belong to fewer professional societies, and are much more likely to be in governmental, less in academic or industrial, work. Many characteristics of those wishing to join either the APS or the ASPP are attributable to youth (lower age range, lower salaries, membership in fewer professional societies, and lower research output); others can be grouped under low maturity or professional status (lower research output, lower salaries, more time spent in teaching). Whether failure to attain membership relates

TABLE IX-18. RELATIONSHIP BETWEEN EXTENT OF INTEREST IN MEMBERSHIP IN A PROFESSIONAL SOCIETY (AMERICAN PHYSIOLOGICAL SOCIETY OR AMERICAN SOCIETY OF PLANT PHYSIOLOGISTS) AND BACKGROUND VARIABLES (Q, II, 59-64).

	In Animal Physiology			In Plant Physiology		
	APS Memb. %	(N = 2912) Non-Memb., Would Like To Join APS %	All Others %	ASPP Memb. %	(N = 977) Non-Memb., Would Like To Join ASPP %	All Others %
Identification with physiology						
Central	56	61	14	47	45	21
Peripheral	44	39	86	53	55	79
N ^a	(961)	(313)	(1638)	(645)	(42)	(290)
Age						
Under 40	27	67	56	51	65	56
40 or older	72	32	43	48	33	43
No answer	1	1	1	1	2	1
Annual salary						
Under \$7000	22	71	58	59	96	65
\$7000 or more	76	29	40	38	2	32
No answer	2	0	2	3	2	3
Membership in professional societies						
0-2	14	50	40	29	60	39
3 or more	86	49	60	71	40	60
No answer	0	1	0	0	0	1
Research papers published in last three years						
0-4	28	56	53	53	52	60
5 or more	69	44	45	44	45	36
No answer	3	0	2	3	3	4
N	(845)	(280)	(1420)	(557)	(38)	(248)
Kind of institution						
Academic	73	73	66	66	59	60
Industrial	4	4	11	10	5	11
Government	11	13	13	18	31	19
Other	12	9	10	6	5	9
No answer	0	1	0	0	0	1
N	(913)	(305)	(1570)	(604)	(42)	(270)
Major function						
Research	30	42	44	47	52	54
Teaching	6	21	12	11	14	15
Administration	7	3	6	8	5	4
Other, combination	56	33	37	33	29	25
No answer	1	1	1	1	0	2
N	(913)	(305)	(1570)	(604)	(42)	(270)
Undergrad. grade average						
A or A-	43	34	36	44	44	36
B+ or B	43	54	49	44	47	51
B- or lower	10	10	12	9	9	8
No answer	4	2	3	3	2	5

^a These N values (in parentheses) apply to all parts of the table where no others are given.

to age or ability or some other characteristic, membership, by and large, is obviously determined by professional standards of maturity and proven capacity as a physiologist. These standards are more stringent for the American Physiological Society than for any other physiological organization studied.

Attitudes Towards Societies

Since society membership is a major factor in promoting scientific communication, the attitudes of physiologists toward the conduct of these professional groups, including their scientific sessions and membership policies, are important. The complete array of data from the Survey questionnaire, presented in Table IX-19, shows the attitudes of animal, plant, and bacterial

TABLE IX-19. ATTITUDES OF PHYSIOLOGISTS TOWARDS CONDUCT, SCIENTIFIC SESSIONS, AND MEMBERSHIP REQUIREMENTS OF THE SOCIETY OF PRIMARY AFFILIATION (Q, I, 20, 24, 25; II, 68).^a

	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Conduct										
Very satisfied ...	35	34	32	34	34	34	25	44	33	33
Fairly satisfied ..	48	50	59	51	51	52	57	42	51	51
Neither satisfied nor dissatisfied.	11	12	5	10	10	8	12	11	10	10
Fairly dissatisfied	3	3	4	3	3	4	3	2	3	3
Very dissatisfied .	#	#	0	#	1	#	1	0	1	1
No answer	3	1	0	2	1	2	2	1	2	2
Total	100	100	100	100	100	100	100	100	100	100
Scientific sessions										
Satisfactory now.	40	44	39	41	43	44	43	45	43	42
Some improvement needed ..	49	47	57	49	48	49	50	46	49	49
Much improvement needed ..	7	6	2	2	7	5	5	4	6	6
No answer	4	3	2	2	2	2	2	5	2	3
Total	100	100	100	100	100	100	100	100	100	100
Membership requirements										
Satisfactory now.	83	92	75	85	85	93	77	87	87	86
Qualifications too low—raise requirements ..	10	5	24	10	10	5	20	10	10	10
Qualifications too high—lower requirements ..	3	1	1	2	3	1	2	1	2	2
No answer	4	2	0	3	2	1	1	2	1	2
Total	100	100	100	100	100	100	100	100	100	100
N	853	359	164	1376	1788	566	348	111	2813	4189 ^b

Less than .5%.

^a For societies of primary affiliation, see Table IX-14.

^b Does not include 234 respondents who did not belong to any professional societies, or 148 who did not indicate any professional societies with which they identify: total 382.

physiologists and also of central and peripheral groups. The data apply to the separate societies in accord with the primary affiliations of respondents (Table IX-14).

Of all physiologists, 84% indicate satisfaction with the conduct of their primary society while 14% are neutral or dissatisfied. Although only 4% express positive dissatisfaction, across the board, enough critical opinion exists to warrant attention by each professional society. These data have not been correlated to apportion these expressed attitudes among the primary animal, plant or bacterial societies; but the only noticeably deviating group is the central bacterial one, 91% of which are satisfied and only 5% neutral.

Attitudes regarding the conduct of APS and ASPP were specially studied, for those respondents primarily associated with one of these societies, in relation to: length of membership in the society, holding of offices or committee positions, annual salary, kind of institution in which employed, major function, undergraduate grade average, and number of research papers published within a three-year period. For each variable, a high number shows a positive correlation. Except for 'function', the data are based on 519 to 588 APS members (Q, II, 69-70) and on 295 to 348 ASPP members (Q, II, 71-72). The range and approximate median for the seven variables tested are as follows:

	Range	APS %	ASPP %
Very satisfied	{ High	50	38
	{ Median	41	32
	{ Low	35	22
Fairly satisfied	{ High	55	63
	{ Median	47	53
	{ Low	41	38
Neutral or dissatisfied	{ High	16	21
	{ Median	12	15
	{ Low	2	4

No common pattern appears for the two societies, with regard to either extremes or medians. Interrelationships between the seven variables have not been examined by the Survey but the data cards are available.

The scientific sessions as now conducted satisfy 42% of all physiologists; 55% feel that some or much improvement is needed. The specific improvements suggested and the critical comments made are less significant than are the general distributions of the types; comments of unidentified respondents collected by the Survey were, however, made available to all program officers, of the various societies, who expressed interest in them (*Preliminary Report VIII-B*, p. 26). The distribution of all suggestions was not markedly different between central and peripheral physiologists, nor between those in the three area groups; and most respondents made only one comment, since total comments exceeded by only 6% the number who had indicated need of improve-

ment (Q, I, 21-22). The suggestions may be summarized as relating to: *content* of papers (total 23%, distributed between 2% desiring longer papers, 12% wishing improvement in quality, 3% improvement in presentation, and 6% a change in content); *conduct* of individual sessions (total 21%, distributed between 6% wishing smaller sessions, 5% more discussion, 8% fewer papers, and 1% each criticizing loose scheduling and introduction of unrelated topics); and *program* organization (total 13%, distributed between 7% wishing fewer conflicts and overlappings in program arrangements and 6% who ask for different program arrangements, including round-tables, symposia, etc.). A variety of other suggestions (21%) included too few in any one category to be discussed separately.

The scientific sessions of the APS were further analyzed by the Survey. APS members for 6 and 10 years are more often (45%) dissatisfied with the conduct of scientific sessions than are members for less than 5 (34%) or more than 10 years (41%) (*Preliminary Report VIII-B*, p. 28). One might guess that younger members are grateful for a forum where they can present their ideas, 'middle-aged' ones are more generally critical and perhaps somewhat disgruntled at the reaction to their ideas, while older members, more appreciated, are also complaisant about presentations; but these data do not permit analysis. One safe generalization is that, of those who are critical, most desire an increase in quality of the papers. Also, the most common reason for presenting papers was to share research results with other scientists and to elicit honest criticism and ideas by stimulating discussions. In any event, a distinction should be made between those participants in scientific sessions who wish to tell the audience about their findings and those who rather seek guidance in their work from fruitful discussion.

Membership requirements of their primary professional society are generally satisfactory to physiologists, especially so for the plant group (Table IX-19). At least one-fifth of the bacterial physiologists wish membership requirements raised; but only 10% of animal physiologists feel so with reference to their primary societies, and very few suggested that membership requirements were too stringent.

In general, the officers and committee members of professional societies appear to be responsive to members' needs and desires. Members regard their societies primarily as providing an opportunity for discussing their research findings, either informally or in larger and more formal groups. Perhaps those more concerned with prestige prefer an audience held captive by a program, while those more interested in communicating about ideas are better satisfied with smaller, more informal groups. Those who attend meetings to learn can be instructed as a member of an audience; or one can participate in personal and informal debate as he achieves close relations with fellow investigators in his own area of research.

When a physiologist's professional needs are not satisfied, he is more apt to attend or to start other societies than to press for a change in program or policy of his own organization. To retain the central interest of its members, each physiological society must therefore keep abreast of trends within its field and anticipate future interests of its members. This is not made less difficult by the increasing diversity of physiologists; so it seems inevitable that professional enclaves will form within original societies and eventually emerge as new entities, either independent of or associated with the parent group. As physiological societies retain or develop an intimate professional relationship with new derivative groups, the science of physiology demonstrates flexibility and adaptiveness to a changing scientific climate; as its members are diverted to other groups, especially if not physiological in nature, the society restricts its usefulness.

The principal physiological societies find themselves in considerably different positions. The APS is the primary association for 50% of the central and 8% of the peripheral animal physiologists. The ASPP includes 71% of the central plant physiologists and 13% of its peripheral group. (See also reports by the Committee for Professional Status and Training, 7a.) Practically all (86%) central bacterial physiologists belong to the SAB, as do over half (54%) of the peripheral ones. Biochemists tend to have their primary allegiance outside of physiology; whereas the SGP—one of the youngest societies—draws its small membership from all physiological fields. Physiologists must learn how to benefit from all the differences within the profession, while building on the basic unity of physiological concepts to advance all physiological research and teaching, and to better inter-disciplinary communication.

SUMMARY

The prime aim of scientific publications and meetings is the communication of new information to peers; a scientist has been defined as one who views the work of his colleagues with quarrelsome interest. Publication is generally more satisfactory than oral communication, at least to the recipient attempting to 'keep up with the literature'; and the output of physiologists was estimated quantitatively by their reports of papers published during three years, qualitatively by the citation of their papers in the battery of *Annual Reviews* over a like period.

About one-tenth of the physiologists published 15 or more papers, almost as many none at all, and the remaining four-fifths divided equally between 1 to 4 and 5 to 14 publications. Animal physiologists proved more prolific than average; plant physiologists, less. Productivity is greater with: age, to a peak at 40 and a sharp drop after 60; high salary, for a variety of possibly unrelated reasons; freely chosen research program; adequate funds,

and the responsibility of securing them; and a high grade average in school and early attainment of a doctorate. The obvious inference of this last correlation, that able men perform well scholastically and professionally, is complicated by the great concentration in academic institutions of men with high grades, six to nine times the proportion in government or industry. Partialling out the factors here, as in many other correlations of this Survey, would prove most desirable (see Appendix to Chapter IV).

Publication quality seems highest for the members of the Society of General Physiology (SGP), with an average citation score of 11, compared with 6 for the American Physiological Society (APS) and 3 for the American Society of Plant Physiology (ASPP). Similarly, 25% of SGP members, 9% of APS, and 5% of ASPP were in the middle or high range. Moreover, the general physiologists were most widely cited in the eight different review series, and about half the SGP members belong to the APS or ASPP as well—truly, the term 'general' seems well deserved. By contrast, animal and plant physiologists were most cited in their specific review series, and only six physiologists (five also members of SGP) belonged to both the APS and the ASPP; a cleavage and specialization based, it may be hoped, more on history than on outlook.

Three-fourths of all physiologists seem reasonably content about breasting the flood of literature, 11% feel very well updated; but half still wish that time did not limit their coverage. Much greater dependence is placed on primary journal literature than on any secondary source; and oral communication, in meetings and especially in seminars, is less satisfactory. Indexing, abstracting, and reviewing publications, though now essential, are often strongly criticized—by physiologists more than the average amount. Radically new devices for storing, organizing, and presenting information are appearing only in time; for the invention of printing, while still a necessary condition for scholarly advance, is no longer a sufficient one.

Most members find their society meetings reasonably adequate, though the quality of scientific papers receives continued criticism,¹ and only one-third

¹ That important problems vexing the APS today are not new is evidenced by some notes from the History of the American Physiological Society Semicentennial (Survey Project 16).

"The congested nature of the programs was discussed in a business meeting of the Society, and the following propositions were submitted from various members as methods of meeting the difficulty: 1. Meeting in sections. 2. Lengthening the time of the meetings to four or more days. 3. Changing the time of meeting to June. 4. Making the submission of abstracts mandatory. 5. Dispensing with the reading of papers and proceeding directly to the discussion on the basis of printed abstracts. 6. Closer affiliation with the biochemical and pharmacological societies. And lastly 7, limiting the number of papers. After a prolonged and earnest discussion, according to the minutes, the problem was referred to the Council with instructions to report to the Society at the next annual meeting. No record is made in the minutes of subsequent meetings of a report from the Council."

This was in 1911!!

are required to present material in order to have their travel paid. Size increases with age for the group of physiological societies, and details on growth and member attributes are available. One-fourth of all members have belonged for 3 to 5 years and two-fifths for 6 to 15. Almost nine-tenths of physiologists above forty years of age (or with salaries above \$7000) belong to three or more societies; but for 80% of central physiologists, compared to 25% of peripheral ones, the APS or ASPP is the primary allegiance. Half of all animal physiologists are in the APS, the others scattered widely; in contrast, the bacterial physiologists are nearly all in the SAB. In the APS, nervous system, circulation, and renal physiologists are the main groups with primary adherence, over half of each; respiration, gastrointestinal, and environmental physiologists are also strong, 40 to 50% of each. Most growth and metabolism specialists center elsewhere (APS primary only for 8%), and endocrinologists are only one-fifth committed to the APS.

About two-fifths of the population questioned, mostly young men or men not professionally established, wished to join some society. Next to the obvious primary professional society, chemical and biochemical attachments were most desired. Central bacterial physiologists as a group had considerable yearning; and not for SAB, since its easy standards permit wide membership. APS and ASPP take notice! Indeed, when a society does not satisfy the needs of a sector of its presumptive territory, physiologists, whether members or not, seem more inclined to seek or create another group than to attempt to change the one in question. The choice, if indeed there be one, is between malleability and splintering of the established bodies.

X

PROFESSIONAL TRAINING AND RECRUITMENT

COURSES IN BIOLOGY AND PHYSIOLOGY

Types of Courses With Physiological Content

University and college courses in physiology, biology, and kindred subjects with physiological content have as their function the communication of scientific principles, the facts which underlie them, and the techniques and skills required for their investigation. They range in content from the highly specialized to the highly generalized; in level from those for the graduate or advanced professional student to the undergraduate freshman; and in purpose from helping prepare for a research career in physiological science or for work in such applied fields as clinical medicine, veterinary medicine, plant pathology, or bacteriology, to meeting the general education objectives of teaching biological and physiological principles or such applications as hygiene or personal health. This latter aspect, discussed more fully in Chapter XI, is an extension into the college years of the enculturation of youth into the community, and its objective is therefore non-vocational and non-technical. Yet, when students are preparing for semi-professional careers in school science teaching, in physical education or physical therapy, or in medical or biological technology, the objective is more technical and some grounding in physiology becomes important. The standards of courses in biology and physiology designed for these groups should be above average quality in scientific content, method, and outlook.

Another type of course for undergraduate science majors is intended to lay a foundation for careers in or related to science. It is from students in these courses that future biologists and physiologists are to be recruited. Many students at this stage are medically oriented; in these years, therefore, lie the opportunities to explain, explore, and select between the clinical or applied and the basic fields among the biological sciences, and courses for these students are thus most important to the future of physiology. Comparatively few institutions offer an undergraduate departmental major in physiology, so new generations of physiologists must be nurtured from the biological science majors taking these basic courses.

TABLE X-1. PHYSIOLOGICAL SCIENCE COURSES IN COLLEGES AND UNIVERSITIES, BY TYPE OF STUDENT FOR WHOM PRIMARILY DESIGNED (Preliminary Report, Table V-E-1; Survey Project 1).

Type of Student	Cult. or Hyg. %	Special Curric. %	Verteb. or Mammal. Physiol. %	Gen. or Cell. Physiol. %	Plant Physiol. %	Special or Advanced %	More Than 1 Type %	Type Unspec. %	Total All Types %
Grad., in biol. sci.	0	#	5	13	11	17	3	8	8
Med., dent., or vet.	0	6	36	10	1	14	0	0	13
Physiol. majors	0	0	16	10	3	23	17	30	11
Biol. sci. majors	0	#	16	39	34	11	7	4	15
Pre-med.	0	0	0	2	0	0	0	0	#
Med. technol.	0	6	#	1	0	0	3	0	2
Nursing, pre-nursing	0	20	0	0	0	0	11	0	6
Pharmacy	0	4	0	0	0	0	3	4	1
Osteopathy	0	0	1	0	0	0	7	0	#
Agric. majors	0	9	8	1	14	8	0	0	8
Engineering	0	0	0	0	0	#	0	0	#
Other sci. majors	0	2	6	21	30	21	7	13	14
Physical or health educ. majors	7	32	0	0	0	0	31	8	10
Educ. and psychol. majors	0	11	0	0	#	2	0	25	4
Teachers (licenses)	0	2	3	0	#	#	0	0	1
Home economics	7	4	#	0	0	#	11	0	2
Other majors	14	1	0	1	3	1	0	1	1
Open to any student	51	0	4	0	0	1	0	0	1
Requirement for 'general education'	14	0	0	0	0	0	0	0	#
Not specified	7	3	6	2	4	2	0	8	3
Total	100	100	100	100	100	100	100	100	100
N	14	303	196	135	151	259	29	24	1111
% of total	1	27	18	12	14	23	3	2	100

Less than .5%.

A summary of courses in the physiological sciences, in terms of the students for whom they are designed, is given in Table X-1.¹ A similar analysis, in

¹ The following note, based on comments by one committee member (CLP), may be helpful here, especially to academic administrators.

'Hygiene', when taught by the Health Service, and 'General Education Physiology', taught by the Physiology Department, are very different and should not be lumped; and the class 'General or Cellular Physiology' is misleading.

Existing courses at the advanced *undergraduate-graduate* level are classified, with courses listed under each general heading as:

I. *General Physiology*. Universal principles of dynamic biology. Processes widely common to organisms and illustrated by appropriate cases. This term, however, has been used to cover many kinds of courses—from human physiology to applied physical chemistry—and might well be dropped.

II. *Cellular Physiology*. Basic physico-chemical reactions of living things. Although often used as a synonym of 'General Physiology,' it is more restricted. Includes: cytochemistry (molecular morphology), intermediary metabolism, enzymology (kinet-

terms of department offerings, is given in Table X-2. These two listings are based on an examination of the catalogues of some 450 'schools' or faculties in about 150 institutions, made in connection with Survey Project 1 by Dr. Baker of Drew University. This sampling is biased, by size, in favor of those universities and colleges which have professional schools, and of the main institutions from which Ph.D. physiologists had received their bachelors' degrees. It intentionally omits institutions with less than 200 students—colleges in which physiology, if taught at all, is presented only in general education biology courses or those in health or physical education. On a nationwide basis, the percentage of cultural or hygiene courses shown in Table X-1 is therefore probably much too low. Table X-11 shows the distribution of these courses by type of school or faculty.

Responses to a questionnaire sent to departmental chairmen (Survey Project 18H) indicated that undergraduate courses accounted for 72% of all students enrolled in courses with physiological content. As Table X-1 shows, an estimated 21% of the courses offered is designed primarily for graduate or professional (medical, veterinary, and dental) students, so four-fifths are open to undergraduates. Within this area, potentially so important because of the large body it reaches, there are several quite different student groups. Students majoring in physiology and the biological sciences, including those specified as pre-medical, are the most important group, and one-fourth of all courses involving physiology are intended for them. Another 35% of the courses are intended for other science majors and for those in agriculture, pharmacy, nursing, and medical technology. Physiology for engineering students is usually given as 'human engineering' or biotechnology. Osteopathy students are treated separately, because of different sources of information

ics), biophysics (in the sense of applied techniques), radiobiology, photobiology, electrobiology, physiology and growth, development and aging.

III. *Comparative Physiology*. The kind of organism is the experimental variable. Related are: physiological ecology, experimental embryology, and physiological genetics.

IV. *Physiology of Special Groups of Organisms*.

- A. Mammalian and Human—the classical course in animal physiology
- B. Environmental and Stress Physiology, including: bioclimatology, engineering physiology (human engineering), aviation physiology
- C. Veterinary Physiology
- D. Plant Physiology; of algae and of higher plants
- E. Insect Physiology
- F. Bacterial Physiology
- G. Physiology of Parasites

The coding of research in physiology—by experimental variable, type of organism, structural level, functional response, and socio-economic orientation—may also be a helpful guide to teachers. At present most university departments in biology are based on the 'type of organism' studied; yet it is more important to emphasize the common properties of living organisms than their differences. The major division under 'socio-economic orientation' is into fundamental or applied; and that under 'variable' and 'response' is perhaps into the chemical, physical, and biological viewpoints.

TABLE X-2. PHYSIOLOGICAL SCIENCE COURSES IN COLLEGES AND UNIVERSITIES, BY TYPE OF DEPARTMENT IN WHICH OFFERED (Preliminary Report, Table V-E-24; Survey Project 1).

Type of Department	Cult. or Hyg. %	Special Curric. %	Verteb. or Mammal. Physiol. %	Gen. or Cell. Physiol. %	Plant Physiol. %	Special or Advanced %	More Than 1 Type %	Type Unspec. %	Total All Types %
Preclinical									
Physiol., physiol.									
chem.	0	12	50	13	0	37	24	42	24
Bact., microbiol. ...	0	#	1	0	1	9	0	5	3
Anatomy	0	#	0	1	0	0	0	0	#
Pathology	0	#	0	0	0	0	0	0	#
Pharmacology	0	#	0	0	0	0	0	0	#
Clinical									
Surg., surg. spec....	0	0	2	1	0	2	0	0	1
Obst. and gynec....	0	#	1	2	0	0	0	0	1
Medicine, med. spec..	0	#	1	1	0	#	0	0	#
Medical ancillary									
Optometry	0	1	0	0	0	1	0	0	#
Nursing	0	1	0	0	0	0	0	0	#
Dentistry	0	#	0	0	0	0	0	0	#
Pharmacy	0	#	0	0	0	0	0	0	#
Other	0	4	2	1	0	4	3	0	3
Agricultural									
Animal husbandry ..	0	1	3	0	0	1	0	0	1
Dairy products	0	0	1	0	0	4	0	0	1
Horticulture	0	0	0	0	1	0	0	0	#
Other	0	3	2	0	1	4	0	0	2
Non-medical									
Biology, biol. sci....	50	19	15	21	24	5	35	8	17
Botany	0	0	1	3	48	9	0	8	9
Zoology	0	8	6	27	1	7	14	8	9
Psychology	0	9	0	0	0	3	0	29	4
Biophysics	0	0	0	0	0	#	0	0	#
Chemistry	0	#	0	0	0	0	0	0	#
Other	7	4	3	1	2	5	0	0	3
Non-science									
Home econ., nutr....	0	1	0	0	0	0	0	0	#
Speech	0	1	0	0	0	0	0	0	#
Other depts.	7	9	0	0	0	#	0	0	3
Depts. not indicated..	36	27	12	29	22	9	24	0	19
Total	100	100	100	100	100	100	100	100	100
N	14	303	196	135	151	259	29	24	1111

Less than .5%.

and sampling procedures for obtaining the institutions represented; a little over 0.1% of annual college graduates is in this field. The third student group, for which undergraduate physiology courses are designed, is in education, particularly physical education and home economics. Courses intended to meet teacher certification requirements should probably be placed with those for education majors. These courses, directed to future school teachers and athletic coaches and to the many nutritionists who teach home economics, comprise 17% of the total. They are likely to be denigrated by most physiological scientists; yet whatever future school teachers and coaches learn about physiology now will affect the general public definition of and attitude toward physiological science a generation hence.

Of the remaining courses, 3%, not specifically designed for any one type of student, represent a miscellany of approaches to physiology. The last group, nominally 2% but probably seriously underrepresented, includes courses for other majors, for general students, or for meeting requirements of general education, and fall largely under the poorly-sampled health and hygiene group. Freshman requirements for some knowledge of hygiene are common, but frequently they are catalogued under Physical Education, or as a general requirement to be tested by an examination on readings listed by the college health officer. Physiology is part of biology in the general education courses given in junior and community colleges and in the first two years of four-year colleges; and such cultural type courses are especially prevalent in the smaller institutions, many of them junior colleges. Public secondary schools hesitate to teach more than the general elements of sex education, so some material on the physiology of reproduction, as well as on other phases of human physiology, is probably taught in hygiene and health courses designed for undergraduate women; but the prevalence or need of such courses was not explored.

As shown by Table X-2, 35% of the courses in physiological science were offered by departments of biology, botany and zoology and 24% by departments of physiology. Other medically related departments offered 8%, agricultural departments 4%, other science departments—including psychology—7%, and non-science departments 3%; leaving 19% not indicated. Courses for special groups, such as nursing, education, and physical education majors, are mostly offered by biology, physiology, or zoology departments, although over a quarter were not specified. Courses in plant physiology are given almost entirely by biology or botany departments. Medical school departments of physiology, explored by Survey Project 11, mostly (three-fourths) offer courses for M.A. and Ph.D. candidates; and somewhat fewer (two-thirds) for dental and for nursing students; one-fifth or less for students in physical therapy, in undergraduate biology, or in pharmacy; and one-sixth, for graduate medical students (*Preliminary Report*, Table V-E-3).

The distribution of courses in a sampling of universities and colleges with various educational programs is shown in Table X-3. Four-fifths of the courses, listed in the catalogues analyzed in Survey Project 1, were given in liberal arts colleges and universities containing professional schools. Of all such institutions in the continental United States (1847 in 1955), about 16% (299) include professional schools; and some two-thirds of these offer programs leading to the doctorate. The second group of institutions, comprising liberal arts colleges with teacher-training programs and including both those with and those without terminal occupational or junior college programs, accounts for 5% (with) and 6% (without) of the physiology courses listed. Four-year liberal arts institutions with two-year programs often are expanded

TABLE X-3. DISTRIBUTION OF TYPES OF PHYSIOLOGY COURSES, BY TYPE OF INSTITUTION (Preliminary Report, Table V-F-2; Survey Project 1).

U.S. Office of Education Designation ^a	Type of Institutional Program	Cult. or Hyg. %	Special Curric. %	Verteb. or Mammal. Physiol. %	Gen. or Cell. Physiol. %	Plant Physiol. %	Special or Advanced %	More Than 1 Type %	Unspec. %	Total All Types %
(j,k)	Universities and colleges (liberal arts program + professional schools)	43	71	82	94	78	96	53	83	81
(e,f)	Liberal arts + teacher-preparatory + terminal-occupational . .	36	20	11	4	11	#	35	0	11
(g,h,i)	Professional or technical + teacher-preparatory	0	3	5	1	6	3	0	13	4
(c)	Liberal arts + terminal-occupational	14	4	#	0	2	0	3	0	2
(b)	Liberal arts	7	#	0	1	2	1	3	4	1
(d)	Mainly teacher-preparatory	0	2	2	0	1	#	3	0	1
(a)	Terminal-occupational	0	0	0	0	0	0	8	0	#
	Total	100	100	100	100	100	100	100	100	100
	N	14	303	196	135	151	259	29	24	1111

Less than .5%.
^a The designations of institutions by type of program, following the U.S. Office of Education, are as follows:
 (a) Terminal-occupational (below bachelor's degree)—to represent a program not extending beyond the 14th or 15th grade, designed to prepare directly for an occupation, and not intended to prepare for advanced study.
 (b) Liberal arts and general—including those institutions offering a 4-year program leading to the bachelor's degree.
 (c) Liberal arts and general and terminal-occupational—for institutions offering programs described by (a) and (b) above.
 (d) Primarily teacher-preparatory.
 (e) Liberal arts and general, and teacher-preparatory.
 (f) Liberal arts and general, teacher-preparatory, and terminal-occupational.
 (g) Professional or technical—including those institutions offering a program of occupational preparation (excluding teacher-preparatory).
 (h) Professional or technical, and teacher-preparatory.
 (i) Professional or technical, and terminal-occupational.
 (j) Liberal arts and general with 1 or 2 professional schools.
 (k) Liberal arts and general with 3 or more professional schools—including institutions organized as universities.

teachers colleges; those with the teacher-training program alone tend to be private institutions founded in the liberal arts tradition. There are 219 in the former group and 465 in the latter; respectively, 12% and 25% of the total number. The private liberal arts colleges are particularly important in scientific education; 23 of them are among the top fifty institutions producing, at the baccalaureate level, our recognized scientists. Only 16 universities or colleges having professional schools appear in that list (Knapp, Goodrich, 50).

The third major group, the professional and technical institutions, including those with teacher-preparatory or terminal-occupational curricula, offers 4% of the physiology courses sampled. Of these institutions, 181 are primarily technical or professional schools and 101 offer added programs; together they comprise 15% of the institutions of higher education. Among the final four groups, the general liberal arts colleges, three-quarters of which are privately controlled four-year institutions, are of particular importance. Eight of this latter group were among the first fifty institutions in producing American scientists at the baccalaureate level. The numbers and percentages of institutions in these four groups are: liberal arts and terminal-occupational, 307 (16.6%); liberal arts and general, 112 (6.6%); primarily teacher-preparatory, 127 (6.8%); terminal-occupational, 36 (1.9%).

According to the data collected in Survey Project 1, many more physiology courses (81% of the total) are offered by liberal arts colleges with professional (usually medical) schools attached than by all other institutions; liberal arts colleges without professional schools offer only 13%. Similarly, over half (52%) of all courses are in the large institutions (enrollments over 12,000), only 18% in small (enrollments under 4000) and 30% in medium-sized schools. By level, 46% are in undergraduate colleges, 22% in graduate schools, 12% in schools of medicine, and the rest scattered through various other types of institutions. Clearly, relatively few physiology courses exist in independent small colleges, perhaps for such reasons as: physiology is properly an advanced subject, with chemistry, biology, and physics prerequisite; it is expensive to teach; professional physiologists are lured away by better jobs in research and specialized institutions; medical schools discourage undergraduate physiology courses; there is far less agreement as to what should be taught undergraduates in the area of physiology than there is in those of embryology, comparative anatomy, and genetics.

When the physiology courses in the 450 institutions are classified by consumers, 25% are preprofessional or special curricular; these do not lead to further professional training in physiology per se; another 25% are seminar, research, or specialized courses, essentially graduate in nature; 2% are cultural or hygiene-like, usually for freshmen and given without prerequisite; and the remaining 45% constitute the core of professional training in physi-

ology and divide into 19% vertebrate (primarily mammalian), 15% plant, and 11% general (cellular and comparative) physiology. This distribution of courses for all institutions examined is essentially the same as for the accredited liberal arts colleges, where 19% are for specialized curricula; 11%, vertebrate; 12%, plant; and 10%, general physiology (Survey Project 1, Table V). It may be concluded that advanced undergraduate physiology courses are approximately equally divided among vertebrate, plant, and general physiology.

These data show the great importance of the physiology teaching in the liberal arts college or university; forty-seven of the fifty institutions leading in production of scientists were of this type. The potentially important field of applied physiology would be served by expansion of courses in schools of engineering or industrial management; and there is a great need for training technical laboratory aides. Moreover, physiological orientation and concepts can be presented to the mass of undergraduates—particularly to those preparing to be school teachers—in the cultural or hygiene courses in physiology and in the general biology courses. The concepts of biology and physiology taught to youth by future school science and health teachers are crucial to the welfare of the biological sciences.

Courses Taught by Physiologists

Cursory inspection, even without formal correlation, indicates that most academic physiologists are located in universities and colleges with professional schools. Data from the Survey questionnaire therefore probably apply primarily to the group of institutions giving four-fifths of the physiological science courses. Table X-4 shows that over two-fifths of teaching physiologists apparently teach no course with physiological content. The percentages are especially high for all groups of peripheral physiologists, least for the central animal and plant ones. This estimate, based on interpretations of subject-

TABLE X-4. PERCENTAGE OF PHYSIOLOGISTS TEACHING COURSES WITH PHYSIOLOGICAL CONTENT, BY ACADEMIC LEVEL (Q, 1, 109).

Academic Level	Central			Peripheral				Totals	
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	%	%
Undergraduate	38	65	20	16	22	11	8	26	} 55
Graduate	45	67	43	24	23	17	13	32	
Professional	55	2	5	17	1	6	8	23	
No course with physiological content indicated	11	16	47	54	65	71	73	43	43
No answer	1	0	1	2	1	1	2	2	2
Total	#	#	#	#	#	#	#	#	100
N	646	147	84	1154	278	150	61	2520	2520

Percentages total more than 100—respondents could indicate teaching at more than one level.

matter listings by questionnaire respondents, might be modified somewhat on thorough investigation.

Some of the 55% who do teach courses with physiological content (roughly 1380 respondents, or 1745 physiologists when projected in proportion to the total number) overlap the undergraduate, graduate, and professional (including medical) levels. From Table X-4 it can be estimated that half or less of this group teach undergraduates or professional and medical students, while nearly six-tenths teach graduate students. The professional level involves primarily medical teaching, as indicated by the high relative percentage of animal physiologists in this category. Plant physiologists teach undergraduate and graduate courses about equally; bacterial physiologists teach more graduate ones. The number of courses taught by physiologists is shown in Table X-5, along with the percentage of all physiologists who teach and also the percentage of those who teach courses with physiological content.

The departmental distribution of physiologists with teaching responsibilities is shown in Table X-6. Departmental affiliations of those teaching courses with physiological content in technical and professional or in teacher-preparatory institutions have not been analyzed; but again casual inspection of college catalogues and of lists of physiologists and biologists indicates that, while many physiologists teach their specialties in technical institutions, biologists teaching physiology in departments emphasizing teacher-training are mostly not physiologists. This does not augur well for bringing the physiological point of view to those who will teach science or biology in the public schools, or to future school administrators, or even to a large proportion of college graduates. These teachers need to be exposed to good physiology, during training or by refreshment, if biology is to come alive to the citizenry.

TABLE X-5. PERCENTAGE OF PHYSIOLOGISTS, WITH TEACHING RESPONSIBILITIES, WHO TEACH COURSES HAVING PHYSIOLOGICAL CONTENT (Q, I, 107; II, 150).

No. Courses With Physiological Content Taught	Central				Peripheral					Total ^a %	Total ^b %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %		
None	11	16	47	15	54	65	71	73	59	43	
1	33	33	38	33	26	25	22	18	25	28	50
2	29	32	12	28	11	6	5	7	10	16	29
3	16	14	1	14	4	2	0	0	3	7	13
4	7	3	1	6	2	#	1	0	1	3	5
5	2	1	0	2	1	0	0	0	#	1	2
6 or more	1	1	0	1	#	0	0	0	#	#	1
No answer	1	0	1	1	2	1	1	2	2	2	
Total	100	100	100	100	100	100	100	100	100	100	100
N	646	147	84	877	1154	278	150	61	1643	2520	1400 ^c

Less than .5%.

^a Percentage of all teaching physiologists.

^b Percentage of those teaching courses with physiological content.

^c Estimated.

TABLE X-6. DEPARTMENTAL AFFILIATION OF PHYSIOLOGISTS TEACHING COURSES WITH AND WITHOUT PHYSIOLOGICAL CONTENT (Q, II, 151 corrected).

Department	Any Courses With Physiological Content Taught?				N ^a
	Yes %	No %	No Ans. %	Total %	
Physiology	94	5	1	100	478
Zoology	72	28	0	100	120
Botany; plant pathology, plant nutrition	71	29	0	100	168
Biology	61	39	0	100	257
Psychology	61	39	0	100	112
Home economics	60	40	0	100	45
Animal husbandry; dairy products	58	42	0	100	89
Medicine; medical specialties	45	52	3	100	145
Other medical and ancillary medical science	42	57	1	100	163
Bacteriology	40	60	0	100	131
Biochemistry	38	62	#	100	226
Anatomy	25	75	0	100	100
Pharmacology	23	76	1	100	92
Chemistry	21	78	1	100	75
Other ^b		(data not analyzed)			319
					2520

Less than .5%.

^a For percentage of the total, see Table V-10.

^b Horticulture, agronomy, other agriculture; physics, biophysics; other departments; and no answer as to department (Q, I, 104-105).

Undergraduate Course Content

As Table X-1 shows, one type of physiology course is intended for undergraduates in general, another for majors in education, physical education, pre-nursing, or home economics. A survey of the courses in Utah (Survey Project 5B), perhaps not typical of all states, showed a wide variety of undergraduate offerings by departments of physiology and biology and some offerings by departments of psychology, speech, health, and physical education and recreation. In the college of agriculture, physiology receives special treatment in departments of zoology, botany, vocational agriculture, home economics, biochemistry, and psychology. In all, about 36 courses given by the three major colleges and universities in Utah are either outright physiology or place a considerable emphasis on it. In the former group are 10 courses in mammalian or human physiology (5 elementary and 5 advanced), 4 in plant physiology, and 2 in cellular physiology; in the latter, are 11 courses in nutrition, 4 in health, and 5 in other subjects.

Because of their importance in the education of laymen rather than of scientists, and thus basic to the popular understanding of scientific concepts, courses in physiology and general biology at the lower undergraduate (freshman-sophomore) level are later considered (Chapter XI) in relation to college education and the impending mass of undergraduates.

Undergraduate courses in biology and physiology directed to general edu-

cation or to training for non-scientific vocations are different in content and method and at a lower scientific standard than are those prerequisite for advanced work in biology and physiology. The Utah survey also reveals a multiplicity of course offerings, ostensibly different in objective but often varying little in actual physiological content. Moreover, some courses seem to be neglected because the departmental objectives of the teachers have little relation to the aims of the students; as when members of a medical physiology department teach courses designed for home economics or physical education majors. The problem of reconciling standards on different levels is basically administrative, but its effective solution will require sound professional advice.

In view of the undergraduate curricula suggested by medical schools, and which govern the course selection of most pre-medical students (even though many do not receive medical training) and, indirectly, of many biology students of all kinds, division of opinion as to placement of the basic course in general physiology is important. On this point the Survey questioned only physiologists teaching Ph.D. candidates, so the point of view of those in clinical fields may be underemphasized. As seen in Table X-7, only 14% of all physiologists, but double this in the plant groups, believed that no course in general physiology should be required for graduate students in the physiological sciences. Of the great majority who favored such a course, an undergraduate position was preferred to a graduate one by a three-to-two ratio; least so by animal and most by plant physiologists. Since the separate elements of requirement and of level were included in one question, and since the interpretation of 'general physiology' may have varied, this important question deserves further study.

Graduate and Professional Course Content

As shown in Table X-1, 8% of the physiological science courses considered by Survey Project 1 were intended primarily for graduate students in biology,

TABLE X-7. PERCENTAGE OF PHYSIOLOGISTS, TEACHING PH.D. CANDIDATES, WHO FEEL THAT "A COURSE IN GENERAL PHYSIOLOGY SHOULD BE TAUGHT AS A PREREQUISITE FOR GRADUATE STUDENTS IN THE PHYSIOLOGICAL SCIENCES" (Q, I, 126).

	Central			Peripheral				Total %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	
No	12	30	21	8	26	13	21	14
Yes, at undergrad. level	43	41	40	47	50	51	42	45
Yes, at grad. level	37	20	26	36	13	30	33	32
Yes, unspecified or both ^a	3	2	2	3	1	0	0	3
No answer	5	7	11	6	10	6	4	6
Total	100	100	100	100	100	100	100	100
N	362	74	47	543	141	80	24	1291 ^b

^a Not in questionnaire; added to code.
^b Does not include 1202 respondents who indicated that they do not teach any students working for a Ph.D. in the physiological sciences, or 27 respondents who did not answer that question.

and 13% for professional students in medicine, dentistry, and veterinary medicine. Some of the courses for agriculture majors were also probably at the graduate level. Since most specialized or advanced courses are for upper undergraduate and beginning graduate students, it may be estimated that 34% of these, about 8% of the total courses listed, are also intended for graduate students in physiology and biology. Thus about 29% of all courses in physiology are at the graduate or the medically-oriented professional levels. (The sample may, however, be biased towards the traditional type of liberal arts college and university, including those having professional schools.)

Graduate courses in vertebrate or mammalian physiology may, therefore, actually represent more than the 5% of the field indicated in Table X-1; since some courses designed for physiology and biological science majors are also in this area. A like situation may increase the actual graduate courses in cellular or general physiology above the 13% listed in that field. For plant physiology as well, besides the 11% of courses ostensibly for graduate students, others, for majors in biology, are probably also at the graduate level. The proportion of graduate course content in these various fields is thus probably higher than the data indicate. In 1953-54 thirty-six institutions granted masters' level degrees and twenty-nine granted doctorates in physiology per se, not counting degrees for physiological work under the auspices of other departments. Since, moreover, the findings of Survey Project 7 indicated that, for two recent years, only 12% to 18% of the doctoral theses on physiological subjects were produced by departments of physiology, graduate work in physiological science is obviously carried on in many academic departments.

A questionnaire sent to 331 heads of departments, including medical school departments, in connection with Survey Project 18H, resulted in the following data for 1953-54: 37% of the graduate students taking courses in physiological sciences, widely defined, were in physiology as a major field, 12% in zoology, 11% in medicine (graduate as distinct from medical students), 6% in biochemistry, 6% in bacteriology, 4% in pharmacology, 4% in botany, 3% in agriculture, 3% in agronomy, and 3% in surgery. These data are reasonably precise for liberal arts institutions with professional schools, since 76% of the institutions in two of three groups sampled were of that type, and 70% offer work at the doctorate level. For comparison, the report of the Third Teaching Institute of the Association of American Medical Colleges in 1955 (4, p. 76), on anatomy and anthropology, shows 278 fourth-year medical students of 560 sampled, doing research. One-sixth (46) were in physiology,—probably one-fourth including 24 in vascular research—, 28 in biochemistry, 26 in pharmacology, 20 in endocrinology—also partly physiology—, and 10 to 12 in anatomy, bacteriology, and pathology.

The content of courses in professional schools of medicine, dentistry, and

veterinary medicine may be estimated from data in Table X-1. Similarly, the amount of physiological teaching done by members of medical school departments may be obtained from data in Table X-2 (based on the sampling of catalogue announcements examined in Survey Project 1), which lists departmental contributions in the preclinical, clinical, and medical ancillary sciences. Survey Project 18H, partially based on that sampling, estimated that nearly one-third of all students in medical and dental schools in 1953-54 were enrolled in these professional courses (Table X-12). No data were obtained concerning physiological science courses in professional schools of agriculture, engineering, or other applied sciences.

The content of medical school courses was estimated (Table X-8) from lecture schedules and laboratory manuals, studied in connection with the First Teaching Institute of the Association of American Medical Colleges. Both lecture and laboratory emphasis is great on heart, circulation, and respiration taken together, and on the nervous system with its receptors and effectors. Probably the proportion of lecture material represents the relative importance of the topics more than does the proportion of laboratory work, the latter being subject to material considerations. Delegates to the Teaching Institute from physiology departments reported attempts to introduce, into the medical physiology course, information basic to the special topics of aviation and space medicine, psychosomatic medicine, atomic medicine, and rehabilitation

TABLE X-8. NUMBER OF MEDICAL SCHOOL DEPARTMENTS OF PHYSIOLOGY LISTING PHYSIOLOGICAL TOPICS IN LECTURE SCHEDULES, AND PERCENTAGE OF LECTURES AND OF LABORATORY MANUAL EXERCISES DEVOTED TO EACH TOPIC (Preliminary Report, Table V-E-6 corrected; Survey Project 11).

	No. Depts. Listing Lec- tures ^a (N = 64)	% of Total Lectures Devoted to Topic	% of Exer- cises in Laboratory Manuals
General physiology	33	4.1	0.5
Body fluids	46	4.3	6
Blood	42	5.3	
Heart and circulation	62	20.4		27
Respiration	62	10.0	11
Digestion	60	9.1	5
Metabolism	43	6.3	5.5
Kidney	60	6.1	5
Endocrines, reproduction	60	12.1	3
Nervous system	60	28.1	36 ^b
Temperature regulation, aviation medi- cine, exercise	40	3.5	
Miscellaneous			1

^a The topic may be covered (a) in a special course (e.g., neurophysiology), (b) in another course (e.g., metabolism in biochemistry), (c) under another topic (e.g., 'body fluids' under 'heart and circulation'); or (d) not at all. For these reasons, the data listed under lectures in general physiology, body fluids, blood, metabolism and temperature regulation, etc., may be erroneous; this does not apply to the laboratory exercises because those data were derived from study of the complete laboratory manuals.

^b Central and autonomic nervous system, 12%; nerve-muscle, 14%; special senses, 10%.

and geriatrics. Of these, only aviation medicine at present receives significant attention in medical school physiology courses (Survey Project 11, p. 6).

Data compiled in connection with the First Teaching Institute of the AAMC (Survey Project 11), including the opinions of the 301 physiology faculty members in attendance, deal with other aspects of medical school courses in physiology: fewer facts and more general concepts should be taught to medical students; the student should be encouraged to read and evaluate critically for himself; more basic science-clinical conferences during the latter half of the medical curriculum might be helpful; physiology, biochemistry, and pharmacology courses should be better correlated although remaining discrete. Comparable data on the teaching of physiology in other professional schools and in graduate schools of different types of institutions are not available.

Further data on academic status, content emphases, and enrollments in courses in physiology or having appreciable physiological content are desirable for sound generalizations concerning advanced education in physiology. Detailed studies on the educational status of bacterial and plant physiology and their applications in technical and applied sciences, comparable to those available for animal physiology and medical science, would be desirable.

Teaching Methods and Facilities

As noted earlier (Table VI-11), 68% of the respondents engaged in teaching felt that they have a very good or good chance of being effective. Teaching conditions need most improvement in laboratory space and storage facilities, some in laboratory equipment and demonstration facilities (Table X-9). Three-quarters of teaching physiologists now use the lecture method to a considerable extent and would continue to use it; but those who now make little use of discussions or seminars wish to use them more and lectures

TABLE X-9. ADEQUACY OF TEACHING FACILITIES (Q, I, 110-113; II, 154)
N = 2520.

	Satisfactory Now %	Some Improvement Needed %	Much Improvement Needed %	No Ans. %	Total %
Lecture facilities	61	28	8	3	100
Living plants or animals	48	29	8	15	100
Supplies, other than living	45	38	6	11	100
Textbooks	40	36	19	5	100
Audio-visual aids	35	37	20	8	100
Demonstration facilities	34	40	20	6	100
Laboratory manuals	34	34	19	13	100
Teaching assistants	32	36	23	9	100
Laboratory space	32	31	28	9	100
Repair and replace. facilities	30	39	21	10	100
Storage facilities	29	34	27	10	100
Laboratory equipment	28	44	17	11	100

less. Likewise, interest in audio-visual aids is greater than its present use, for half the teaching physiologists. The laboratory method is used to a considerable extent, and preferred for teaching, by 63%; demonstrations are not much used and only a slight increase is desired (Table X-10).

The teaching load for physiologists on medical school faculties is considerable, certainly as compared with biochemists and pharmacologists in like departments. Based on answers of 285 medical physiologists for the First Teaching Institute of the AAMC, 36% spend 100-200 hours a year in actual teaching in medical schools and 31% spend 200 to 300, with those teaching less about equal to those teaching more. Thus, 54% of physiologists teach less than 200 hours; compared to 60% of biochemists and 75% of pharmacologists. These same men teach an additional load in graduate and other university departments—37% under 50 hours, and one-fourth each 50 to 100 and 100 to 200. (The original interpretation of these figures, in Table 7, Survey Project 11, is in error.)

Medical students perform 44% of their experiments (average of 64 laboratory manuals) on human subjects or materials, as contrasted with 15% each on frogs and dogs, 6% on turtles, and 5% on cats (Survey Project 11, Table 3). Outside of medical school laboratories, however, more physiologists use rats in their laboratory teaching than any other animal, plus an appreciable number of dogs, rabbits, and mice (Q, II, 155-156). About 28% of all employed physiologists (58% of the central animal group) use animals in both teaching and research; only 4% use them solely in teaching (Q, I, 65).

The function of the instructor in laboratory teaching was regarded as 'general supervision with immediate intervention when things are not going

TABLE X-10. PERCENTAGE OF TEACHING PHYSIOLOGISTS USING VARIOUS TEACHING METHODS AND EXPRESSING ATTITUDES AS TO USE (Q, I, 114-117; II, 157) N = 2520.

	Teaching Methods Now Used				Total %
	Considerable Extent %	Some Extent %	Little or No Extent %	No Ans. %	
Lectures	78	16	2	4	100
Laboratories	63	21	9	7	100
Discussions or seminars	31	45	19	5	100
Demonstrations	14	55	24	7	100
Audio-visual aids	10	48	34	8	100

	Extent to Which Methods Should Be Used				Total %
	About Same As Now %	More Than Now %	Less Than Now %	No Ans. %	
Lectures	74	3	19	4	100
Laboratories	63	26	5	6	100
Discussions or seminars	42	53	1	4	100
Demonstrations	45	45	4	6	100
Audio-visual aids	36	53	3	8	100

well' by nearly half of 296 physiologists, reporting to the First Teaching Institute of the AAMC, while somewhat fewer—and significantly more instructors than chairmen of departments or full professors—felt that their function was that of 'general supervision with intervention only after serious trouble develops or students ask for help.' Actual laboratory teaching, according to department chairmen, in two-thirds of the departments surveyed, is carried on mainly by professorial staff; in somewhat less than a third, by equal numbers of graduate students, instructors, and professorial staff. In more than a third of the departments polled, one laboratory instructor supervised from 16 to 20 students; in a little less than a third, 11 to 15 students (Survey Project 11, pp. 21-22). These data primarily reflect the practices of medically-oriented animal physiologists; no comparable data are available regarding the teaching laboratory practices of bacterial or plant physiologists, but they are probably not too different, unless influenced by smaller class sizes.

Number of Courses in Physiological Science

The number of university and college courses in physiological science may be estimated on several bases. Listing of courses from a sampling of catalogues and course announcements, Survey Project 1, cannot safely be projected for all institutions. Another Survey Project (18H) made a statistical estimate of 4306 courses; based on questionnaires sent to department heads in medical schools and institutions offering at least one course in physiological science, chosen on the basis partly of findings in Survey Project 1 and partly of medical school listings, and with corrections for non-respondents and figures projected to the total schools in the United States. Except for the medical school material, these data cannot be taken as representative.¹ Examination of the student enrollment in the three institutional groups sampled indicates that this estimate may need correction. From 1953-54 enrollment data, the distribution between the three upper quartiles of institutions, according to enrollment, appears as follows:

	Institutional Groups		
	1st Quartile: Over 10,000 Students	2nd Quartile: 4,000-10,000 Students	3rd Quartile: 200-4,000 Students
Number of institutions in continental U.S..	34	91	1200 ^a
Number of departments giving courses ^b ..	87	273	1470
Number of courses in physiological science ^b	321	1215	2770
Departments per institution.....	2.6	3.0	1.2
Courses per institution.....	9.4	13.3	2.3
Courses per department.....	3.7	4.5	1.9

^a Estimated.

^b Projected data: Survey Project 18H.

¹ Office of Education data indicate a median enrollment of little over 400 and an upper quartile line at under 1000. The Project figures, 4000 and 10,000, clearly show the bias towards large institutions.

Since 30 of the 34 largest institutions have professional schools in addition to the arts and sciences faculty, and 29 of them grant a Ph.D., the number of departments and of courses per institution in the above estimate seems small. This is further evidenced by the finding of Survey Project 7, also using a wide definition of physiological science, that doctoral theses in physiological subjects were consistently produced by at least twelve departments.

Similarly, of the 91 institutions in the middle group, 68 have professional schools and 6 are technical or professional institutions: 59 of them award the Ph.D. degree. Even if nine junior colleges below baccalaureate level were omitted, the number of departments or courses per institution would not rise appreciably, to 3.3 departments and 14.9 courses per institution. On the other hand, 72% of the remaining 82 institutions award the Ph.D., which might tend to make the figure high. In the large group of small schools, not over 90 award doctoral degrees and many are mainly undergraduate, with vocational as well as academic programs.

If physiology is defined narrowly, in its technical or professional sense, there may be many fewer courses than the 4300 estimated; but if defined widely, as in the questionnaire of Project 18H, nearly every institution is likely to have one or more general biology or health courses for undergraduates which would be included. The estimate of 4300 is thus probably low if all courses having physiological content are intended; high if physiology is narrowly defined. The problem is similar to that in estimating the number of scientists who could be counted as physiologists (Chapter IV).

A more satisfactory estimate from the point of view of professional physiologists, although overconservative—much physiology given in peripheral courses as well as in general undergraduate courses in biology or health, and all physiology taught in university and college departments of education and physical education are then omitted from consideration—is obtained by counting the courses in physiological science taught by physiologists. Assuming (improbably) no duplications or joint courses, the percentage data in Table X-5 permit the estimate that about 2560 courses dealing with physiology are taught by about 1400 respondents, or—projecting these figures for the estimated total number of physiologists—3210 courses are taught by 1825 central and peripheral physiologists. This figure is 75% of the 4306 estimated by Survey Project 18H; and the 1825 teaching physiologists are 64% of the 2847 estimated for 1953-54 by that project. The figure of almost two courses per physiologist compares with the report of medical school anatomists that about half teach two courses a year, and two-fifths teach one(4).

Considerable overlapping occurred in teaching undergraduate, graduate, and professional level courses, within the 55% (Table X-4), reporting that they teach courses with physiological content. Without correlation of courses per person at each level, therefore, an accurate estimate of the number at

TABLE X-11. PERCENTAGE OF PHYSIOLOGICAL SCIENCE COURSES ANNOUNCED BY VARIOUS FACULTIES OR SCHOOLS (Preliminary Report, Table V-F-3; Survey Project 1).

	Cult. or Hyg. %	Special Curric. %	Verteb. or Mam- mal. Phys- iol. %	Gen. or Cell. Phys- iol. %	Plant Phys- iol. %	Special or Ad- vanced %	More Than 1 Type %	Type Unspec. %	Total, All Types %
Undergrad.; arts and science	93	59	33	57	66	22	66	25	47
Grad. school	0	5	16	26	17	49	25	50	22
Med. school	0	8	29	11	0	13	3	8	12
School of agriculture . . .	0	8	8	1	13	9	0	0	8
School of vet. medicine . .	0	2	6	1	0	3	0	0	2
School of education . . .	0	6	0	0	1	0	3	0	2
School of nursing	0	4	0	0	0	0	0	0	1
School of dentistry	0	1	5	1	0	0	0	0	1
School of pharmacy	0	2	0	0	0	0	0	4	1
School of publ. health . . .	0	1	0	0	0	2	0	0	1
Other schools	7	3	3	3	2	2	3	13	3
Not specified	0	1	0	0	1	#	0	0	#
Total	100	100	100	100	100	100	100	100	100
N	14	303	196	135	151	259	29	24	1111

Less than .5%.

each level cannot be made. Other evidence is available, however, from Table X-11 and shows that 47% of the courses listed by Survey Project 1 were given by the arts and science faculty at the undergraduate level. This includes undergraduate courses in schools of education, nursing, pharmacy, or agriculture, totaling 12%; professional courses in schools of medicine, veterinary medicine, dentistry, and public health (but omitting agriculture) totaling 16%; and graduate school courses, 22%. Taking the conservative estimate of 3210 courses with physiological content as a base, there might be, then: about 1900 undergraduate courses (probably more, since undergraduate general biology and cultural or hygiene courses are minimized both by professional physiologists and in the sample used by Survey Project 1); about 700 graduate school courses; and at least 510 professional level courses. This leaves 3% (90 courses) unaccounted for in other types of schools.

Enrollments in Physiology

The difficulty of estimating enrollments, for courses in physiology or with appreciable physiological content, has been discussed in relation to identifying courses at different levels. An estimate from Survey Project 18H (described above) gives 74,300 students enrolled in all types of physiology courses in 1953-54. Of these, 53,800 were undergraduate, 6300 graduate, 9000 medical, 4100 veterinary, and 1150 dental students (*Preliminary Report IV-I*, pp. 10ff. Table 1). As noted earlier, these data are principally from institutions with

a liberal arts program, both including and lacking professional schools, and are not representative of all institutions of higher education. The total number enrolled was estimated as some 6000 less than in 1948-49, a reflection of the nation-wide dip between 1949 and 1954 in enrollment for higher education rather than of a drop in physiology enrollments as compared to other subjects. At the graduate and professional school level, the effects of this dip will be felt for several years to come, since three or four years of preparation are prerequisite to enrollment in most of these schools. The increase in undergraduate enrollment after 1954 will thus be felt at the professional and graduate levels in physiology within four or five years.

Another estimate, from the same source, indicated that 474 of the 780 graduate students working in departments of physiology in 1953 would be Ph.D. candidates. Allowing for 10% drop-outs, the prediction was that 93 would obtain the Ph.D. in the spring of 1954. The actual number of doctorates in physiology granted in 1953-54 was 85; a reasonable agreement. A similar estimate, including all departments, gave 1607 graduate students in physiological science in 1953-54, 980 Ph.D. candidates, and a prediction (with 7% failures) of 209 Ph.D. degrees in 1954. The actual number of 1953-54 doctorates in physiological science is obtainable by analyzing the annual list of doctoral dissertations, as done for earlier years by Survey Project 7. These estimates and predictions by Survey Project 18H, regarding graduate students in physiology, are based upon much more accurate and complete information than are those regarding over-all enrollments.

For predicting future entrants into physiological science, the greater part of the undergraduate enrollment data is of little help. Chairmen predicted some 550 entering physiology departments for graduate study. Findings of Survey Project 18H indicate that about 13% of the undergraduate enrollment in courses in physiology is accounted for by pre-medical, pre-dental, and pre-veterinary students; a like percentage each by physical education and home economics students; and 3% to 4% each by undergraduate majors in agriculture, biology, education, pharmacy, psychology, and zoology. Thus, less than 20% of those enrolled in physiology courses are at all likely to have the academic background for further work in the whole biological science area. Nor are biologists who incline to physiology essentially different in abilities from biologists in general, according to a study of comparative ratings on the Graduate Record Examination conducted as Survey Project 3C. On the other hand, however, the mass of undergraduates exposed to course work in physiology, whatever its emphases, are laymen, and to some extent teachers of the future—their view of physiological science will be conditioned by the kind and quality of physiological teaching offered at the undergraduate level.

TRAINING OF GRADUATE STUDENTS

Abilities of Graduate Students in Physiology

In the opinion of those teaching doctoral candidates, 16% of the graduate students would become 'very good' physiologists; 56%, 'good'; and 21%, 'fair' (Q, I, 121). These subjective opinions can be supplemented to some extent by objective data. No significant differences were found between physiologists and other biologists by either the methods of clinical psychology (Survey Project 3A) or by performance on the Graduate Record Examination (Survey Project 3C). A sample of 102 biologists at the Ph.D. level divided into 47 judged physiological and 55 non-physiological. GRE scores for the two groups were 475 and 468, respectively; with the former averaging higher in most fields, especially biology, but lower in literature and mathematics. These small samples are only suggestive; indeed ten men with Ph.D.'s in physiology rated only 442; and, for other N's of 55 to 85, biology graduate students in general (434), while above the average (424), were below medical (439), zoology (450), and biochemistry (465) students.

Scores on the Army General Classification Test, designed to measure the learning ability of literate adults, however, suggest some difference between physiologists and other biologists. Further, of men starred as leaders in the first seven editions of *American Men of Science* (after which time the elaborate procedure for voting this distinction was discontinued), 375 were self-classified physiologists; constituting 13% of the 3000 self-labeled physiologists listed and 5% of all starred scientists (Survey, *Preliminary Report*). This compares with an estimated 2.8% of all scientists in 1953.

The data on AGCT scores in Table X-12, made available to the Survey

TABLE X-12. QUARTILE SCORES ON ARMY GENERAL CLASSIFICATION TEST OF PH.D.'S IN PHYSIOLOGY AND OTHER SCIENTIFIC FIELDS (Preliminary Report IV-G-2, p. 13; Ref. 122, pp. 317, 322).

Field of Degree	Quartile Scores ^a			Students Scoring Within Top 10% of Distribution of College Scores %
	25%	50%	75%	
Biochemistry (N = 89)	119	134	139	51
Botany (N = 47)	118	126	134	30
Physiology (N = 25)	123	136	145	64
Zoology (N = 80)	122	128	136	38
All biology (N = 308)	125	129	139	39
Biological sciences ^b	122	129	137	
Chemistry ^b	127	135	143	
Physical sciences ^b	129	138	149	
Earth sciences ^b	128	134	144	
All natural sciences ^b	125	133	143	
All science (N = 1088)	129	134	142	51

^a 100 = mean score.

^b Data from ref. 122, p. 319.

by Dr. Dael Wolfe of the Commission on Human Resources and Advanced Training, have been compared with other data in the published report of the Commission. The last column shows that students receiving Ph.D.'s in scientific fields are a superior group relative to the total college population. Over half the Ph.D.'s in all scientific fields obtained AGCT scores in the top 10% of the college scores. The highest of Ph.D.'s in this top decile, in turn, is for physiologists; but the small number here makes comparison of doubtful value. The first three columns of the table give the scores for the top of each quartile; for example, 25% of the physiologists tested scored below 123 on the AGCT, 50% scored below 136 (their median score), and 75% scored below 145. Of the first four groups, physiologists have a slightly higher median score than do the other three. They also resemble physical more than biological scientists in the high score of their upper quartile.

Major Graduate Fields of Physiologists

The fields in which physiologists received their doctoral degrees give some indication of the graduate training of physiologists in general, despite recent shifts in number of doctorates—to such new departments as biophysics. As shown in Table X-13, 32% of all physiologists took their Ph.D. degrees in the three kinds of physiology departments, 24% in chemistry or biochemistry, 12% in biology or zoology, and 10% in botany or horticulture. Bacterial physiologists mostly do their graduate work in bacteriology or biochemistry rather than in physiology; practically all plant physiologists do theirs in either plant physiology, botany, or horticulture; and graduates of physiology departments mostly become central animal physiologists. This imbalance in departments designated as 'physiology' is largely responsible for physiology being classified as a medically-related subject in studies of academic and professional manpower, and being regarded by laymen (if they know it at all) as only a servant to medicine. Actually, although nearly two-thirds (63%) of all animal physiologists received their doctoral training in physiology (compared to 16% in zoology and 5% in biochemistry), only one-third eventually become identified as central animal physiologists (see Table IV-2).

Table X-13 illustrates the wide range of disciplines from which the profession of physiology draws its membership and also emphasizes the divergent academic backgrounds of the three major groups of physiologists. Table X-14, obtained by judging the physiological character of titles of all doctoral theses produced during four academic years (Survey Project 7), also illustrates the diverse departmental training in physiological science. The reciprocal relation of theses in physiology and in biochemistry and the recent shift toward microbiology are clear.

TABLE X-13. PERCENTAGE OF PHYSIOLOGISTS OBTAINING PH.D. OR SC.D. DEGREES IN VARIOUS SCIENTIFIC FIELDS (Q, I, 142-143; II, 13, corrected).

Field	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Animal physiol. ^a ..	63	#	1	38	18	0	#	0	11	21
Plant physiol. ^a	#	60	1	16	#	25	0	0	5	10
Bacterial physiol. . .	0	0	9	1	#	0	4	0	1	1
Biochemistry	5	2	9	5	30	7	22	41	25	20
Bacteriology	#	0	73	8	1	2	48	4	6	7
Clin. and preclin. med. sci. (other) .	2	#	1	1	6	#	1	3	4	3
Home economics . .	0	0	0	0	1	0	#	3	1	#
Chemistry	2	1	1	2	7	3	5	6	6	4
Physics	1	0	1	1	4	#	2	5	3	2
Biology	6	3	1	5	3	3	4	0	3	4
Zoology	16	#	1	9	11	2	1	9	8	8
Psychology	1	0	0	1	11	0	0	5	7	5
Agriculture	#	1	0	1	1	3	2	4	2	1
Botany	#	26	1	7	#	26	5	3	6	6
Horticulture	0	4	0	1	#	26	2	4	6	4
Animal husbandry .	1	0	0	#	3	#	1	3	2	1
Science (gen.), pre-med. (gen.)	#	0	0	#	#	#	0	1	#	#
Other	1	1	1	1	1	1	1	9	1	1
Non scientific	#	#	0	#	1	0	1	0	#	#
No answer	2	2	0	2	2	2	1	0	2	2
Total	100	100	100	100	100	100	100	100	100	100
N	750	307	138	1195	1565	520	298	105	2488	3683 ^b

Less than .5%.

^a In those instances where the respondent only indicated 'physiology', it was assumed that his training was in the area (animal, plant, bacterial) of his present identification.^b Includes only those respondents who indicated that they have a Ph.D. or Sc.D.

TABLE X-14. PERCENTAGE OF PH.D. DISSERTATIONS IN PHYSIOLOGICAL SCIENCE, BY TYPE OF DEPARTMENT, 1939-1951 (Survey Project 7).

Department	1939-1940	1944-1945	1950-1951	1951-1952	4-yr. Av. %
	%	%	%	%	
Agriculture	5	8	8	9	
Anatomy	1	1	2	2	
Bacteriology, microbiology	6	8	9	13	
Biochemistry	30	41	41	27	
Botany	7	8	7	7	
Entomology	1	2	2	3	
Genetics	2	0	1	#	
Horticulture	2	3	4	3	
Medicine, surgery	1	1	5	3	
Pharmacology	2	1	2	2	
Physiology	24	18	12	18	17
Psychology	10	6	5	8	
Zoology	9	3	2	5	
Total	100	100	100	100	
N	293	145	555	598	1591

Less than .5%.

Distribution of Graduate Training

As seen earlier, Table IV-8, the proportion of doctorates earned in physiology departments averaged, over the fifteen-year period 1940-54, 6.6% of those in all biological science, including agriculture and medical science but excluding psychology. In the four specimen years examined by Survey Project 7 (Table X-14), departments of physiology accounted for 17% of the biological science dissertations. Graduate work in physiology therefore lies to a large extent outside the departments called 'physiology', and approximates 11% of all doctoral work in the biological sciences. (Allowance is made for inclusion of psychology in the second set of data.) The extent to which physiology is taught by these 'non-physiological' departments may be gauged from Table X-6. It is clear, on the present evidence, that any study of the production of physiological scientists must take into account this wide distribution of graduate training. It is a source of both strength and weakness to physiological science.

The institutions which have granted Ph.D. level degrees in physiology per se, during the twenty-year period 1936-1955 are shown in Table X-15. Table X-16 compares the institutions granting most higher degrees in physiology,

TABLE X-15. NUMBER OF DOCTORATE DEGREES IN PHYSIOLOGY GRANTED BY INSTITUTIONS IN THE UNITED STATES, 1936-1955 (58, 109, Table 1).

Institution	1936-45 (10 Yr.)	1946-50 (5 Yr.)	1951-55 (5 Yr.)	20-Yr. Total	% of Total	Rank Order
Adelphi College	0	0	1	1	#	
Boston Univ.	5	0	5	10	0.9	
Brown Univ.	10	5	0	15	1.3	
Bryn Mawr College	4	2	0	6	0.5	
Buffalo, Univ. of	1	0	2	3	#	
Calif. Inst. of Technology.	5	0	0	5	#	
California, Univ., Berkeley.	39	16	46	101	8.9	2
Catholic Univ. of America.	1	1	0	2	#	
Chicago, Univ. of	67	13	38	118	10.4	1
Cincinnati, Univ. of	3	0	1	4	#	
Clark Univ.	1	0	0	1	#	
Colorado, Univ. of	6	1	1	8	0.7	
Columbia Univ.	27	4	7	38	3.4	10
Connecticut, Univ. of	0	0	8	8	0.7	
Cornell Univ.	33	10	6	49	4.3	7
Duke Univ.	7	2	4	13	1.1	
Florida State Univ.	0	0	3	3	#	
Fordham Univ.	4	8	4	16	1.4	
George Washington Univ.	2	5	17	24	2.1	
Harvard Univ.	28	5	4 ^a	37 ^a	3.3 ^a	11
Howard Univ.	0	0	1	1	#	
Illinois, Univ. of	6	7	35	48	4.2	8
Indiana Univ.	0	1	4	5	#	
Iowa State College	15	1	3	19	1.6	
Iowa, State Univ. of	23	7	16	46	4.1	9

(Continued next page)

TABLE X-15.—*Continued*

Institution	1936-45 (10 Yr.)	1946-50 (5 Yr.)	1951-55 (5 Yr.)	20-Yr. Total	% of Total	Rank Order
Jefferson Med. College.....	0	0	4	4	#	
Johns Hopkins Univ.	9	4	2	15	1.3	
Kansas, Univ. of.....	2	1	1	4	#	
Louisiana State Univ.....	3	0	0	3	#	
Loyola Univ.	0	0	1	1	#	
Maryland, Univ. of.....	4	0	2	6	0.5	
Mass. Inst. of Technology.	1	2	0	3	#	
Massachusetts, Univ. of...	1	0	0	1	#	
Michigan State Univ.	0	1	12	13	1.1	
Michigan, Univ. of.....	17	0	10	27	2.4	
Minnesota, Univ. of.....	39	10	9	58	5.1	5
Missouri, Univ. of.....	5	4	3	12	1.0	
Nebraska, Univ. of.....	1	2	2	5	#	
New York Univ.....	13	3	2	18	1.6	
Niagara Univ.	2	0	0	2	#	
North Carolina, Univ. of.	0	3	2	5	#	
Northwestern Univ.	33	6	12	51	4.5	6
Ohio State Univ.....	8	5	11	24	2.1	
Oregon, Univ. of.....	0	1	0	1	#	
Pennsylvania State Univ...	1	0	0	1	#	
Pennsylvania, Univ. of...	8	4	5	17	1.5	
Pittsburgh, Univ. of.....	1	0	0	1	#	
Princeton Univ.	13	0	0	13	1.1	
Purdue Univ.	5	2	0	7	0.6	
Radcliffe College	6	3	0	9	0.8	
Rice Institute	1	0	0	1	#	
Rochester, Univ. of.....	21	10	29	60	5.3	4
Rutgers Univ.	3	4	12	19	1.6	
St. Louis Univ.....	0	0	1	1	#	
South Carolina, Med. Col..	0	0	1	1	#	
Southern Calif., Univ. of..	4	3	4	11	1.0	
Stanford Univ.	11	3	2	16	1.4	
Syracuse Univ.	0	1	4	5	#	
Texas A. & M. Coll.....	1	0	0	1	#	
Texas, Univ. of.....	9	1	1	11	1.0	
Tufts College	0	1	3	4	#	
Tulane Univ.	2	2	7	11	1.0	
Utah, Univ. of.....	0	1	1	2	#	
Virginia, Med. Coll. of..	0	0	1	1	#	
Virginia, Univ. of.....	1	0	0	1	#	
Washington Univ. (St. L.).	2	0	0	2	#	
Washington, Univ. of....	0	0	2	2	#	
Western Reserve Univ....	7	1	0	8	0.7	
Wisconsin, Univ. of.....	45	7	10	62	5.4	3
Yale Univ.	15	1	17	33	2.9	12
Total	580	176	377	1133	100	

Less than .5%.

^a The figures have been increased by 4 (percentage, 0.4) on the basis of information that at least this many degrees in physiology, given under the catalogue rubric Medical Sciences (special field, Physiology), had been overlooked. More were perhaps buried in other categories, as Public Health. Obviously, further special situations may have introduced perturbations; this is the only specific one brought to the Survey's attention, although the ratings of California Institute of Technology, Johns Hopkins, and Princeton have been challenged. Indeed, the whole problem of defining physiologists in various data collections should be re-examined by the collecting agencies.

TABLE X-16. RANK ORDERS OF INSTITUTIONS GRANTING 3% OR MORE OF DOCTORATE DEGREES IN PHYSIOLOGY AND IN THE PHYSIOLOGICAL ASPECTS OF THE BIOLOGICAL SCIENCES.

<i>A. Institutions Granting Ph.D. Degrees in Physiology ^a</i>							
1936-45		1946-50		1951-55			
	%		%		%		%
Chicago	11.5	California	9.1	California	12.2		
Wisconsin	7.7	Chicago	7.4	Chicago	10.1		
California	6.6	Cornell	5.7	Illinois	9.3		
Minnesota	6.6	Minnesota	5.7	Rochester	7.6		
Harvard-Radcliffe	5.8	Rochester	5.7	George Washington	4.5		
Cornell	5.7	Fordham	4.5	Yale	4.5		
Northwestern	5.7	Illinois	4.0	Iowa State	4.2		
Columbia	4.7	Iowa State	4.0	Stanford	4.2		
Iowa State	3.9	Wisconsin	4.0	Michigan State	3.2		
Rochester	3.6	Northwestern	3.4	Northwestern	3.2		
Total	61.8	Total	53.5	Rutgers	3.2		
580 = 100%		176 = 100%		Ohio State	2.9		
				Total	69.1		
				377 = 100%			
<i>B. Institutions in Which Ph.D. Dissertations Were Judged Physiological</i>							
1939-40		1944-45		1950-51		1951-52	
	%		%		%		%
Wisconsin	9	Columbia	10	Wisconsin	10	Wisconsin	9
Cornell	8	Wisconsin	9	Cornell	7	California	7
Minnesota	7	Cornell	8	Illinois	5	Illinois	6
California	6	California	8	Chicago	5	Minnesota	5
Chicago	6	Illinois	4	Minnesota	5	Ohio State	4
Illinois	4	Michigan	3	California	5	Chicago	3
Iowa State	4	N. Carolina	3	Purdue	4	New York	3
Iowa State Col.	3	Rochester	3	Columbia	3	Pennsylvania	3
Michigan	3	Texas	3	Harvard	3	Total	40
Rochester	3	Ohio State	3	Yale	3	598 = 100%	
Columbia	3	Minnesota	3	Total	50		
Northwestern	3	Toronto	3	555 = 100%			
Harvard	3	Total	60				
Yale	3	146 = 100%					
Johns Hopkins	3						
Total	72						
293 = 100%							

^a See Table X-15.^b From Survey Project 7.

and those granting them in all biological departments on dissertations judged to be physiological. The data do not exactly coincide chronologically and particular errors can arise from administrative labeling (see footnote, Table X-15), but the general patterns of leadership in graduate training, as well as the changes in leadership, are apparent. For instance, both the University of California and the University of Illinois have risen in ranking, with respect to both degrees in physiology and physiological theses in other biological sciences; the University of Chicago has maintained its high ranking in both groups; the University of Wisconsin now gives relatively few degrees in physiology, yet maintains first place in producing physiologically-oriented biological scientists.

TABLE X-17. INSTITUTIONS FROM WHICH FACULTY OF DEPARTMENTS OF ANATOMY RECEIVED HIGHEST DEGREE (4, Table A-11).

	%
Chicago, Univ. of.....	5.5
Michigan, Univ. of.....	4.8
Minnesota, Univ. of.....	4.5
Cornell Univ.	4.5
Harvard Univ.	4.4
Yale Univ.	4.3
Johns Hopkins Univ.....	3.4
New York Univ.....	3.0
Columbia Univ.	2.8
Iowa, State Univ. of.....	2.8
Total	40.0
726 = 100%	

The University of Minnesota has dropped in ranking in physiology but remains a leader in producing physiologically-oriented biologists. The University of Rochester no longer appears in the latter category, but has greatly advanced in ranking among institutions granting degrees in physiology. Some institutions appear to have withdrawn from physiological work on the graduate level entirely, while new names—George Washington University, Rutgers, Michigan State—forge ahead. Certainly, about half the graduate work in physiology and also in physiological aspects of biology is given in a relatively few institutions; all characterized by a complex academic organization, the presence of professional schools on campus, and location in the Northeast, North Central, and Western regions of the country. As a further dimension for comparison, the top ten producers of professional anatomists are given in Table X-17.

In the past, graduate training in the physiological sciences has increased in the East and West North Central and the Pacific regions, but has gradually decreased in New England, the Middle Atlantic, and the South Atlantic regions. These trends are detailed in Table X-18, which gives the geographic

TABLE X-18. GEOGRAPHICAL DISTRIBUTION OF HIGHEST DEGREES OF PHYSIOLOGISTS LISTED IN *American Men of Science*, 1906-1944 (Survey Project 13A, Table 8).

Region	1906 %	1910 %	1921 %	1927 %	1933 %	1938 %	1944 %
New England	15	16	18	16	13	14	11
Middle Atlantic	26	23	21	19	19	18	17
East North Central.....	17	20	24	28	28	28	29
West North Central.....	3	4	7	8	9	11	11
South Atlantic	17	16	14	12	11	10	9
East South Central.....	0	0	0	0	#	#	#
West South Central.....	1	0	#	#	2	2	2
Mountain	0	0	0	#	#	#	1
Pacific	4	4	4	5	7	6	7
Other, incl. Canada.....	17	17	12	12	11	11	13
Total	100	100	100	100	100	100	100
N	97	135	209	331	561	719	882

Less than .5%.

distribution of institutions granting the highest degrees to physiologists listed in *American Men of Science* from 1906 to 1944. These data may also be compared with geographical trends in research activity, shown in Tables VII-15, VII-16, and in employment, Table V-13.

Preceptor-Student Relationships

Those acquainted with departments of physiology in these universities will at once connect Cannon with Harvard, Carlson with Chicago, Howell with Hopkins, and so on. The influence of preceptors on their pupils, and the line of descent in the personal and organizational genealogy of American academic departments of physiology, was investigated by Survey Project 4A. Information was obtained from the questionnaires and also from historical material assiduously collected and generously made available by Dr. Carlos I. Reed, of the University of Illinois Medical School. These data are of great interest to the historian of higher education or of physiology; but they could not be rendered sufficiently complete or exact by the Survey, in the limits of time and attention available to this project. The data are on file at the American Documentation Institute and provide a good start for study of the relationship of preceptors to their students over decades and institutions. The march of physiology westward in this country, and the intellectual lineages of its leaders, is well worthy of scholarly investigation.¹ One relatively simple and effective trick of the pharmacologists deserves emulation: at each Fall Meeting on a campus a history of the local department is prepared. As suggested by Knapp and Goodrich, in their survey of the origins of American scientists (50, p. 258):

. . . The teacher-student relationship at its best is an interpersonal relationship of a fundamental order involving the total character of the two individuals. . . . As we have known the eminent teacher, he has typically been a rather masterful figure, possessed of considerable aggressiveness and vitality. In this role he has been able to inspire his students both through their desire to emulate his qualities and achievements and through their fear of his disapprobation.

Most graduate training in physiological science takes place in a small group of institutions; but the preceptor is especially influential in setting the stand-

¹ Some of Reed's figures on men trained at various schools were mentioned in the volume on *Perspectives in Physiology* (117, pp. 165-6). His tabulation was never completed, but additional institutions, finishing the 'C's and continuing through 'O', with five or more products are: George Washington U. (7), U. of Illinois (22), Indiana U. (5), U. of Iowa (21), U. of London (13), U. of Maryland (12), McGill U. (24), U. of Louisville (6), U. of Michigan (21), U. of Minnesota (33), U. of Missouri (10), Northwestern U. (31), Ohio State U. (16), U. of Oregon (6), Oxford U. (7). Unfortunately, similar figures are not available on such important centers as Rochester U., U. of Toronto, Tulane U., Washington U., Western Reserve U., and U. of Wisconsin. A study of the training and later careers of physiologists, on an individual rather than a statistical basis, would be possible from the Survey card deck (although anonymity would have to be penetrated to a minor extent) and should be highly rewarding.

ards of scientific scholarship in smaller institutions or those remote from urban or university centers. The Survey questionnaires elicited information from physiologists on both the institutions and years of their undergraduate and graduate training; but the data were collated only for identification of some larger academic institutions. The rich material could and should be used to investigate more fully the preceptor-student relationship; but special handling will be required to penetrate anonymity for individual cases while adhering to its general preservation in the files.

Inadequacies in Graduate Training

Several measures are available as to the effectiveness of training of physiologists. Respondents indicated subjects in which further training would have been helpful (Table X-19); also, 61% of those respondents actively responsible for training Ph.D. candidates indicated, in an open-end question, their evaluation of inadequacies in graduate student training (Table X-20). Comparison of these tables shows that 42% to 48% of all physiologists and 26% of those responsible for doctorate training consider training in physics and chemistry inadequate. On both counts, this attitude is especially strong among plant physiologists. Lack of mathematical training is felt by 54% of all physiologists, but only by 17% of those training graduate students. High proportions of all groups of physiologists feel that their biochemical training was inadequate, but such a lack is not felt by present preceptors—perhaps an indication that more such training is now offered at the undergraduate level, even though a bachelor's degree specifically in biochemistry is granted by few universities. Biological training is generally regarded as adequate; training in techniques appears much more satisfactory today than previously.

'Other' felt inadequacies in training could be inserted by respondents; but

TABLE X-19. PERCENTAGE OF PHYSIOLOGISTS INDICATING SUBJECT IN WHICH FURTHER TRAINING WOULD HAVE BEEN PROFESSIONALLY HELPFUL (Q, I, 132; II, 172).

Subject	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Physics	59	40	33	51	41	33	32	29	38	42
Chemistry	47	62	61	52	40	57	54	38	45	48
Botany	2	13	13	6	5	24	10	14	9	8
Zoology	7	3	9	7	13	7	7	21	11	10
Biochemistry	43	60	47	48	38	54	43	33	42	44
Psychology	6	1	2	4	5	3	3	6	4	4
Mathematics	63	49	58	59	52	51	47	53	51	54
Techniques	17	15	23	17	16	15	14	17	16	16
Total	a	a	a	a	a	a	a	a	a	a
N	961	382	171	1514	1951	595	385	126	3057	4571

^a Percentages total more than 100 because respondents could indicate more than one subject.

TABLE X-20. PERCENTAGE OF PHYSIOLOGISTS, NOW TEACHING PH.D. CANDIDATES, WHO REPORT INADEQUACIES IN PRESENT OR PREVIOUS PH.D. TRAINING (Q, I, 122-123).

First Two Things Mentioned	Central			Peripheral				Total %
	Animal %	Plant %	Bact. %	Animal %	Plant %	Bact. %	Other %	
Inadequate training in biological sciences — biology, anatomy, etc..	7	4	11	8	9	8	12	7
Inadequate training in physical sciences — chemistry, physics, etc..	28	48	26	19	35	29	12	26
Inadequate training in science (gen. or unspecified)	7	13	11	10	15	13	4	10
Inadequate training in mathematics	21	22	19	13	25	15	4	17
Inadequate training in English, speech, writing, etc.	3	2	4	4	4	4	8	4
Training too specialized; concentrated in one field	8	7	6	8	5	9	4	8
Not enough training in specialized techniques, research	3	2	4	4	4	1	4	3
Situational inadequacies —in facilities or program, courses etc.	4	1	9	5	1	4	8	5
Other	12	3	9	8	3	3	25	9
No answer	37	31	28	43	34	40	43	39
Total	a	a	a	a	a	a	a	a
N	362	94	47	543	141	80	25	1291 ^b

^a Percentages total more than 100 because respondents could mention more than one item.

^b Does not include 1202 respondents who indicated they do not teach students working for a Ph.D. in physiological sciences, or 27 respondents who did not answer that question.

none proved of statistical interest. Preceptors today, however, are concerned about their students' inadequacies in the use of English. This was indicated by about 4% of the physiologists teaching doctoral candidates; and at the First Teaching Institute of the AAMC this factor was consistently rated high by faculty members of every department (*Preliminary Report IV-G-2*, p. 24C, Table 118); in fact, inadequacy in English was rated more serious than that of pre-medical training in chemistry, biology, and mathematics. Undergraduate teachers place the responsibility for inadequate preparation upon the secondary schools, just as deans of undergraduate schools of engineering complain that high school preparation in mathematics is inadequate for their student needs. This is less notable for chemistry or physics, which frequently are not taught in the smaller high schools and begun in college. The situation in high school biology is discussed in Chapter XI.

Undergraduate Major Fields of Physiologists

Some deficiencies in the preparation of graduate students in physiology may be traced to poor undergraduate schooling in basic concepts of mathematics, chemistry, and physics. Very few professional physiologists were undergraduate physics majors and a vanishing number were mathematics majors. As indicated by Table X-21, nearly one-quarter (23%) of all, especially those whose identification with physiology is peripheral, majored in chemistry as undergraduates; while those who majored in biology or zoology (22%) tended to become physiologists primarily rather than secondarily. Undergraduate botanists tend to become plant physiologists; undergraduates in biochemistry, agriculture, pre-medical, or general science fields (even in non-scientific fields which, surprisingly, account for 6% of the total), have become identified with all branches of physiology. The relatively small trickle of pre-medical or general science majors could result from a disposition of graduate departments in physiology to reject candidates refused admission

TABLE X-21. PERCENTAGE OF PHYSIOLOGISTS OBTAINING BACHELORS' DEGREES IN SCIENTIFIC AND NONSCIENTIFIC FIELDS (Q, I, 138-139; II, 14 corrected).

Field	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Animal physiol. ^a . . .	6	#	0	3	2	0	0	0	1	2
Plant physiol. ^a . . .	0	1	0	#	#	1	0	0	#	#
Bacterial physiol. ^a . .	0	0	1	#	#	0	1	0	#	#
Biochemistry	3	1	2	2	3	1	3	5	3	2
Bacteriology	#	0	32	4	1	1	22	1	4	4
Clin. and pre-clin. ^b .	1	#	1	1	2	#	1	1	1	1
Home economics . . .	#	#	1	#	1	0	0	2	1	1
Chemistry	15	9	23	15	33	13	29	40	28	23
Physics	1	0	0	1	3	#	1	3	2	2
Biology	24	12	21	20	11	9	16	7	11	14
Zoology	16	2	6	11	9	2	4	8	7	8
Psychology	1	0	0	1	6	#	0	4	4	3
Agriculture	2	13	2	5	5	18	3	5	7	6
Botany	1	37	1	10	#	20	3	1	5	7
Horticulture	0	10	0	3	#	26	3	3	5	5
Animal husbandry . .	2	0	1	1	3	1	1	4	2	2
Gen. and pre-med. ^c . .	11	5	4	8	8	2	5	6	6	7
Other	1	1	1	1	#	#	1	0	#	1
Nonscientific	8	5	2	7	6	3	3	6	5	6
Other fields ^c	1	1	1	1	1	1	1	1	1	1
No answer	7	3	1	5	6	2	3	3	5	5
Total	100	100	100	100	100	100	100	100	100	100
N	885	376	170	1431	1838	582	376	122	2918	4349 ^d

Less than .5%.

^a In those instances where the respondent only indicated 'physiology,' it was assumed that his training was in the area (animal, plant, bacterial) of his present identification.

^b All medical sciences other than physiology, biochemistry, and bacteriology.

^c Undetermined if scientific or not.

^d Includes only those respondents who indicated that they have a bachelor's degree.

to medical schools; or may indicate that young students with clinical aspirations rarely look to physiology as a second field. It is also likely that the data do not adequately represent the number of pre-medical majors, since many later declare a basic science major and obtain an undergraduate degree in a specific subject field. Although 45% of all physiologists thus have their undergraduate training in chemistry, biology, or zoology; physiology looks, if not uniformly, to all scientific fields for its recruits. A simple run of the Survey card deck would show whether the experience of psychologists (Clark, *America's Psychologists*, 12) applies to physiologists—that, contrary to general belief, prior experience in a different field does not favor outstanding research performance in the one of final choice.

Undergraduate grade averages reported by Survey questionnaire respondents were 38% 'A' or 'A-' and 55% 'B+', 'B', or 'B-' (Q, I, 128). Grade averages are used as achievement measures and have considerable validity, despite different standards of accomplishment in similar types of institutions (29% of the respondents obtained bachelors' degrees in institutions with over 12,000 students in 1953-54). They probably reflect, besides ability, personality characteristics which may influence grading and which surely contribute to future leadership, honors, income, and similar evidences of achievement which are often correlated with undergraduate grade averages. The Survey data were not coded for a full institutional analysis, as in such studies as that of Knapp and Goodrich, *Origins of American Scientists* (50); and the intended comparison data on other professional groups were not obtained. Extended comparisons could be made beyond those mentioned in various connections (e.g. Chapter IV, Appendix)—another area asking further study.

RECRUITMENT OF PHYSIOLOGISTS

Awareness of Physiology

The initial factors that attract people to scientific subjects and, eventually, careers have been discussed briefly in relation to eminent scientists (Chapter VI, p. 75); and the Westinghouse Science Talent Search revealed that an early interest in some field of science, as biology, was usually continued. Those with early interest in both the biological and physical sciences may turn either way. Theoretically, at least, it would be possible to identify potential physiologists at an early age; sometimes in the ninth grade, when strong scientific motivation is apparent, but more generally in the tenth or eleventh grades of high school.

The difficulties in making and acting on such identifications are not insurmountable; but under the conditions of mass education, school counselors and science teachers need strong contacts with and support from the scientific community, as in Junior Academies of Science, to accomplish much. Science

contests and science fairs at the high school level have a place in scientific recruitment, but personal contacts of scientists with promising youth and with their science and mathematics teachers have even more potential. Initial awareness of the career possibilities of chemistry and physics has been fostered at the high school age and is strongly reinforced by AEC training activities, intense advertising by industry, and the like; awareness of career possibilities in the biological sciences, with the exception of medicine, has not been backed by that continued and concentrated program of public education only possible with heavy support by the profession and the industries which it serves. If physiologists wish young people to know the place of physiology in scientific endeavor, they must themselves acquaint promising youngsters with career possibilities in physiology, and their teachers with its intellectual content.

Happily, the scientific community is at last coming alive to these matters. The Biology Council of the NRC has sponsored a pamphlet (Stevens, *Career Opportunities in Biology*, 79) on careers in biology and the Education Committee of the APS has a parallel one in the narrower field of physiology; the Committee on Education of the Academy-Council has been highly effective and a report of the college division (Hall, *Improving College Biology Teaching*, 38) contains important achieved and recommended actions. The NSF has supported a growing program of summer institutes for high school and college teachers to work with established scientists—in 1957, \$4,800,000 was committed to reach nearly 4800 teachers in 95 institutes (NSF # 186, release Dec. 16, 1956)—and the physiologists' Education Committee has spearheaded these institutes in its field. In general, this country is responding to the threat of a scientific manpower shortage with funds from government and foundations and service from professional scientists.

Physical science and engineering tend to be stressed; the physiological scientists, all biologists, must forward their own disciplines. That this can be achieved—without a special attack by the 'hidden persuaders'—is at least suggested by the experience of Holland. This country has been disproportionately strong in biologists over several decades. A Dutch plant physiologist attributes this to a merchandising happenstance: the Verkaade company early introduced into its packages of cookies a series of picture cards about the living world. These were distinguished in text and drawing, and were so prized by the people that, when the company wished to stop distribution, public clamor demanded their continuation. This interpretation of the situation should be checked and, if verified, this chance experiment in recruiting biologists could guide more deliberate efforts.

The physiologists interviewed by the Survey, so far as they could recall, usually became aware of physiology between the ages of 17 and 20 (Survey Project 8B). The Survey questionnaire presented a list of ten factors which might have contributed to entering the general field of primary identification;

respondents checked 'college teacher', 40%, 'graduate school teacher', 27%, and 'secondary school teacher', only 9%. (High school teachers, questioned in Iowa—Survey Project 5A, were more optimistic; 38% felt they had influenced students into biology. Perhaps students forget.) Plant physiologists in particular, bacterial ones somewhat less, noted the influence of undergraduate teachers on their decision; while animal physiologists were influenced more equally by undergraduate and graduate mentors (Q, I, 3). An earlier analysis of forty-eight physiologists starred in *American Men of Science* (Landis from S. Visser's data; 14, p. 525) indicated that three-fourths had decided to enter science by age twenty and most were committed to physiology by twenty-two. About one-third each were stimulated 'to achieve' by college and by graduate or medical school teachers; less than one-fifth were influenced toward science (4%, 'to achieve') by high school teachers.

The main factor affecting the choice of a general field, however, was 'interest in the content of the field', indicated by 82% of the respondents and consistently high for all branches of physiology. What led to this interest was not asked; but an investigation of the underlying factors might well help future scientific recruitment. The problem now facing the physiological profession is to communicate the many-faceted nature of its work; primarily to undergraduates in biology and chemistry, more generally to the public at large and especially to high school students who show capability and interest in the natural sciences.

The physiologists teaching doctoral candidates felt strongly (72%) that these students would become either very good or good physiological scientists (Q, I, 121); and the personal characteristics judged to affect achievement may also apply to recruitment into scientific work. Adverse items mentioned in response to an open-ended question, answered by 48% of respondents teaching doctoral candidates, included: not intelligent enough, or lacks ability, 14%; not motivated enough, 13%; bad or inappropriate personality traits or attitudes, 9%; not scholarly enough, or with poor thinking habits, 8%; too young, not mature enough, or with goals not adequately developed, 2%; lack of interest in the field, or stronger interest in other fields, 9%; too money-oriented, or overly desirous for financial reward, 5%; conflict for time with other activities, or part-time work, or financial difficulties, 3%. Other reasons were mentioned by 8%, and 3% (primarily animal and bacterial physiologists) considered entrance requirements not high enough, or felt that too few students applied or they were not well selected (Q, I, 124-125). These opinions, averaging almost two reasons to a respondent, are further evidence that successful recruitment of professional scientific personnel must take into account, besides the simple academic criteria of achievement and potential, factors of personality, motivation, and attitude.

Previous Fields of Interest

Before entering their present fields of primary identification, 62% of the Survey respondents had seriously considered other professional fields. As shown in Table X-22, medicine led all others, nearly a quarter (24%; largely animal and bacterial physiologists) having at one time considered a medical career. Since no time is indicated, these alternative careers might have been considered at almost any point in the maturation process; but probably most who made an early, and perhaps seemingly inconsequential, choice did not indicate any past interest in another field. The possible choice of chemistry by 9%, notably among bacterial physiologists, reflects the close relation between biochemistry and physiology. Eleven per cent, alike in all branches of physiology, contemplated non-scientific work. Figures from limited personal interviews (Survey Project 8B) indicate that 50% of the physiologists drifted in from chemistry and 20% each from medicine and biology-zoology. Undergraduates do not seem to be made adequately aware of physiology as a separate career.

Concerning medicine as an alternate choice of many who enter physiology,

TABLE X-22. PROFESSIONAL FIELDS CONSIDERED BY PHYSIOLOGISTS PRIOR TO ENTRANCE IN PRESENT GENERAL FIELD (Q, I, 9; II, 32).

First Field Mentioned	Central				Peripheral					Total %
	Animal %	Plant %	Bact. %	Total %	Animal %	Plant %	Bact. %	Other %	Total %	
Physiology	1	2	1	1	2	2	1	1	2	2
Agriculture	1	2	1	1	1	2	1	4	1	1
Botany	1	2	1	1	1	3	1	0	1	1
Horticulture	0	3	0	1	#	2	1	1	1	1
Forestry	1	5	1	2	#	1	#	1	1	1
Animal husbandry	0	#	1	#	#	#	0	0	#	#
Psychology	1	#	1	1	1	0	0	0	#	1
Zoology	3	3	0	3	2	1	2	2	2	2
Biochemistry	3	2	4	3	1	1	1	5	1	2
Medicine	32	10	19	26	25	11	26	19	22	24
Microbiol., bacteriol.	1	1	3	1	1	1	1	2	1	1
Chemistry	6	10	15	8	10	5	12	11	9	9
Physics	2	2	1	2	3	1	1	3	2	2
Biology	1	0	1	#	#	0	0	0	#	#
Gen. sci., premed.	#	#	0	#	#	1	0	1	#	#
Other	3	3	2	3	3	3	4	6	3	3
Non-scientific	10	12	10	10	10	13	10	10	11	11
Other fields ^a	1	1	2	1	1	2	1	1	1	1
None indicated ^b	32	41	34	34	38	50	36	31	41	37
No answer	1	1	3	2	1	1	2	2	1	1
Total	100	100	100	100	100	100	100	100	100	100
N	961	382	171	1514	1951	595	385	126	3057	4571

Less than .5%.

^a Uncertain if scientific or not.

^b Includes 1669 respondents who indicated they were not previously interested in going into another field, and 51 respondents who did not answer that question.

it should be remembered that a career in medicine is a common goal of biologically-minded youth. Some, often among the best, discover biological science as they study, others fail to complete the pre-medical curriculum, for a variety of reasons, and some are not accepted by medical schools. In all cases, alternate vocations and careers should be exhibited to youth of high school and early college age. To quote a recent study of undergraduate pre-medical majors at the Chicago campus of the University of Illinois:

Enough alternate vocational plans are conceived in high school to make an effective guidance program an absolute essential. College, however, is the time when most alternate plans are formulated, since this is where the student first discovers what the requirements for medical school really are and encounters top-flight competition, all of his caliber or better. A few, who will not be convinced, must wait until having failed in the premedical curriculum or even having graduated from the university before formulating practicable alternate plans.

The logical solution . . . was to stress early in the college career the importance of an alternate vocational choice and/or a second major field of interest. This . . . presents no difficulties or problems administratively; in fact, it is possible for the student to fulfill both the premedical requirements and those of the alternate vocational field concurrently (39, pp. 264-265).

This study showed that, of those not admitted to medical schools, 47% were studying or working in some scientific area, the remainder being mainly in business, social science, and education. The majority of those entering education would probably teach biology or chemistry, however, and could be included in the scientific area; so about half made an alternate vocational choice in science. A high percentage of those who completed the pre-medical curriculum, or who dropped it during college, continued in efforts to enter chemistry, biology, or psychology. Physiologists, whatever their specialties, thus have a real opportunity to recruit those undergraduates who appear qualified to become scientists, by presenting physiology as an attractive scientific vocation with ultimate rewards and satisfactions comparable to those of medicine. At least 37% of physiologists in medical departments have the M.D.—with or without the Ph.D.—compared to half the pharmacologists, one-third of the anatomists, and one-ninth of the biochemists (AAMC, First and Third Teaching Institutes, 3 and 4).

Clinical Versus Basic Science Careers

Within medically-oriented physiology there is a divergence not only in the subject matters of clinical and basic science, but also in the personal traits, motivations, and attitudes of those who choose these different careers. In connection with the First Teaching Institute of the Association of American Medical Colleges, groups of eight or more senior medical students, representing about a third of the medical schools, were asked what would make a career of teaching and research in the basic medical sciences more attractive. The factor checked most frequently was, 'income commensurate with clinical

fields'; and next was, 'closer correlation with clinical medicine'. Similarly, the two major factors which influenced medical students against such a career were 'low income', and 'liking for personal doctor-patient relationships'; and, indicative of basic content differences, was 'more interest in clinical medicine'.

Such attitudinal differences have their roots in personality factors which may well determine success or failure in careers of research, teaching, or administration, or in ones involving basic or applied science. Selection and recruitment of medical students on such criteria have been considered by some investigators, e.g. Schofield at the University of Minnesota, and Early at the University of Illinois. The problem of analyzing and communicating the results of research on personality, attitude, motivation, learning, and achievement has been examined in a pilot project under the auspices of the Scientific Manpower Commission, which is interested in the application of these findings to the recruitment of scientists and technicians. Measurement of student motivation has been considered by a current project of the Educational Testing Service, in connection with its college admission and graduate record examinations. The findings of these and other research studies will be of great value for the wise recruitment and selection of future students, not only in medicine and in physiology, but in every field of science; indeed in all occupations.

SUMMARY

Tracing the flow of students into physiology or of physiology into students, through the courses, departments, and schools that contribute to undergraduate, graduate, and technical or professional education, is as confused as is tracing precursors and products through a metabolic pool. Certainly, this chapter on training has received more critical comment by Committee members than has any other—perhaps because the education of scientists is today in such focus; perhaps because every professor is an expert on the subject.

With a wide view of physiological content, there were in the Survey period over 4300 courses containing physiology taught to over 74,000 students in 1800 departments (only one quarter called 'physiology') in 1300 colleges and universities (omitting those with an enrollment under 200), mostly liberal arts institutions with professional schools. Undergraduates can enter four-fifths of the courses—72% are specifically for them—and 54,000 (73%) do so. Graduate students in biology (6000) are served by 8% of the courses; professional students (medicine 9000, veterinary medicine 4000, dentistry 1200) by 13%. The 80% undergraduate courses include: one-fourth (of 100%) directed to majors in biology (rarely does one called 'physiology' exist); one-third, to students in the semi-professions (medical technology, nursing, pharmacy, agriculture); and one-sixth, to education students (in-

cluding home economics, nutrition, and coaching). Less than half of all physiologists (two-thirds of the plant group) teach undergraduate courses with physiological content, and 70% of peripheral physiologists (43% of all physiologists) teach no course containing physiology. Most biology courses for teachers, who train future citizens as well as scientists, are taught by men and women who have had no reasonable exposure to physiology. Only 9% of present physiologists were influenced toward their career by high school teachers; 40% by a college teacher, usually some biologist.

More narrowly, 3200 courses are taught by 1800 central and peripheral physiologists. Of these courses, 1900 are for undergraduates, 700 for graduate students in biology, 500 for professional students, and 100 unassigned. Higher level courses divide between 1 mammalian physiology to 2 plant physiology to 2.5 cellular physiology. The mammalian courses are mostly professional and, on the average, devote one-third of their time to neurophysiology and one-fourth to circulation. Opinion is strong that general physiology should be required in Ph.D. training, probably in the undergraduate years.

Nearly a thousand graduate students, half of them in physiology departments, are working on physiological theses for a Ph.D.; and, of the fourth-year medical students doing research (39% of those sampled in 1955) the largest groups, some one-third, were working on clearly physiological problems. Other estimates place in physiology departments, of all those in physiological science, only 37% of Ph.D. candidates, and 7% to 18% of completed theses. Half of all Ph.D. candidates are judged 'good' by their department chairman; and half also rate, on an ability test, in the top 10% of the whole college student body. (A small sample of professional physiologists scored on this test with the physical science group rather than with other biologists. Survey respondents placed their undergraduate grades almost entirely at the A, 38%, or B, 55%, levels.)

Teachers mostly (68%) feel that teaching conditions are propitious, space limitations being most troublesome; and 180 schools give a Ph.D. in physiology. But so far as the present professional physiologists are concerned, a dozen or so institutions—mostly the large liberal arts universities—account for over half. Despite such good opportunities, many physiologists feel defects in their own training and see such in current Ph.D. programs. Poor skill in English is seen far more than felt; inadequate basic science is more felt than seen. Few physiologists mention a deficiency in biology; about half wish their mathematics, physics, or chemistry were better. Animal physiologists crave mostly mathematics and physics; plant and bacterial physiologists, mostly chemistry and biochemistry. Perceived deficiencies obviously do not represent failures in training—bacterial physiologists have strong roots in chemistry—but rather reveal the directions of advance of the science. Plant

physiology is moving into a strong biochemical development, beyond the training of older professionals; and animal physiology, having split off biochemistry, is now similarly tugging its devotees towards biophysics.

The non-congruence of physiology as a subject matter and as an administrative area (which made this section of the Survey so difficult) is also clear from the multiple streams into and out of graduate training in physiology. This is rarely an undergraduate major, so most students enter from biology (22% of the central group) or chemistry (23% of the peripheral group). By areas, the sources are: for animal, plant, and bacterial physiologists respectively, 40% biology-zoology and 15% chemistry; 37% botany and 23% agriculture-horticulture; and 32% bacteriology and 23% chemistry. On the output side, while two-thirds of the central animal physiologists received their doctorate in a department of physiology, only one-third of the Ph.D.'s in physiology have become central animal physiologists. Indeed, over two-thirds of present professional physiologists at one time considered another career—as medicine by one-third of the animal group and chemistry by one-sixth of the bacterial group—and over 10% were even headed away from science. Physiology has, of course, also lost potential or actual workers; but it seems clear that the profession and the science would gain greatly if the subject were better recognized in course offerings and departmental organization and in course content and teacher training.

XI

THE PUBLIC AND PHYSIOLOGY: COMMUNICATION AND EDUCATION

PHYSIOLOGY IN THE PUBLIC MIND

What Is Physiology?

The term 'physiology' means little to the public. In contrast, 'chemist' or 'surgeon' or 'psychiatrist' immediately conjure up readily recognizable figures—scientists with test tubes, men in white with scalpels, or graybeards with couches. But physiology and physiologists are indistinct: in definition and in function they merely 'have something to do with the body,' meaning—almost without exception—the human body. Public recognition of physiology in terms resembling Claude Bernard's classic view, as the study of the physical and chemical processes of all living organisms, is practically non-existent.

This situation stems from the historical vicissitudes of physiology in relation to hygiene and from the habit of journalists of attributing anything physiological to the 'doctor', so that such concepts are 'tied to the tail of the medical disease kite'. A century and a half ago, physiology was regarded, in learned circles, as part of natural philosophy and of natural history. At first this primitive biology reflected the preoccupation of scientists with systematic botany and ecological and taxonomic zoology; later, in the mid-nineteenth century, it emphasized the morphological aspect of zoology. Physiology for the layman became entirely related to human anatomy and shifted gradually toward hygienic considerations. This view merged easily with a growing popular concern about the practical and social aspects of community health and welfare, and also served as a convenient platform for temperance evangelists and reformers. After World War I, popular demand led to legislation requiring school courses in physiology, health, and physical education. Such measures, while perhaps raising national standards of health information and practices, have reinforced the popular notion limiting physiology to its application relative to the functioning human body. The public's image of physiology is important;—it influences the appreciation of, interest in, and support for the work done by physiologists as scientists.

Physiology in the News

This view of physiology is naturally the one utilized by science writers and editors. The term is only occasionally used, but the concept of physiology mostly underlies the presentation of medical news items. With simple language and ideas the *sine qua non* of all newswriting, it is difficult to present the intellectual significance of a finding; so the layman is given a new test or treatment for cancer or heart disease as a tidbit relating to his personal or national life. Furthermore, the backgrounds of editors and science writers are those of reporters and writers in general and rarely contain much science; indeed, it is a recognized policy of some publications to keep their science writers innocent in this field. And when the writers do become knowledgeable, they are often thwarted, in turn, by the copy desk. Of course, scientific discovery is rarely proper spot news; and the magazines usually do a better job than the newspapers—occasionally a superb one.

Project 2B of the Survey attempted to gauge the effectiveness of the public presentation of physiology and to detect factors operating against public awareness of this field and its workers. A brief questionnaire was prepared for circulation to members of the National Association of Science Writers; but pretesting it showed that personal interviews with even a few representatives would be more productive, since orientations to the area of interest are so individual. Furthermore, it was necessary first to clarify with the respondents what physiology is and then to learn the extent of their interest and competence in the field as reporters.

The science writers and editors were questioned as to: their concept of physiology and use of the terms physiology and physiologist; the requirements for presenting their sort of news; the factors influencing their judgment of news items as important and valuable; the nature of their sources; their own backgrounds; the factors influencing the inclusion of physiological material in their news articles, such as source, appropriateness, and public acceptance or awareness; and finally their own reactions, suggestions, and comments concerning the effect of publicity on scientists and scientific efforts. All those interviewed felt that medical news appeals to the public because the layman easily personalizes the content, and because the several health fund drives emphasize special areas of disease and medical progress. A newspaper science editor estimated that 65% to 85%—the larger figure during medical conventions—of his coverage is medical, and the greater portion of the balance is physics and chemistry; with plant science and agriculture receiving rare attention. The medical editor of a news magazine estimated that the rank order of appearance of content material was medicine, disease, physiology, biochemistry, and anatomy. Physiological phenomena are presented as 'medicine'; if the term 'physiology' or 'physiologist' is used at all, it is mainly because of the source of the news lead. Science writers and

editors are primarily concerned with timeliness and newsworthiness, their sources are often personal, and their leads are either articles in technical journals or press releases from professional, governmental, or commercial bodies. Some sources provide press releases of high accuracy and pertinency, which may be used almost verbatim; many do not.

Public Relations for Physiology

All journalists interviewed strongly urged the establishment of public relations machinery to ensure the vigorous and extensive presentation of physiology in lay media. They urged, in short, 'If you have something to say, say it!', but cautioned against assuming that the public will read or understand technical terms. A central clearinghouse, or rewrite service, is required for this purpose. The American Chemical Society, as an example, has had such an organ in operation for years and, by indicating the role of chemistry in everyday industrial, agricultural, medical, and other scientific fields, it has given the public a friendly awareness of the importance and attractiveness of the chemical field. This program has resulted in increases in industrial support of basic research and teaching, and the establishment of weekly television and radio programs, both national and local. The Society supplies speakers in the field of chemistry to a variety of organizations and searches the literature for new items to put in releases for press and radio. As with other sciences, the principal difficulty is in translating technical terminology into common terms.

Good public relations for science develop only when scientists themselves are active in establishing them. The situation in other countries, as to public knowledge of physiology and efforts to improve it, was explored in essays contributed by participants in a symposium at the 1953 International Congress of Physiology (Survey Project 8A and *Perspectives in Physiology*, 117). In general, these further emphasized the limited impact of physiological science upon the general public; but in Sweden a public campaign for betterment, launched by physiologists and other medical scientists, has greatly advanced research. Through this appeal for popular interest and support, members of Parliament were led to establish a Medical Research Council and provide research funds for medical science. New professorships and staff positions were created, and physiological research in Sweden was greatly strengthened. Physiology now receives 13% of all medical research grants, undoubtedly the result of this campaign by the profession for its support.

Few American physiologists volunteered comment on the need of public understanding of physiology, but the topic was not included in the Survey questionnaire. In interviews with physiologists (Project 8B), there were frequent remarks to the effect that 'physiology' means nothing to the public and that the position of physiologists would be improved if a different term

were used to describe their work (biophysics and bio-mechanics were explicitly suggested) ; but physiologists are overwhelmingly disinterested in the problem of public relations, however alert they become on the matter of public support. Such a depersonalized attitude helps make physiologists diffident about publicizing their work or their profession. It is rather significant that only 4% of the Survey respondents indicated that the prestige of physiology was a factor influencing them to enter this field (Q, I, 3). Disinterest of physiologists in the public image of their profession implies poor public relations, future recruitment, and support.

INFORMING THE ADULT PUBLIC

The Journalism of Popular Science

The major value to science of the scientific and quasi-scientific articles in newspapers and magazines is probably in creating a public awareness that various scientific disciplines exist and of the socio-economic importance of scientific research. The predominance of medically-oriented publicity has focused public attention on clinical medicine at the expense of non-medical animal physiology and of plant and bacterial physiology, which are also important to the national welfare. In addition, the bias of the whole field of mass communication to make science interesting to the public by stressing its applications encourages the notion that scientists are concerned primarily with the tangible gains from applying their science, rather than with extending the frontiers of understanding to appease intellectual curiosity.

Any attempt to assess the quality of mass communication of scientific knowledge must obviously consider both scientific and journalistic standards. The problem, touching all science, transcends physiology; but Project 2A of the Survey was initiated by Dr. Alan Burton as a small pilot study of the amount of biological material appearing in periodicals of general interest. The length of articles was measured and the average number of magazine columns devoted to a particular field (as the biological or the physical sciences) and to all science, was related to all articles published. These data are condensed in Tables XI-1 and XI-2.

In thirteen years, 1938 to 1951, there has been an over-all increase in popular periodical space given to articles on science but the percentage has changed little. The number has increased perceptibly in some magazines, particularly the *Saturday Evening Post*, with a high proportion of fiction (Table XI-1). The *Reader's Digest*, a monthly of general information, has increased the number and proportion of science articles but not the fraction of space devoted to science; while *Time*, a weekly concerned with current news, has slightly decreased the proportion of both space and articles on science. If mass communication policies reflect public interest, as well as

TABLE XI-1. PERCENTAGE AND AMOUNT OF MATERIAL IN CERTAIN POPULAR PERIODICALS DEVOTED TO ALL SCIENCE, AND TO THE BIOLOGICAL SCIENCES, INCLUDING MEDICINE (Survey Project 2A).

Periodical	% of Science Material to Material on All Subjects				% of Biological Science Material to All Science Material			
	1938		1951		1938		1951	
	Space	Articles	Space	Articles	Space	Articles	Space	Articles
Reader's Digest	15	17	16	24	82	81	67	71
Sat. Eve. Post.	2	3	5	6	58	56	74	72
Collier's	^a	^a	5	6	^a	^a	77	81
Time	7	9	6	8	56	64	54	54

Periodical	Science Material				Biological Science				All Subjects			
	1938		1951		1938		1951		1938		1951	
	N	Art.	N	Art.	N	Art.	N	Art.	N	Art.	N	Art.
Reader's Digest	473	74	638	100	390	60	433	71	3200	430	3900	420
Sat. Eve. Post.	201	16	519	43	116	9	381	31	8500	570	9500	730
Collier's	^a	^a	241	26	^a	^a	186	21	^a	^a	4600	460
Time	333	367	365	362	186	235	196	245	4933	3944	6184	4338

^a Not included in analysis.

form them, it may be inferred that the general public is interested in science, but hardly in competition with national and local affairs, sports, entertainment, or fiction.

Within the space devoted to science, biology has both gained and lost (Table XI-1). As shown by Table XI-2, the medical group dominates in biological science, with considerable variation of other areas. Psychology, with a high personal-interest value, has held a considerable and steady rating, in the two analyses which included it as a biological science. The attention given particular topics may also reflect inherent differences in the audiences reached by these periodicals.

One analysis of general periodicals attempted to identify specific material about physiology. The fraction of all articles in *Time* devoted to physiology was: by number, 0.8% in 1938 and 0.4% in 1951; by space, 0.6% and 0.2%, respectively. The fraction of all science articles also shrank from 1938 to 1951; from 8% to 5% in number and from 9% to 4% in space (Project 2A Addendum). Another comparison was made of the amount of physio-

TABLE XI-2. PERCENTAGE OF BIOLOGICAL SCIENCE SPACE IN POPULAR PERIODICALS DEVOTED TO CERTAIN SUBJECTS (Survey Project 2A).

Periodical	Medical Sciences ^a		Zoology		Botany		Agriculture		Psychology	
	1938	1951	1938	1951	1938	1951	1938	1951	1938	1951
	%	%	%	%	%	%	%	%	%	%
Reader's Digest	37	40	23	11	1	0	9	8	23	24
Sat. Eve. Post.	65	65	14	25	22	10	^b	^b	^b	^b
Collier's	^b	69	^b	11	^b	2	^b	10	^b	^b
Time ^c	50	61	8	4	2	0	2	2	5	6

^a Medical sciences include social aspects of medicine.

^b Not included in analysis.

^c Estimates based on data given in Project 2A.

logical material in a popular periodical, *Reader's Digest*, with that in a semi-popular periodical, *Scientific American*, and a fully professional one, *Science*. The data were compiled on varying bases, so quantitative comparisons are loose; but the *Digest* in 1951 published 29 medical science articles, of which three were on the physiology of sex and one on physiology in general—no others had significant physiological content—and two of fifteen medical science articles in the *Scientific American* in 1951 concerned physiology. In *Science*, however, of 264 articles judged to be in the medical sciences (twice as high a proportion of all biology articles as so judged in the other periodicals) 51 were physiological—roughly 19% of the medical and 15% of all biological articles. In all three magazines there were more biochemical than physiological articles, but fewer were classified in other areas of medical science. Although the definition of physiology used in making these analyses might have excluded articles concerning plant and bacterial physiology, such articles were lacking even when definitely sought.

This is probably also true of an analysis of scientific articles appearing in the *New York Times* in 1950. Of a thousand articles indexed, 36% were on physiology, 4% on biochemistry, 12% on zoology, 11% on physics (including atomic and nuclear energy but excluding their social aspects), 7% on chemistry and chemical products, and 6% on botany or agriculture, with 24% distributed among other subjects. Also, among the 25 scientific articles listed as highlights of the year 1950, 40% were on biochemistry or physiology and 32% on physics and atomic or nuclear energy. In 1942, by comparison, a similar analysis had shown only 20% of the articles devoted to 'health and medicine' (Berger, ref. 6, pp. 484-488).

A comparable study, made for the Biology Council of the National Academy-Research Council by Berwind Kaufman (48), analyzed the 'Science in Review' column of the Sunday *New York Times* for 1941 and 1954. Total news columns increased from 120 to 126, the fraction devoted to medicine remained at 21.5%, and biology space fell from 24 to 20%. Biochemistry accounted for a fifth of biology space; zoology, 18%; microbiology, 9%; and botany, 6%. Perhaps 10% could be called physiology. For January and February 1955, clippings were made of science news in newspapers in the east, 8000 column inches, including the *New York Times* (2560 inches) and the *Washington Post* (1430 inches). Two-thirds of all were on medicine (half of this on cancer)—one-half in the *Post* and one-fourth in the *Times*. Agriculture plus botany was given one-third of science space in the *Times*, only 5% in the *Post*.

On television, science receives 1% of the total hours of New York area stations, medicine another 1%; and science programs of the Educational Television and Radio Center at Ann Arbor are used by ten stations. (Lists of their films are available.) Yet the science series, 'The World We Live In',

was reported as the most successful ever published by *Life*; and science T.V. programs have been well received by the public. Science can be disseminated, and is, for better or worse, by comics, museums, traveling exhibits, science fairs, and lecturers, as well as by the more obvious routes of teaching and of mass communication.

A comparison of the relative emphasis on 'pure' and 'applied' science in three magazines (Survey Project 2A) is shown in Table XI-3. In the two popular magazines the consistent emphasis on application indicates that science per se is minimized in presenting scientific phenomena or progress. The great increase in attention to pure science in the *Scientific American* reflects a major change in editorial policy and audience level of that journal. In these analyses, classification of content as 'pure' or 'applied' was necessarily somewhat arbitrary, but the proportion of applied material in the physical compared to the biological sciences is clearly greater in the popular magazines.

Though these data are fragmentary and omit such other media of mass communication as newspapers, cinema, radio, and television, it is apparent that a tiny amount of physiological material reaches the general public and that this dribble is almost entirely linked with medicine. Even agricultural applications of biological science receive little public attention, although they receive a large share of taxpayer support and employ a sizable proportion of scientific workers. If physiology—whether human, animal, plant, or bacterial—is to receive public notice, it will have to be brought to the public in comprehensible terms and made attractive enough to gain attention, even in competition with the everyday interests of average people.

Sound scientific presentations suitable for laymen, for groups dealing with biological products, or for school science teachers with a general knowledge

TABLE XI-3. PROPORTION OF 'PURE' AND 'APPLIED' SCIENCE ARTICLES IN CERTAIN POPULAR AND SEMI-POPULAR MAGAZINES (Survey Project 2A).

Periodical, Classification	Articles on Pure Science			
	1938		1951	
	N ^a	%	N ^a	%
Reader's Digest				
Biological sciences	22/60	37	21/71	29
Physical sciences	2/14	14	5/29	17
Total science	24/74	32	26/100	26
Saturday Evening Post				
Biological sciences	1/9	11	8/31	26
Physical sciences	1/7	14	1/12	8
Total science	2/16	12	9/43	21
Scientific American				
Biological science	9/30	30	32/41	77
Physical science	27/71	33	28/39	72
Total science	33/101	33	60/80	75

^a Note: 22/60 means that out of 60 articles on the biological sciences, 22 were classified as 'pure' science.

of the field, are also important to the spread of physiological knowledge. Pharmaceutical and other companies, government agencies, and others are now contributing in this area, and broadcast programs can be powerful popularizers of physiological science. The Survey has not assessed the present offerings nor the fields of physiology most needing more or better presentation. Cooperation with the mass media, especially television which can actually show phenomena, is likely to prove most profitable for physiology and all science. Certainly, help in guiding programs to exhibit the process of discovery as well as the facts discovered, the method as well as the findings, would aid the cause of true science (see, e.g., 31).

PHYSIOLOGY IN PUBLIC EDUCATION

The Background of Education

Those concerned with the present Russian mass output of technicians and skilled workers, as well as of professional engineering and scientific personnel, must bear in mind that the American educational system, unlike European systems, does not force a student during the secondary school years to make an irrevocable choice of vocation. Individual motivations underlie the choices of American students, as also of general public interest, attitude, and support. It is, therefore, important to assess the place of physiology and of biological science in what is being taught the future American public, and why it is being so taught.

What has already been said, about the public image of physiology as concerned primarily with the human body and with health, applies with special force in public education. With few exceptions, elementary and high schools and undergraduate colleges (particularly at the freshman-sophomore, or junior college, level) are today instruments of mass education. Two generations ago this was not so; and any consideration of public education in physiology, health, biology, chemistry, or physics must take this change into account. Today many, if not most, educators favor schooling for 'life-adjustment'. The United States Office of Education has given this viewpoint expression in the following terms:

Life adjustment education is designed to equip all American Youth to live democratically . . . as home members, workers, and citizens. It is concerned especially with a sizable proportion of youth of high school age (both in school and out) whose objectives are less well served by our schools than are the objectives of preparation for either a skilled occupation or higher education.

. . . Each student's school program should include experience in: health, safety, leisure-time habits, citizenship, economic competence, general work skills and attitudes, self-understanding, human relations, and home and family—built during each year. The instructional experiences should be discontinued only when a level of competence suitable for American living has been achieved. (113, pp. i, 84, 85)

Against this orientation is one—since the 1920's in eclipse to the extent that college admission requirements have not controlled standards of secondary school accomplishment—which is again beginning to receive public attention, although hardly to be felt in the school curriculum for another generation. This is expressed by the Council for Basic Education in its recent (1956) statement of purpose:

That all students without exception receive adequate instruction in the basic intellectual disciplines, especially English, mathematics, science, history, and foreign languages;

That the fullest possible opportunity is afforded to students of high ability to reach mature levels of achievement without waste of time;

That clear standards of actual accomplishment are used to measure each student's progress and to govern promotion to higher levels of the educational system;

That teachers are thoroughly educated in the subjects they teach and in current developments therein;

That vocational training is offered in due subordination to the school's fundamental purpose of intellectual discipline, and that standards of achievement are maintained as rigorously in vocational as in academic fields;

That school administrators are encouraged and supported in resisting pressures to divert school time to activities of minor educational significance, to curricula overemphasizing social adjustment at the expense of intellectual discipline, and to programs that call upon the school to assume responsibilities properly belonging to . . . other agencies.

Between these two extremes of educational objectives there are necessarily many shades of practical compromise in different schools and different communities. With the manifold increase in pupil enrollment, including 100% of the elementary school age population and 75% of the secondary school age group, it is becoming apparent that the public school cannot meet all the needs of all its pupils. From this background—of change in educational objectives, of enlarged curricula, and of phenomenal increase in enrollment—arise the major problems in providing pupils with an adequate foundation in science and mathematics.

Physiology in Elementary Education

What most people know about physiology is the result of formal schooling, beginning with the health habits courses and general science teaching of the earliest grades. As part of Project 5A of the Survey, a questionnaire investigation was instituted by Dr. Norma Hajek, a physiologist with special interest in the schools of Iowa. The elementary school teachers' questionnaire was returned by 299 teachers of the 501 elementary schools selected as a one-thirtieth sample of all in the state. Only 5% of the teachers reported that they taught physiology as a separate subject, and half of these indicated that it was given as a one- or two-period course for only half the year. Some physiological subject matter, as perceived by the elementary grade teachers, is presented throughout the first eight grades, almost always under another

guise. Almost a third of the teachers reported that physiology is integrated with other subject matter. Slightly more than half at each grade level teach science or health-hygiene courses as separate subjects; the remainder teach them integrated with other material. These varying modes of presentation do not indicate a quantitative difference in the material presented, but rather reflect different pedagogical methodologies.

Whether called science, physiology, or health, and whether presented separately or integrated, the physiological topics covered at each grade level are not significantly different. Nutrition and growth-development enter at all grades. At the fifth grade and above, respiration, circulation, and muscle activity appear. Information about structure, as also about functional processes, increases with grade level; but, to the extent that physiology is recognized at all, physiology and anatomy are equated. The realm of physiology is limited to the human body, teaching is largely by discussion, and living laboratory materials are rarely used. The level of reading about and knowledge of physiology of the average elementary school teacher is that of the pupils' own textbooks, supplemented by teacher-aids—provided mainly by health-centered organizations.

The elementary teachers surveyed in Iowa had a median age of 42; only 27% (81 of 299) held a bachelor's degree and a bare dozen a master's degree, apparently all in education; 56 had done some graduate work, mostly in the teaching of science, but only four had taken graduate courses in a biological science. Only one-third of these elementary school teachers had taught for less than a decade, and one-third each had taught for more than two or more than one decade. These statistics are primarily from teachers in small urban and rural communities; nor is Iowa fully representative of the nation, even of its neighboring states, in its requirements for elementary school teaching. The national situation is perhaps somewhat better: for example, of the nation's elementary teachers (1954-55), 68% have 120 or more semester hours of credit preparation; 26%, from 60 to 119; and only 6%, less than 60. The figures for elementary teachers in Iowa, excluding the city of Des Moines, are, respectively, 22%, 46%, and 31% (*Journal of Teacher Education*, March, 1955). Since physiology is relatively unrecognized in the elementary curriculum, however, it is doubtful that more credit hours of preparation would improve the quality of teaching of this subject. Furthermore, the faculties of teachers' colleges will not easily change their time-honored concept of physiology as a subject primarily related to human anatomy, nor will science and health textbooks do other than follow the lead of established curricula.

Teaching methodology in elementary science and health habits courses is vastly improved over even a generation ago, however, and it can be hoped, if not proven, that a more realistic, hence favorable, attitude towards these

TABLE XI-4. PERCENTAGE OF SCHOOLS OFFERING BIOLOGICAL SUBJECTS, 1860-1900 ^a

Subjects	1860-70	1871-80	1881-90	1891-1900
	%	%	%	%
Physiology	80	90	90	75
Botany	48	85	85	83
Zoology	20	42	53	40
Biology				10

^a Based on ref. 10, vol. 11, pp. 170-200, 278-287; vol. 12, pp. 273-350. Figures rounded.

subjects is being engendered. This, in turn, would make possible more effective mass communication to the adult population of the future, and might occasionally inspire an individual with an abiding interest in natural phenomena. The concept of physiology can be broadened in elementary and secondary schools, however, only after re-educating those who are training future teachers of science and of health.

*Trends in High-School Science and Health Teaching*¹

The status of biology and of physiology in secondary education must be evaluated in terms of the developments in science and health education which, in turn, reflect major changes in educational objectives. At the end of the nineteenth century, biology was a new subject—the outcome of a new attitude toward integration of scientific content, induced largely by the teachings of Huxley. Secondary school courses in biology were first introduced in the newly settled and progressive, rather than the older and conservative, portions of the country. They were begun at Milwaukee in 1881-85, and by 1900 had appeared in seven more cities in the mid-west. Some conservative states changed only when the national pattern had become quite clear; Kentucky did not put biology into its curriculum until 1915. The relative status of physiology, botany, zoology, and biology courses in the latter half of the nineteenth century is shown in Table XI-4; and course enrollments in science and health subjects in the twentieth century are illustrated by Table XI-5. General science today is normally given in the ninth grade and general biology in the tenth, with other science courses in the last two years of high school; and physiology remains as a separate course only in a few states, largely because of legislative requirements.

Health and hygiene in the secondary school curriculum also have their roots in the nineteenth century, but by the twentieth century the emphasis in human physiology had changed from the anatomical to the practical and social aspects of hygiene and community health, and knowledge of physiological facts has held a steadily diminishing place. Legislation requiring statewide physical education in schools was adopted in North Dakota in 1899,

¹ Except where otherwise indicated, this and subsequent sections of this chapter are based on the report of Survey Project 17.

TABLE XI-5. PERCENTAGE OF STUDENTS IN THE LAST FOUR YEARS OF PUBLIC SECONDARY SCHOOLS ENROLLED IN SCIENCE AND HEALTH SUBJECTS, 1910-1948 (U. S. Office of Education Data^a).

	1909-10	1921-22	1933-34	1948-49
Enrollment ^b	739,000	2,155,000	4,496,500	5,399,500
	%	%	%	%
General science		18.3	17.8	20.8
Biology	1.1	8.8	14.6	18.4
Botany	15.8	3.8	0.9	0.1
Zoology	6.9	1.5	0.6	0.1
Physiology	15.3	5.1	1.8	1.0
Agriculture	4.6	5.1	3.6	6.7
Chemistry	6.9	7.4	7.6	7.6
Physics	14.6	8.9	6.3	5.4
Health-hygiene				
Physical education		5.7	50.7	69.4

^a Based on ref. 14, pp. 107, 108. Figures rounded. Present plans call for comparable data to be collected in 1958-59.

^b The percentage of public schools reporting data varies at different periods. Enrollments reported are generally for grades 9-12 but may represent other grades in the earlier periods.

Ohio in 1904, and Idaho in 1913, and gained momentum from the draft mobilization of World War I. The same general circumstances also gave impetus to statewide requirements for the teaching of health and hygiene, and led to a change in the titles of school books as well as in their content; textbooks on physiology and hygiene became textbooks on health.

For many years science education in secondary schools was dominated by the necessity of meeting college entrance examination standards. Public pressures for content emphasis, felt in the field of health courses, have not been apparent in biology, physics, or chemistry, but there has been a continued tendency to stress the applications and social benefits of scientific progress. The dichotomy of objectives has been between those who valued scientific content for its own sake and those who regarded it primarily as information useful for everyday living. In 1916, John Dewey commented on trends in high school biology:

We must remember that, although in school we are always treating pupils as embryonic scientists who somehow are interrupted and cut off before they get too far, the great mass of the pupils will never be scientific specialists. The value of science for them resides in the added meaning it gives to the usual occurrences of their everyday surroundings and occupations.

In 1918 the National Education Association's Commission on Secondary Education produced a statement of educational objectives in terms of the 'needs' of pupils; and, on this basis, a national commission recommended, in regard to biology:

. . . that it follow general science and that it be taught with special attention to health, purposeful interest in the living things of the environment, important applications, training to observe accurately, aesthetic appeal of plants and animals, and scientific progress.

A study comparing the period 1926-35 with 1936-45 found that social, economic, and vocational aims in the teaching of secondary school biology had increased at the expense of such intellectual objectives as scientific method and knowledge of content. In the 1930's and 1940's the progressivist theory of 'general education' became fused with the pragmatic goal of 'functional' learning for 'life adjustment'. By 1947, to quote Dr. Fred Fitzpatrick, Professor of Natural Sciences, Teachers College, Columbia University:

. . . the Committee responsible for the preparation of the *Forty-Sixth Yearbook* ("Science Education in American Schools") looked upon secondary-school biology in a manner that would have been impossible in 1900 and improbable in 1920. The general objectives . . . include the acquisition of functional information and functional concepts, functional understanding of principles, the development of instrumental and problem-solving skills, and the fostering of desirable attitudes, appreciations, and interests. The point is made that there is challenge to select wisely from a wealth of potential instructional material without undue concern for traditional 'content' or 'mastery' of a subject at the lower levels of educational experience, but with continuous effort to establish and refine a program that will best fit pupils and future citizens to make appropriate choices and decisions . . . (20, pp. 62, 63).

All science course enrollments (excluding hygiene-physical education), as listed in Table XI-5, totaled only 60% of the student body in 1948-49. Since some students take several science courses, probably over half of all high school students have no science. With the soft objectives of the courses that are taken, it is not surprising that the motivation to enter science is enfeebled.

Trends in Undergraduate Science Education

The educational trends which affect high school biology teaching also apply to the first two years of undergraduate education, especially in the junior and community colleges. These years are regarded by proponents of progressive education as extending an opportunity to all the nation's youth who desire to continue beyond high school. In 1955, 510 colleges, over one-fourth of all colleges and universities in the country, offered two years, but less than four, beyond the twelfth grade. These institutions produce technicians and semi-professional workers, including many women who turn into homemakers, and are becoming increasingly important in education of the general public.

The 'functional' objectives of general education have also spread into the first two years of the four-year college; a survey of science courses for general education in 1948 found that 45% of 500 liberal arts colleges were teaching such courses, and that 9% more were considering introducing them. Most courses were of the two-semester lecture-demonstration type—essentially informative, with little opportunity for class discussion, and rarely including individual laboratory work. Another recent study, of two- and four-year colleges in the Southern Association of Colleges and Secondary Schools, like-

wise indicates that the attitudes of secondary school science education are penetrating undergraduate teaching.

An understanding of the leading laws and concepts of science that affect the daily life of the individual is given first rank by senior colleges. The junior colleges rank an appreciation of the social implications highest. The development of laboratory skills and techniques is rated lowest by all groups of colleges.

The rapid growth of general education science courses since World War II, the number of colleges planning to introduce courses soon, and the feeling among college administrators, especially in junior colleges, that general education in science is needed for all college students point to future progress in this field (Wilson, ref. 121, pp. 140, 185).

A contrasting concept of 'general education' is:

In contemporary higher education there is a new emphasis on general education, a new invitation to teachers to cross departmental lines and feel the inter-relatedness and eventually the unity of all learning. . . .

Simultaneously in American undergraduate education is the growing sense that a liberal education must have its depth as well as breadth. . . . "Uneducated people are . . . not as dangerous as . . . the half-educated, who have learnt enough to express an opinion on subjects which they do not really know, but have never learnt to be aware of their ignorance." (Lowry and Tausch, ref. 51A, pp. 17, 18.)

Physiology in Undergraduate Courses

The physiological content of undergraduate biology courses was studied by Dr. Julian L. Solinger of Simmons College as Project 6 of the Survey. Over two hundred (224) mid-term and final examinations in 32 elementary biology courses in 29 colleges and universities were analyzed as a sample of undergraduate biology. The institutions, while not equated with scientific productivity nor covering the South or West, nevertheless constitute a wide and probably fair sample. As shown by Table XI-6, the percentage of physiological material in the examinations varies somewhat with course objective, the range being wider in courses designed for non-biology majors or for general education than in those for biology majors. There were only minor differences between these two types of courses; but those for prospective biology majors tend to give relatively less attention to physiology than do

TABLE XI-6. PERCENTAGE OF CONTENT WHICH IS PHYSIOLOGICAL IN TEST MATERIAL OF ELEMENTARY COLLEGE BIOLOGY COURSES (Survey Project 6).

Physiological Content	Courses for Prospective Biology Majors	Courses for Non-Majors or General Education	All Courses
Under 15%	0	0	0
16-25%	0	3	3
26-35%	9	4	13
36-45%	3	8	11
46-55%	2	1	3
56-65%	0	2	2
Above 65%	0	0	0
N (Courses)	14	18	32

TABLE XI-7. PERCENTAGE OF SPACE DEVOTED TO VARIOUS TOPICS IN SIX BIOLOGICAL SCIENCE TEXTBOOKS USED IN SOUTHERN ASSOCIATION JUNIOR AND SENIOR COLLEGES.^a

Topic	Average %	High %	Low %
Basic structures and functions.....	12	19	5
Plant kingdom	10	15	3
Animal kingdom	15	22	1
Human body organization and functions ^b	22	37	8
Reproduction and embryonic development.....	7	13	4
Heredity	8	11	5
Microorganisms and disease	5	7	2
Evolution and adaptation.....	15	21	10
Man and the balance of nature (4 texts).....		10	0
Man's cultural and social development (1 text).....		11	0
Scientific methods in biology (3 texts).....		3	0
Overview of the universe (1 text).....		3	0

^a Based on ref. 121, Table 14. Figures rounded.

^b An analysis of the averages for the units within this topic is given in Table XI-8.

general-education biology courses, probably because the latter stress health education.

The tendency of general-education biology courses to stress human physiology and also to give major emphasis to circulation, nutrition-digestion, reproduction, and the nervous system is indicated by a study made in 1951 of six textbooks, widely used in general education biology courses in the junior and senior colleges of the South. Presumably similar emphases would be found at the high school level, the general education objective being relatively constant for both. Table XI-7 indicates the topics treated in these textbooks and Table XI-8 analyzes the most emphasized topic—organization and functions of the human body.

Physiology, besides appearing in biology courses, is also part of the physical education course required of first-year women in many institutions and, less frequently, of first-year men. In colleges offering a major in physical education teaching, a course in human physiology is generally given at the sophomore or junior level.

Physiology teaching at the lower undergraduate level in terms of the human

TABLE XI-8. ANALYSIS OF CONTENT OF THE TOPIC, HUMAN BODY ORGANIZATION AND FUNCTIONS^a IN SIX BIOLOGICAL TEXTBOOKS USED IN SOUTHERN ASSOCIATION COLLEGES.^a

Sub-topics	Average % of Space, Six Texts
Blood and circulation	15
Respiratory system	7
Digestive system and metabolism.....	23
Excretory system	3
Skin, skeleton and muscles.....	10
Nervous system and sense organs.....	30
Endocrine system	12

^a See Table XI-7, note ^b.

body follows the pattern of the elementary and secondary schools, and has similar objectives. In courses for prospective biology majors, physiology is perhaps neglected in relation to the morphological and taxonomic aspects; but in general education biology it receives more attention. In all courses, the imbalance between animal, plant, and bacterial physiology continues, and the partial view of the scope of physiology results in a narrowing rather than a widening of the layman's appreciation of physiology within his over-all view of science.

Physiology in Secondary Schools

The content of high school courses and textbooks in physiology, health, and biology closely follows the trends in science teaching objectives, and includes subject matter of most immediate appeal—such as, today, implications of atomic energy. Textbooks on general science and health, analyzed in 1953 by a committee of the American School Health Association, were considered scientifically inaccurate in the health information presented; statements were misleading, ambiguous, outdated, and controversial. In high school texts these errors averaged 43 (range 21 to 126) per book or 13 per hundred pages; in general science texts, 14 per book (0 to 31) or 20 per hundred pages of health material; and in three biology texts 22 (5 to 32).

The percentage of errors was high for nutrition, and increased with the age of the book. Communicable diseases were often inaccurately discussed, particularly in general science texts and in relation to such topics as immunization, vaccination, and drugs. In the area of mental health and family living, outright factual errors were rare but debatable presentations were not. Errors in anatomy and physiology involved most of the body systems. The topics of tuberculosis and dental health included a notable number of errors per unit of space. A typical text-surveying team consisted of a physician, a dentist, a nurse, a nutritionist or home economist, and a teacher of health, physical education, general science, or biology (Kilander, Hein, and Mitchell, ref. 47).

The emphases given physiological topics by secondary science texts has shifted with time. Alcohol and narcotics received up to 12% of page space after World War I; far less today. The digestive system was given much scientific attention a hundred years ago; by the end of the 19th century the treatment was 'practical', about alcoholism, overexercise, and the like; attention lagged for a couple of decades until vitamins and calories brought renewed emphasis; and then dwindled to the mechanics of food movement and occasional forays into chemical processes. Many other topics similarly shifted with public awareness and interest. Muscle, despite its relation to exercise, developed slowly as a topic and only relatively recently has received serious consideration in school texts.

Textbooks have not been analyzed for their emphasis on the physiological approach to biology as compared to that of morphology, taxonomy, or ecology; but cursory examination of twenty secondary-school texts in biology and general science, Survey Project 3A, indicated that 40% of their average content, range 10% to 80%, is physiological or functional biology, using the term 'functional' in its scientific sense.

The physiological content of high school courses in Iowa was estimated by Survey Project 5A, based on responses (82%) from 410 secondary school teachers, a 15% sample of those in the state. Iowa is representative of national norms of enrollment in courses in biology, general science, physiology, health, physical education, and home economics; somewhat higher in agriculture. Only 5% of the respondents taught physiology as a separate course, 38% taught general science, and 38% taught biology. Since the two latter subjects are often given in successive years, the same teachers may be involved.

The proportions of Iowa teachers presenting, or emphasizing, various physiological topics is given in Table XI-9. Practically all courses stress growth and development, and nutrition—a pattern in science and health education noted earlier. Nutrition naturally is emphasized in home economics and agriculture courses; muscle activity, in physical education. Teachers of physics and chemistry seem, in a small sample, to emphasize basic physiological phenomena; chemistry teachers present more applications.

A less detailed inquiry in Utah, by Dr. Horace Davenport, Survey Project 5B, showed similar conditions, but with an added emphasis on compulsory health education courses—Utah has a legal requirement that the adverse effects of alcohol, tobacco, and narcotics be taught. Examination papers and laboratory manuals sampled call for detailed factual information, mostly on a true-false basis, but for little consideration of concepts. A higher proportion (8.4%) of senior high school pupils in Utah than in any other state takes courses in physiology; California ranking next with 3.3%. Utah physiology, however, does not ask much beyond memorized textbook facts; from the viewpoint of science, the quality of physiological teaching in its secondary schools is demonstrably low.

For California, the different emphases given by teachers of biology, life science (general science), and physiology are illustrated in Table XI-10. These rankings reflect statewide curriculum standards and also, to some extent, the textbook content—largely predetermined by the demands of the large city and state educational agencies. 'Human anatomy and physiology' is given first rank by teachers in all three fields, and 'maintenance of health' ranks either second or third; after these, the content rank order varies considerably. Heredity in humans outranks that in plants and animals in all three courses, perhaps suggesting superficial treatment. Anatomy and physiology are consistently linked, but receive no particular emphasis.

TABLE XI-9. PERCENTAGE OF TEACHERS REPORTING ASPECTS OF PHYSIOLOGY PRESENTED AND EMPHASIZED IN SECONDARY SCIENCE AND HEALTH COURSES IN IOWA, 1952 * (Survey Project 5A).

	Course Subject				
	General Science %	Biology %	Physiology %	Health-Hygiene %	Physical Education %
Basic phenomena					
(osmosis, etc.)	64 (8) ^b	96 (11)	60	24	2
Blood and fluids	48	93 (4)	80	76 (7)	3
Body defenses	64 (9)	90 (9)	80	78 (17)	24
Circulation	76 (6)	97 (9)	80	91 (15)	17
Digestion	77 (6)	97 (16)	80	87 (13)	13
Growth, development . . .	63 (14)	95 (17)	80 (60)	83 (15)	33
Hormones	23 (1)	88 (3)	80	46 (2)	2
Metabolism	35	92 (6)	80	52 (4)	4
Muscle and exercise	81	79 (1)	80	76 (9)	66 (33)
Nutrition	75 (11)	91 (9)	80	81 (26)	25 (1)
Photosynthesis	82 (5)	98 (16)	10	7	1
Reproduction	51 (4)	95 (15)	80	48 (4)	5
Respiration	78 (4)	98 (8)	80	83 (13)	21
Sensation	49 (1)	90 (2)	80	52 (4)	6
Translocation	8	50 (1)	20	11	2
Transpiration	61	96 (1)	30	19	0
Tropism	22	92 (2)	10	0	0
N (Teachers reporting) . . .	127	127	10	47	100
		Nutrition ; Home Economics %	Agriculture %	Chemistry %	Physics %
Basic phenomena (osmosis, etc.) . . .	7 (2)	42	53 (19)	47 (19)	
Blood and fluids	17 (2)	16	3	0	
Body defenses	37 (2)	29	16 (3)	4	
Circulation	15 (2)	42	10 (3)	2	
Digestion	59 (6)	65	34 (3)	2 (2)	
Growth, development	67 (6)	68 (19)	10	2	
Hormones	15	42	25 (3)	0	
Metabolism	37 (2)	32	16	0	
Muscle and exercise	17	26	10	2 (2)	
Nutrition	85 (52)	71 (29)	41 (13)	2 (2)	
Photosynthesis	6 (2)	71 (3)	41 (3)	4	
Reproduction	33	77 (10)	3 (3)	0	
Respiration	9	48	22	2 (2)	
Sensation	7	6	3	15	
Translocation	4	6	0	0	
Transpiration	2	48	10	4	
Tropism	0	6	3	0	
N (Teachers reporting)	54	31	34	47	

* Based on an 82% response of a 15% sample of Iowa secondary school teachers (335 of 410). Grade placement of courses not stated.

^b Number in parentheses indicates percentage of teachers who reported emphasizing this topic.

TABLE XI-10. RANK OF TOPICS EMPHASIZED OR INCLUDED BY HIGH SCHOOL TEACHERS IN CALIFORNIA.^a

Topics	Teachers		
	Biology (N = 199)	Life Science (N = 95)	Physiology (N = 45)
Human anatomy and physiology.....	1	1	1
Maintenance of health.....	3	2	3
Conservation	2	3	14
Scientific method and attitudes.....	5	3	4
Human heredity	6	3	2
Interrelations of living things.....	4	6	12
Control of harmful organisms.....	9	7	5
Embryonic development	15	8	5
Heredity in plants and animals.....	10	9	10
Classification of living things.....	11	11	17
Animal anatomy and physiology.....	7	12	9
Plant anatomy and physiology	8	10	13
Biological basis of social problems.....	13	13	8
Nature study	12	14	18
Evolution	16	15	11
Geographic distribution	17	16	19
Chemistry of living things.....	14	17	7
History of biology.....	18	13	15
Care of animals.....	19	19	16
Gardening, landscaping, cultivation.....	20	20	19

The ranking in each group was determined by allowing two points for emphasis, and one for inclusion.

^a Ref. 24, Tables IX, X, XI, pp. 116-119.

What is communicated by this schooling is indicated by a study of the health knowledge of the American public over twenty years by Dr. Kilander (Survey Project 2C). Few individuals are adequately informed in all areas of health, but the level of information of students and adults has shown a slight steady improvement. Health information increases regularly through the successive school grades, to level off at the senior year in high school; but comparison of the 1936 and 1954 results of multiple-choice questions dealing with physiology and biology showed that, "students in secondary schools and colleges are rather uninformed about basic physiology topics except where such topics have specifically been studied." Higher scores were attained by pupils who had studied scientific subjects or who were in superior groups as to school attainment or as to home or community environment.

The amount and type of physiological information provided by the secondary school thus appear to govern the information or misinformation retained by the average adult. It is limited almost wholly to human physiology and is largely equated in the popular mind with human anatomy. Certainly physiology is nowhere taught in mass education as a basic scientific discipline; nor are the physical and chemical aspects of biology recognized as related to physiological science.

Biology in Secondary Schools

Since courses in biology tend to contain material on physiology and are often the only science taken by high school students, the status of high school biology teaching is also important. In 1948-49, almost a million pupils, 18.4% of all in the last four years of secondary school, were enrolled in biology courses. (A sampling in 1949-50, showing 21.7%, included an excess of large high schools.)

Teachers of biology are proud of the climbing enrollment in that subject; but 18.6% for biology, botany, and zoology together in 1948-49 is a regression from the 23.8% enrollment in those three subjects in 1909-10—even allowing for the 8th and 9th grade shift to courses in general science. An increase in biology, compared to steady or decreasing enrollments in chemistry, physics, and mathematics, however, has a disturbing aspect; high school students without clear scientific or science-related occupational goals in mind are avoiding those subjects which are 'difficult', which present an intellectual challenge. Dr. C. J. Van Slyke, Associate Director of the National Institutes of Health, addressing the National Science Teachers Association in 1953, said:

To the general science teachers among you I would suggest that you ponder the possibilities of becoming, in effect, recruiting agents for young students with aptitude by encouraging them to take up science courses in high school. Many students terminate their science courses with 10th grade biology when they might otherwise be made to realize their potential significance to the scientific welfare of the country by not bypassing, for instance, high school physics or chemistry or mathematics.

That enrollments in high school biology are increasing because it is becoming an 'easy' subject is directly evidenced by the increased proportion choosing to take New York State Regents' Examinations in biology. Over fifteen years, this has risen in relation both to other science subjects and to all subjects of study; while chemistry and physics, holding their own in relation to all subjects, have steadily lost ground among the sciences. This is shown in detail in Table XI-11. The severe decline in physical science courses and students—even more so vis-a-vis Russia—has been pointed up in many statements by high government officials.

The national enrollment in biology is also heavily loaded with pupils who expect either to finish their education at the high school level or to enter terminal-occupational courses in technical schools and junior colleges; over 15 years it increased by 51%, compared to 20% for all pupils in secondary school. Over the same period, the proportion of pupils electing Regents' Examinations in biology increased 117%—from 5.1% to 11.1% of all the papers written (Table XI-11). General biology thus serves to teach the mass of students at the least common intellectual denominator. Even in New York City in 1953, 44 of the 54 high schools offered 'modified' science courses specifically for non-college or general students and only 11 also gave advanced

TABLE XI-11. PERCENTAGE OF PAPERS WRITTEN IN NEW YORK STATE REGENTS' EXAMINATIONS (EXCLUDING NEW YORK CITY).

	Biology		Chemistry		Physics		Earth Sciences	
	% of Science Papers	% of All Papers	% of Science Papers	% of All Papers	% of All Papers	% of Science Papers	% of Science Papers	% of All Papers
1935	30.6	5.1	32.6	5.4	27.2	4.5	9.3	1.6
1940	38.3	6.4	30.6	5.1	24.2	4.1	7.1	1.2
1945	49.0	9.0	28.1	5.1	20.8	3.8	1.8	0.3
1950	46.5	10.2	27.0	5.9	21.0	4.5	5.6	1.2
1951	49.8	11.1	26.7	6.0	18.4	4.1	5.1	1.1

^a Data from New York State Department of Education. The pupils who take the Regents' Examinations are ordinarily between 21.7% and 22.4% of the total high school enrollment outside of New York City.

science courses. On a nationwide basis, where 84% of the high schools have less than 500 pupils, there is little chance of adding formal offerings to favor the minority of pupils who might benefit from them; nor does the supposed 'enrichment' of low-content science courses necessarily improve their quality.

Further evidence that biology is often taught without scientific rigor comes from a survey of laboratory practices of California high school teachers. Table XI-12 shows that laboratory work is sparse and distributed inconsistently

TABLE XI-12. LABORATORY EXERCISES AND DEMONSTRATIONS BY TEACHERS OF HIGH SCHOOL BIOLOGY IN CALIFORNIA.^a

Examples	Laboratory Exercise	Demonstration	Total	% ^b
Use and care of microscope.....	108	37	145	50
Osmosis	33	100	133	46
Tests of various types of foods.....	46	58	104	36
Dissection of frog.....	67	16	83	29
Photosynthesis	27	45	72	25
Bacteria cultures	37	27	64	22
Preparation, characteristics and tests for elements	8	41	49	17
Dissection of type animals.....	29	18	47	16
Collection and culture of protozoa.....	37	8	45	16
Digestion of food.....	21	23	44	15
Dissection of earthworm.....	34	5	39	14
Germination of seeds.....	26	13	39	14
Dissection of animal organs (eye, heart, etc.)	20	18	38	13
Preparation and use of permanent slides.	28	10	38	13
Check lung capacity with spirometer....	16	22	38	13
Cell structure	30	3	33	11
Plant tropisms	8	23	31	11
Preparation and use of temporary mounts.	29	2	31	11
Plant growth and nutrition experiments..	16	13	29	10
Dissection of mammals.....	15	13	28	10
Culture and study of fungi.....	19	9	28	10

Examples reported by less than 10% of the teachers returning the questionnaire are omitted.

^a Ref. 24, Table XIII, p. 125.

^b Percentage of total number of teachers returning questionnaire (N = 199) who listed each activity as an example of laboratory exercise or demonstration.

between exercises by students, as individuals or groups, and demonstrations by the teacher. Except for the classic dissection of a frog, experiments characteristic of the college preparatory course of a generation ago are conspicuously rare. Nor does laboratory work necessarily contribute to scientific training. Of pre-medical students surveyed at the University of Illinois in 1952, for example, less than 15% regarded their high school science courses as good, and only 40% felt their background adequate for the pre-medical curriculum in college.

A national sampling of general biology teaching, in 1949-50, showed that, while nearly all schools reported some form of laboratory work, only 16% had the double laboratory periods so necessary for effective work; and only 37% had regularly scheduled separate laboratory periods. The trend away from solid laboratory periods, followed over twenty years in Nebraska, is shown in Table XI-13. With such limitations, only the exceptional science teacher can do effective laboratory teaching.

The physical condition of laboratory facilities also seriously affects the quantity and quality of high school biology. A national sampling showed that at least 75% of the general biology courses use charts, preserved or living specimens, slides, or posters and pictures; over 60%, filmstrips, motion pictures or models; but only 4% to 8% had available, let alone used, such school- or community-owned facilities as greenhouse, museum, farm, forest, garden, or nature trail. And beyond presence comes quality. State supervisors in Ohio found out of 1133 secondary schools in 1948-50, only 8 ranking 'excellent' in laboratory rooms and apparatus, 99 'superior', and 600 'satis-

TABLE XI-13. SCHEDULING PRACTICES FOR LABORATORY AND CLASS WORK IN SCIENCE IN NEBRASKA HIGH SCHOOLS, 1929-1949.^a

Periods ^b	No. Min.	1929-1930					1939-1940			1949-1950		
		5-0	3-4	3-2	4-2	4-1	3-4	3-2	4-2	3-4	3-2	4-2
General Science ..	40-49	1	152	121	50	2	54	200	21	13	114	
	50-59	3	3	10	1		1	47			90	
	60-over	5	2	27	1		2	88			196	1
Biology	40-49		186	20	1		164	34	3	34	32	2
	50-59		6	5			1	55	2	2	102	1
	60-over	2	1	22			8	104			210	
Physics	40-49		306	14	2		140	18	2	25	16	2
	50-59		11	10	1		4	40	1		58	1
	60-over	3	2	26	1		6	82			114	
Chemistry	40-49		66	5			33	7		16	6	
	50-59		3	5			2	24			43	
	60-over	1	1	12			3	27			55	1

^a Ref. 120, Table 53, p. 144.

^b Key: 5-0 = 5 class periods and no laboratory period.
 3-4 = 3 class periods and 2 double laboratory periods.
 3-2 = 3 class periods and 2 single laboratory periods.
 4-2 = 4 class periods and 1 double laboratory period.
 4-1 = 4 class periods and 1 single laboratory period.

factory'; nearly two-fifths, mostly rural, were judged inadequate for laboratory instruction. Specific equipment lacking is shown in Table XI-14. The dependence on passive experience is emphasized by the general availability of motion picture equipment. It seems sad that the living world, available even to city schools and inundating rural ones, is so little brought inside for teaching biology.

Courses on how to teach science are widely accepted for teacher certification, whether or not the candidate has studied a science in college. In Utah in 1948-49, for instance, half the classes in the biological sciences, mathematics, and the physical sciences were given by teachers who had neither a major nor a minor in those fields (60b). The situation has been found comparable in Alabama(16) and in Massachusetts(118). Although many high school science teachers are well versed in their subjects, they are not the rule among their fellows in the 20,000 high schools covering the nation.

Median scores of graduate students in education and physical education are at or near the bottom of the Army General Classification Test; 122 and 115, compared to 120 and 121 for nurses and dentists, 124 for all groups, and values over 130 for several (Wolfe, 122, pp. 317ff.). Almost every committee concerned with teacher training has emphasized preparation in terms of courses and credit hours. Only the Cooperative Committee on the Teaching of Science and Mathematics, of the American Association for the Advancement of Science, proposed (1946) a set of proficiency examinations for the competence of prospective teachers. Some years later this same Committee also commented (1955):

Scientists have not, on the whole, accepted responsibility for the training of high-school teachers. This responsibility has been left largely to departments of education.

TABLE XI-14. PERCENTAGE OF OHIO SECONDARY SCHOOLS NOT EQUIPPED WITH CERTAIN FURNISHINGS IN LABORATORIES AND SCIENCE ROOMS ^a

	County	Village	City
Number of schools.....	485 ^b	56	136
	%	%	%
Demonstration desk	32	13	2
Water	3	0	1
Gas	21	0	1
Electricity	8	0	1
Shades	22	19	7
Opaque projector	74	50	25
Motion picture equipment.....	11	50	3
Micro-projector	57	10	21
Models	72	46	13
Charts	13	36	3
Specimens	40	9	10
Aquariums	61	20	11
Germinating beds	79	55	33

^a Based on ref. 15, Tables 88, 89, 90; pp. 264, 265, 266. Figures rounded.

^b In addition, 24 county schools were listed as having no laboratories or science rooms of any kind.

College departments of science have not seen to it that prospective teachers had a good background in subject matter; they have not provided—as have education departments—summer-school courses for teachers; they have not encouraged their students to become science teachers; they have not made science teachers feel themselves to be part of the total scientific community. The many individual exceptions to these generalizations are encouraging, but still leave it true that scientists themselves must accept part of the responsibility for the shortage of science teachers and the inadequate preparation of many who are teaching science courses. . . .

What is appropriate on one campus may not be appropriate on another. The following list, therefore, includes what appear to be desirable activities, but the details must be expected to differ from one institution to another.

1) Collegiate departments of science can examine, and frequently improve, their undergraduate courses and major requirements from the standpoint of their appropriateness for future high-school teachers.

2) Working with departments of education and state school officials, they can revise certification requirements to place greater stress on subject-matter preparation of prospective teachers.

3) They can develop courses suitable for high-school teachers who return to the campus for summer work. In many states a teacher with graduate work or a master's degree qualifies for a salary increase. The undergraduate work of many teachers who would like to get such increase is not adequate, however, for enrollment in the traditional graduate courses in science and mathematics. Turned away by departments of science, they concentrate in education, in which they can receive graduate credit. This situation creates a problem for science departments; they do not wish to water down their advance courses; neither do they wish to give graduate credit for their elementary courses. Yet unless they make some adjustment, they are missing an opportunity to raise the level of high-school teaching and improve the preparation of future students in their own fields.

Other adjustments are also possible: a master's degree in science teaching can be given without interference with the usual master's degree in science. . . .

Such recommendations were aimed primarily at the liberal arts colleges and universities; and their scientists are at last becoming active. Without such attention, teacher education will naturally follow its own tradition; U.S. Commissioner of Education McGrath pointed out in 1948 that less than 10% of the 200 teacher education programs surveyed by his office showed any divergence from the normal framework.

Provision of adequate science teaching in the public schools is basic to public understanding and support of science in the future, as well as to recruitment of able youth into careers in science or science-related vocations. The problem must be resolved by cooperation between those scientists willing to give more than lip service to the educational and manpower problems of their profession, and the science educators and school administrators faced with the task of carrying on at the school level. Engineering, mathematics, and the physical sciences have been active; if biology, and particularly biology in its functional physiological aspects, is to receive its share of attention, experimental biologists can do no less. Fortunately, physiological scientists can be found who are not only widely acquainted with the scientific, social, and economic aspects of their profession but also are convinced that the school experience of youth is vital for producing future scientists and will work to

improve, this. That it is high time for this is indicated by some current newspaper accounts, such as one based on poll results given in H. H. Remmers and D. H. Radler, *The American Teenager* (pp. 175-177):

Fourteen percent think there is something evil about scientists. Thirty percent believe you can't raise a normal family and become a scientist. Forty-five percent feel their school background is too poor to permit them to choose science as a career. Nine percent believe you can't be a scientist and be honest. Twenty-five percent think scientists, as a group, are more than a little bit odd. Twenty-eight percent don't believe that scientists have time to enjoy life. Thirty-five percent believe that it is necessary to be a genius to become a good scientist. Twenty-seven percent think that scientists are willing to sacrifice the welfare of others to further their own interests. As the poll director and analysts remark, these responses indicate a lack of information about scientists and their work, and show that negative attitudes have been put in place of such information. This concept may very well be basic in the dwindling supply of technically trained graduates.

SUMMARY

For physiologists the quip may be valid that 'physiology is what physiologists do'; but for the public, if physiology has any meaning—which a random sampling of cab drivers renders doubtful—it is a vague accompaniment to medicine, with astringent overtones of body-build and right-living. Partly, this is a vestige of past (and current) education in biology, and its legal linkage to hygiene and physical education; partly, it is a consequence of present (and past) habits of science writers and editors in the mass media, who regularly evoke a picture of the bedside physician or of the laboratory chemist when reporting new discoveries of physiological science.

When a paper, expanding Erlanger's work on circulation and reported by a foreign physiologist at a meeting of the American Physiological Society, is reported in the local press as a medical discovery by a visiting physician based on an earlier discovery by an American physician reported at a meeting of doctors (28), something needs to be done by American physiologists. When Swedish physiologists stirred themselves, the prestige and support of physiology rose sharply. In this country, the chemists and the physicians have strong public relations units and good public relations; physiologists and other biologists are at last exploring possibilities—with the American Institute of Biological Science, the Federation of American Societies for Experimental Biology, and the National Society for Medical (which really should be 'Physiological') Research.

A limited analysis of science reporting in popular magazines was made for 1938 and 1951. Total attention to science, by number of articles and pages, increased somewhat—to 20% of all material in *Reader's Digest*—but the portion of all science devoted to biology fell, by 10%-15% (for *Digest* and *Time*), to about two-thirds. This seemingly large fraction, however, includes much medicine—earlier about four-tenths, now over half—and

between 70% and 85% is applied biology. Really physiological material (*Time*) fell from 0.7% to 0.3% during this period. In 1951, articles on physiology, compared to all in medical science, were: *Digest*, 4 (3 on sex) of 29; *Scientific American*, 2 of 15; and *Science*, 51 of 264. So much for informal education; the picture of formal education is more somber.

The Survey could not enter into the great and turbulent waters of public education. Since the conditions of science teaching in elementary and high schools are little known to most physiologists, the material collected on these has been presented in somewhat more detail than have other topics. In science, perhaps even more than in less rigorous intellectual areas, there has occurred a progressive dilution in course content and method. Whether this is a necessary leveling down to fit the widening base of students educated in a democracy; whether it is the product of the tender-minded goal of education, prevalent over several decades, to teach life-adjustment, rather than the tough-minded one, to train in basic intellectual disciplines; whether it is the unhealthy outcome of niggardly support given the schools in so many states and smaller voting units; whether it simply reflects an inadequate number of quality people of all sorts; or what combinations of these and other factors are involved, remains to be established. What is certain is that most youth today receive scant and shoddy science teaching.

A number of studies made for or collected by the Survey, involving Utah, Iowa, Ohio, Massachusetts, New York, and other states, agree in general direction. Graduate students in education fell below those in other fields on the Army General Classification Test. Presumably poor quality students are attracted into teaching; and the salary levels and personal strictures that go with the calling make this understandable. The students have limited training and sometimes none in the subject they later teach; a fourth of the elementary teachers in Iowa had a bachelor's degree and fewer than half the science teachers had even a minor in their subject area.

High school texts in biology averaged a serious error per five to eight pages, and commonly emphasized the evils of alcohol and tobacco or the virtues of exercise above any glimpses of the body functions. Only 37% of the nation's high schools have definitely scheduled laboratory periods and only 16% still schedule any two-hour ones. Ohio inspectors declared laboratory facilities unsatisfactory in two-fifths of the high schools; and, in general, movies and exhibits predominate, so that learning is passive and life science is presented with little note of the teeming life outside the school door.

Course content, judged from catalogues, questionnaires and, mainly, examination papers, is thin. Growth and development, nutrition and metabolism, muscle and exercise, and the nervous system tend to be most stressed by one or another group; but the emphasis is on utility more than on understanding and the coverage is superficial. Biology and general science courses, mostly

with vocational or social adjustment aims, have replaced those in botany, zoology, and physiology; these latter reached 15% of the students in 1909, 1% of the enlarged number in 1949. But enrollment in biology courses has greatly increased, especially relative to those in physics and chemistry, at high school and higher levels; not because of positive interest, according to all evidence, but as an avoidance reaction to more demanding science. Indeed, even in New York City in 1953, only 11 of 54 high schools offered advanced courses in individual sciences.

The tendency to learn about rather than learn science has spread from elementary to high school to junior college and general education schools, and is reaching into liberal arts colleges. The ominous warnings of our falling behind Russia in science and technology take on body when our situation is examined. Our education is more a social custom than an intellectual quest. Our teachers are too largely recruited from shoddy material and given shoddy training; are given shoddy facilities with which to teach shoddy content; and are asked to teach shoddy students to shoddy standards. A demonstrated outcome is an adult population with the expected lack of either information or understanding. Suspected ones are the debasement of quality of a 'revolt of the masses', and the general delinquency of a revolt of the young. Democracy and science are both endangered; scientists must join other groups actively at work to better the situation.

XII

INTERPRETATIONS AND RECOMMENDATIONS

The original Survey plan called for a terminal conference to consider the findings of the study and to make recommendations which, as refracted through the Committee, would cap the report from the Survey office. This did not happen, and final responsibility for this report reverted to the Chairman of the Committee. Most of this volume, nonetheless, is simply factual or carries such interpretations as flow from the facts or reflects attitudes on which there has been wide consensus. This closing chapter could be restricted to conclusions from the Survey data or could range more widely, on the basis of additional information and, inevitably, of individual bias, to present a picture and a program. The more hazardous but meaningful course has been chosen. There is some reassurance in the fact that many recommendations presented informally during the course of this Survey have already been acted upon by the APS and its officers and committees with good outcomes; and have influenced the plant and bacterial, the biological and medical groups.

THE PROCESS

Physiology is a 'smokeless industry' that attempts, in the phrase of a colleague, to answer the question, 'What makes it go, boys of biology?' As dynamic biology, it is certainly one of the great cross roads of the life sciences—in the professional aspects of men and administration no less than in the scientific aspects of content and attitudes. To identify and delimit a population of physiological scientists, and to fraction it into central primary physiologists and peripheral secondary ones and into animal, plant, and bacterial groups; to explore these sets, often further divided by type of employment and activity and training and other characteristics, as to achievement and salary and satisfactions and hindrances; and to follow their march through school and university curricula into the business of creating the future and its new bearers, by teaching new recruits, by administratively mapping their way, and by researching new horizons—these have been great and basic tasks.

The coded cards developed by the Survey are on file with the Society and with the Survey Research Center, University of Michigan, and several

documents are on deposit at the American Documentation Institute. Many questions unanswered by the Survey, or even unasked, can be solved by a few machine runs of the deck with minimal cost and trouble. Inquiries made during the active period of the Survey and outside studies already based on or utilizing its findings (e.g. Survey Center articles) give warning and promise of extensive future demand for these materials. Future stocktakings, which must inevitably come, cannot but use these base lines and would be greatly eased and enriched if present files were periodically brought to date. Indeed, since individuals can be traced, by multiple cross checks, while retaining essential anonymity, any number of searching studies can be made at present—relating achievement to grades or school or professor or job, or satisfaction to income or publications or work conditions, or specialty chosen to teacher or ability or position; and great possibilities are opened by repeated studies, which would make available longitudinal data on individual careers, on institutions and publications and subject areas, on costs and yields of all sorts. Study of a more severely chosen elite group, based on four (rather than two—as in this study) of the eight criteria available, would likely show decisive results. Even on the published material, much remains to be learned by proper variance analyses.

A strong recommendation, therefore, is: that a small continuing office be established to further exploit the present materials, to give service to others wishing information from them, to update the data from time to time, and to participate with other offices in later studies involving physiology. This were best done by the AIBS or perhaps the NSF, with aid from the appropriate professional bodies.

It may seem disingenuous, after complaining of the defects of the present effort, to prescribe more of the same. Perhaps it is; and few who labored on this study would lightly undertake another. Yet, it was recognized at the start that this run might merely teach how to do a better job. Moreover, despite breakdowns on the way, a reasonably solid underpinning has now been built; it would be inefficient to leave it without the less costly superstructure.

THE AREA

'What is physiology?' is the sort of irritating question that seems unnecessary to ask yet necessary to answer. The reply, 'Physiology is what physiology does', even the more serious one, 'Physiology is what physiologists do', is not too helpful; and, in fact, the answer is quite different for subject matter, administrative organization, educational offerings, publication outlets, personnel allotments, and still other facets of the totality. Considered broadly, as dynamic biology, physiological science includes: three-fifths of the research projects (8000 of 13,000 in 1953) listed with the Bio-Sciences Information

Exchange; one-fourth of all books (2250 of 9000) listed by Hawkins in the science, medical, technical area; two-fifths of all biology Ph.D.'s (5000 of 13,000 alive in 1953) and one-eighth of all in science (40,000); and courses for one-eighth of all students in higher education. (75,000 in courses in 1953, total enrollment 2.3 million; assuming an average stay of four years, this is 600,000 each year through the set of courses.)

Considered more narrowly, the domain shrinks to about one-third this size and is carried by 1900 central physiologists, who are divided between animal, plant, and bacterial segments in the rough proportions of 12:5:2. The great weight of animal physiology and the dominant interest of the American Physiological Society help explain, though hardly justify, the particular attention given to this subdiscipline. Apologies for relative or absolute neglect of many topics and areas are in order and are offered.

Within the total area, the major segments of core physiology remain distressingly disparate. In education, in scientific focus, in institutional employment, in professional affiliation, in applied fields, there is negligible overlap of the animal, plant, and bacterial groups. Whether by historical accident, embalmed in university departments, or by inherent logic, there is little in common between these three territories; indeed, it might be questioned whether the decision to encompass all in a single survey was a wise one. The recommendation once seriously considered, that the several professional societies (and journals) should be combined into a larger physiological unity, thus now seems unwise.

In contrast to the multinucleate center, the cytoplasmic periphery of physiology is well unified and merges into the total life science syncytium. In the direction of basic science, all portions utilize the physical science disciplines and rely especially on chemistry. General physiologists, biochemists, and biophysicists do cross the lines and operate freely in the three sectors; and the AIBS seems the appropriate agency for the integration of physiology as a portion of biology. In the direction of application the cleavages reappear, with health, food, and some manufactured products as the main respective outlets. Inevitably, animal physiologists will have ties with medical, dental, veterinary, and like groups; plant physiologists, with agriculture, forestry, horticulture, agronomy, and related fields.

Activities

Professional physiologists of all species are research-oriented. They are nine-tenths at the doctoral level of training, well over half their total man hours go to investigation, and two-fifths do no teaching at all—even though two-thirds are in academic institutions. Yet half of all biologists are concerned with education (7000 in high schools, 24,000 in colleges and universities) and, conservatively, a third of these are in the physiological region.

Since under 3800 of the physiologists surveyed are in academic positions and only 2500 belong to a professional physiological society, between half and two-thirds of teaching physiologists are outcasts from the clan.

These teachers of future physiologists, scientists, and citizens will present biology and physiology with the content and flavor they know. Many are able and more than willing to upgrade their training and enliven their approach; so it would seem wise for professional physiologists to find a means of making their less mighty cousins welcome. Special society memberships, personal interactions, publication outlets, and many other maneuvers of cooperation or assistance deserve positive consideration. Study should also be given to making younger physiologists, including graduate students, welcome to the company of their more senior colleagues; the man who stayed after dinner came only on invitation. The thoughtful reports of 'tours' for sampling APS membership deserve attention on this and other recommended actions (Appendix O; President-Elect's Tour, L. N. Katz and Teaching Tour, Wm. R. Amberson).

External Relations

Chemistry earlier and psychology more recently achieved a unified organization, from the most basic science to the furthest applications. The dozens of branches of the American Chemical Society or the American Psychological Association accommodate the academic investigator and the industrial practitioner, a workable *modus vivendi* has been established, and the interests of the major discipline are well served. Biology has more separate organizations and less coherence than any other field of science, and the applied branches are far removed from the basic ones. Perhaps this is a consequence of the early development of life sciences; with the doctor and the farmer, the naturalist and the breeder spawning anatomists and botanists and experimenters of all sorts while chemistry was a turbid art and psychology the province of philosophers and humanists.

In any event, biology is deeply divided between the scientists and the practitioners, and physiology is stretched between the poles. The American Physiological Society affords a fine example of protracted ambivalence—or perhaps of an enduring amboceptor—as between 'biology' and medicine. It has met with clinical groups, as the Congress of American Physicians and Surgeons or the American Medical Association, and scientific ones, as the American Naturalists or the American Association for the Advancement of Science. It is a vigorous member of the American Institute of Biological Sciences and of the Federation—the only Society in both groups. It has representatives to both the Division of Medicine and the Division of Biology and Agriculture of the National Research Council. It has parented the biochemists and the pharmacologists and has contributed heavily to the general

physiologists and the biophysicists. (See 'The United States' in *Perspectives in Physiology*, ref. 117; also Appendix N, on the early affiliations of the APS.)

Perhaps in this country more than abroad the tie with medicine is close. At least, in two United States journals—*American Journal of Physiology* and *Annual Review of Physiology*—28% of the references are to clinical periodicals as compared to 17% for the *British Journal of Physiology* and 18% for the German, *Pflügers Archive*. Also, as compared to biochemists, 11% with an M.D. degree, animal physiologists are well toward the clinical side, 37% with the M.D. Here, again, are suggestions for a membership policy that would make fully at home the clinical investigator concerned with functional processes and mechanisms.

On the other hand, physiology would turn its back on its future were it not to welcome workers from the physical sciences whose concern is with systems of or from the living. Perhaps new splinter groups should continue to form—this may be the best solution to increasing size and diversity—or perhaps they will form though it were better that they did not; but in any case physiologists should encourage the closest identification with existing bodies. Whether or not endocrinologists, for example, are favorably located in a separate society, with strong morphology and organic chemistry as well as physiology represented, there would seem no justification for a membership policy or other action of the American Physiological Society that tended to exclude them. This Society might well aspire to remain or become the primary professional affiliation of all animal physiologists.

Trends

There is a striking current of men moving in science from the more basic and simpler areas to the more applied and complex ones. Mathematicians move into physics and astronomy, physicists into chemistry and meteorology, chemists into biology and geology, physiologists into psychology and medicine, psychologists into sociology and psychiatry, and so around a ring through philosophy and, in principle, back to mathematics. Scientists who shifted in the other direction are few indeed—Helmholtz and Michaelis come to mind as exceptions.

But, as the adherents to a discipline move in one direction, the discipline itself necessarily moves in the other. As chemists and physicists enter physiology and physiologists leave it for clinical research, the center of gravity of the subject moves towards physical science. This trend is, of course, strongly reinforced by the educational shifts—each new class of physiologists has been exposed to additional knowledge in physics and chemistry on the way through its science courses. Inevitably, physiology shows a fifty-year trend in its publications towards the methods and thinking of chemistry and

physics and mathematics. Inevitably, physiologists feel their training in these subjects is inadequate as the tide they rode in on advances beyond them.

Not only do physical sciences penetrate biology; there are other seemingly inevitable changes. Attention was first on living objects and their classification—hence the ancient dichotomy of botany and zoology. Then came the morphological emphasis, followed by that on function and, later, on development—with anatomy and physiology and then genetics and embryology pushing ahead. Further, comes a shift of level: from the individual organism, roughly man-size, to the organ and cell, the particulate and the molecule, in the direction of most physiological science, and to the group and species and community in the other direction. These currents, involving all science, are too far flung to be examined here (40, pp. 433-437); but the shifts revealed over a half century, as in the experimental materials of physiologists (Chapter VII), are in full agreement with expectations.

Subspecialties

One last matter needs attention. Even at the level of organ and system physiology, which remains the focus of the animal physiologists, there has been considerable concentration. The nervous system, with its sensory and motor appendages, and the circulatory system, as a close second, have long dominated in this sector. Metabolism, with nutrition and growth, continues strong and, when all segments of physiology are considered, is the largest subspecialty—engaging 30% of all physiologists. (Of peripheral physiologists, a third are identified with biochemistry, as compared with, roughly, one-tenth each in agriculture, microbiology, and clinical science, and with one-fifteenth in psychology.) Central animal physiologists are divided as follows, according to their field of specialization: neurophysiology, 18%; metabolism and growth, 18%; circulation, 16%; endocrines, 14%; respiration, 7%; renal, 5%; general, 5%; environmental, 3%; other, 14%. Courses in medical physiology, however, devote 28% of lectures to neurophysiology, 20% to circulation, 12% to endocrines, and only 6% to metabolism. Two-thirds of all laboratory experiments are in neural and circulatory physiology. Men most cited in *Annual Reviews* included 21 in neurophysiology, 11 in circulation, 10 in endocrinology, and 9 in metabolism.

Table XII-1, showing the field of interest of departmental chairmen appointed over five decades, is an interesting confirmation of these more general figures. Neurophysiology, long in front, is recently yielding to circulation; perhaps for this reason, in part, the man shortage in recent years is of neurophysiologists. An analysis of Nobel awards, from their inception in 1901 through 1953 (based on Survey Project 3E), is also instructive along these lines. Of 63 laureates in Physiology and Medicine, 31 were judged central physiologists, on the basis of their research area; and 19 men (11 with awards

TABLE XII-1. AREA OF SPECIALIZATION OF CHAIRMEN OF PHYSIOLOGY DEPARTMENTS (Survey Project 4A).

	1910- 1919	1920- 1929	1930- 1939	1940- 1949	1950- 1953	Total	N
Chairmen appointed ^a	13	45	44	87	34	100%	223
% In	%	%	%	%	%	%	
Neurophysiology ^b	23	22	25	31	15	25	56
Circulation	8	27	25	16	26	19	43
General and comparative ^c	23	13	5	14	6	11	25
Metabolism and nutrition.....	8	7	11	8	18	10	22
Digestion	31	13	7	7	9	10	22
Endocrinology	8	11	11	8	9	8	18
Respiration		9	2	6	9	6	13
Blood			7	5	6	4	9
Renal			7	3	3	3	7
Other						4	8

^a Each appointment considered separate as a given man changed institutions.

^b Includes sensory and motor physiology.

^c Mostly in college departments.

in Chemistry or Physics) were judged peripheral physiologists, on the basis of research area, initial training, or later career. Divided into subdisciplines, roughly and with some doubling, the proportions are: nervous system, metabolism, and endocrines, each 30%; and circulation, 15%. Parenthetically, the rise and seeming fall of physiological science, and the steady advance of American physiology on the world stage—frequently enhanced by the importation of European brains—is clear from the trend of Nobel awards as shown below:

	Decade					
	1900-09	1910-19	1920-29	1930-39	1940-49	1950-53
Awards to physiologists.....	4	6	13	16	9	2
% to the United States.....	0	17	18 ^a	31	56	100

^a Canadian.

No one familiar with meetings of the American Physiological Society, both scientific and business sessions, and of the numerous specialty groups that cluster under its wings, can doubt the great influence of the nervous system and circulation members. Some deliberate restraint by these dominant groups, and positive planning by all, may be needed to prevent the Society from becoming binucleate, or even dividing along these lines.

MEN

Man is the world's great catalyst; he transforms deserts into orchards, forests into buildings, coal into fabrics, ore into machinery, and waterfalls into electric current. He can thus achieve food, shelter, clothing, tools, and power because of a still more basic transformation, of the fearsome unknown into the docile solved. Not all men are involved, only the talented and trained few are directly responsible for social evolution; these are mankind's greatest asset.

The present concern is with scientists and biologists, more generally, and with physiological scientists and physiologists in particular. Many data, presented in earlier chapters or gathered especially for this one, bear upon the supply of such men, in 1953, and exhibit past trends in their production and loss; and the data also permit some predictions as to future manpower requirements and their fulfillment. To avoid a heavy overburdening of the text, most of these figures (as also those on finances) have been relegated to Appendix R. Tables XII-2 and XII-3 and Figure 9 and the following text summarizes only some of the most important material.

TABLE XII-2. RECENT AND PRESENT TRENDS.

	1953		1955 ^a	
	Population	Increment	Population	Increment
U.S. population #	160	2.8	165	2.5
Civilian labor force #	63	1.0	66	0.8
High school graduates #	22	1.3	26	1.4
College graduates # ^b	6	0.3	7	0.3
College graduates in science	600	34	700	40
College graduates in biology	235	16	300	20
College grad. in applied biol. and health	590	40	750	50
Ph.D.'s—total	97	8.3	125	8.8
Ph.D.'s in science	41	4.7	55	4.9
Ph.D.'s in biology	14	1.0	17	1.0
Ph.D.'s in applied biology and health	4	0.7	6	0.8
Ph.D.'s in physiological science ^c	5.2	0.2	6	0.4
Ph.D.'s in physiology ^d	1.9	0.1	2.1	0.1
Employed scientists	240	15	290	
Employed biologists	60	3	70	
Employed applied biology and health	980	35	1000	
Employed physiological scientists	5.7	2	6.3	
Employed physiologists	1.9	0.1	2.2	
High school students #	6.8	0.2	7.4	
High school students in biology #	1.3	0.1	1.5	
College students #	2.2	0.1	2.5	
College students taking life science ^e	350	17	400	
College biology majors	100	5	115	
Physiological science majors	1.6	0.1	1.8	
Graduate students	210			
Graduate students taking biology	17			
Graduate students taking physiological science	6.3	0.4	7.3	
Elementary and high school teachers #	1.1	0.1	1.4	
College teachers	200	10	230	
College science teachers	40	2	45	
College biology teachers	10	0.7	12	
College applied biology and health teachers	27	3	35	
College physiology teachers	1.5			

Numbers in thousands unless with #, which indicates millions. For sources, see Appendix R.

^a 1955 values are mostly predicted, based on earlier data.

^b Including first professional degree.

^c 90% of 5750 have a Ph.D. or M.D.

^d Including 10% with M.D. only.

^e Of these, only 9500 were in biological science.

TABLE XII-3. POST TRENDS; TOTAL NUMBERS.

	(Units)	1910	1920	1930	1940	1950
a. U.S. population	m	92	106	123	132	152
a. Labor force	m	37	42	49	53	60
b. Professional workers	m	1.5	2	3	3.5	5
c. College graduates ^a	m	0.3	0.7	1.5	3	5
c. College graduates in science	t	45	90	150	350	500
c. College graduates in biology	t	13	25	50	110	220
c. Ph.D.'s, total	t	2	5	15	40	75
c. Ph.D.'s in science	t	1 ^b	2 ^b	5 ^b	20 ^b	30 ^b
c. Ph.D.'s in biology	t		1	3	7	11
d. Ph.D.'s in physiology	h		0.5	2	8.5	13
c. Graduates in agriculture	t		15	35	70	120
c. Graduates in home economics	t		5	20	55	125
c. Graduates in medicine	t	50	80	110	150	200
c. Graduates in dentistry	t	20	40	60	75	90
c. Graduates in other health	t	25	50	80	100	150
a. College students	m	0.4	0.6	1.1	1.5	2.7
c. Elementary and high school teachers	m	.55	.70	.90	.95	1.1
c. College teachers	t	35	50	80	130	210
c. Members scientific societies	t		33	50	55	120
c. Chemists	t	16.5	33.5	48	60	76
c. AAAS	t	8	11.5	19	21	45
d. American Men of Science	t	6	9.5	18	30	53
d. Federation	t	0.3	0.7	1.1	2.4	3.7
d. AMS physiologists	h	1.3	2	4.5	8	20
d. Core physiologists	h	1.1	2	4	8	16
d. APS members	h		2	4	7	13
d. Papers at Federation meetings	h			2.6		13.3
d. Pages physiological publication	t		45			190
a. Gross national product, current \$	b			90	101	285
a. Gross national product, constant \$	b			140	172	265
b. Federal research and development, current \$	m	15	40	69	97	1140
b. Elementary and high school educ., current \$	b	0.5	1.1	2.6	4.8	6.6
b. Higher education, current \$	b	0.1	0.2	0.6	1.7	2.1

All estimates rounded to nearest figure within 10%.

^a Including first professional degree.

^b Figures from NSF (93) are: 2, 5, 12, 24, 39.

Sources: a—(83); b—(93); c—(122), rounded estimates largely from Appendices B and C, d—Survey, mainly Tables 4-8 and 4-9.

Units: m—millions; t—thousands; h—hundreds; b—billions.

The Committee on Applications and Consequences hoped information would be obtained, for each of some ninety fields in which physiology is used, as to: physiologists employed in it, physiology teaching in relation to it; contributions by physiology to it, technical improvements and financial gains; and needs of it for men, training, improved attitudes, and the like. The fields listed included eighteen in basic sciences, thirty-three in medical

and medical related sciences, four in agriculture and natural resources, four in engineering and industry, twenty in industrial products, eight in education, and home economics, nutrition, and health education. Full exploration of this area proved beyond the resources of the Survey, but a set of essays, some most informative, was obtained from authorities in a majority of these areas. The Committee's plan and the essays obtained for Survey Project 4B are given in Appendix P. Our thanks are due the contributors; publication was not practicable, but all are on deposit at the American Documentation Institute.

In 1953 there were employed in this country some 60,000 biologists, perhaps 15,000 of them Ph.D.'s. Those in colleges and universities, doing teaching and research, numbered over 20,000 and probably included 10,000 of the Ph.D.'s; federal and state governments employed some 15,000, including 2500 to 3000 Ph.D.'s; industry employed fewer than 10,000 and only one-fourth of these were in the non-medical research and development group which would include all the Ph.D.'s, say 1500 to 2000; and another 4000 biologists, perhaps 500 Ph.D.'s, remained in other categories. Of the biology Ph.D.'s, nearly 6000 were in physiological science and 2000 were physiologists. The total employed in all applied biology and health fields was close to one million.

It may safely be assumed that losses are well under 1% a year, so that, over the short range to 1960, specialized manpower will increase as students are graduated. Although 20,000 bachelors per year will graduate in biology and 50,000 more in applied biology and health fields, only about 5000 a year in biology and perhaps 3000 in agriculture can be expected to continue professional work in these fields. At the Ph.D. level, an annual increase of 900 employed in biology and 800 in agriculture and health seems generous; and, of the biologists, 200 can be counted in physiological science, 100 in animal physiology.

The demand, estimated for 1960 and prorated on an annual basis, is necessarily more uncertain than the supply. Allowing for the especially rapid growth of the pharmaceutical field, more than doubling in five years, industry will need each year an additional 1000 life scientists, of whom 400 must be at or near the Ph.D. level to work on research and development (R&D). In higher education, an additional 4000 teachers a year will be needed in the life science area, 1000 of them in biology. Figures on government life scientists are especially varied, but a reasonable guess is that need will increase annually by 2000 life scientists and 400 of these will be at the Ph.D. level.

At the lower training levels, therefore, supply (8000 life scientists produced a year) may meet demand (7000 needed a year); but at the professional level supply (1700) will fall short of demand (2000). For physiological

science, 200 Ph.D.'s produced a year and 700 needed, and for core physiology, 100 produced and 200 needed, the deficit will presumably be great. Considered in relation to type of employment; physiologists are now distributed 72% in academic institutions, 16% in government, and 12% in industry, and the estimated needs for biology Ph.D.'s are 65%, 20%, and 15%, respectively. The academic group will be under especial pressure, not only from a general shortage but also because of the relatively greater demands of government and industry.

It is interesting that these rough figures do come so close to balancing at the lower training levels. The growing shortage of highly trained men in biology and physiology might seem small compared with the widely-proclaimed need for engineers and physical scientists (e.g. 95). With nearly a tenth of all income from sales devoted to R&D in the aircraft industry, and the consequent tremendous increase in growth (see below), it is not surprising that engineers have been at a premium here. Aircraft executives, especially, cried for quality men and preferred to leave positions vacant rather than take what was available (95). Yet no general shortage could be demonstrated in 1953 (105, 7). In 1957, some 'engineers' released when a large missile plant was closed did not easily find jobs (*Sci. Amer.* 197: 106, Sept. 1957); but these men may have been graded above their training. Overall, there seems little doubt—with the more rapid growth of science than of non-science activities (Fig. XII-1), with the increasing diversion of scientists from teaching, with the generally low support of education and status of educators, with the loss of many able students from higher education—that the shortage of trained brains will become more acute over the foreseeable future. The following paragraph, from Trytten's study of U.S. and Soviet manpower (82), is much to the point:

The recent road programs of the Federal Government, the recently announced multi-billion-dollar expansion program of the communications industry, huge research laboratories recently dedicated, all present their evidences that our technology is expanding at a rate as great as during the past half-century, that it is becoming substantially more technologic and, hence, accelerated in its demands for highly trained personnel, and that the extent of training for the personnel required is constantly rising. The prediction seems eminently justified that our schools are unlikely to be able to satisfy the accelerating demand, insofar as one can foresee the future, even though one takes into account the increasing number of youths entering the college age group during the next decade. Our industry has more than doubled its demands every decade. In spite of the formidable increases in enrollment due in another decade, the increase in number of youths of college age causing that increase is not so large as to double present levels.

Research

MONEY

Scientists have long argued that funds invested in research pay great economic dividends. There is rich evidence to support this claim, and also to show that the scientists have been heard. The gross national product

(GNP), \$360 billion in 1953, has been increasing at an average of 3% per year for a quarter century. Total expenditure for research and development (R&D), about \$5 billion in 1953, has increased 10% a year and is accelerating. This rate is three times that for the GNP and for employed scientists and is twice that for science Ph.D.'s. Of the total R&D, basic research received \$435 million, 8%, and \$125 million of this was directed to the life sciences. Table XII-4 shows extramural funds for medical research over six years, and the strong trend from industry to government as the main source. Details for this section, as for the one on 'Men', are presented in Appendix R, and some high spots in Tables XII-2 and XII-3 and in Figure XII-1.

When industries are compared (Ewell, 19), or nations (Johnson, 44), remarkable relations emerge between R&D investment and total production. Food, lumber, paper, and some other industries have invested about 1% of sales in R&D and have doubled production over 15 years; the drug industry, investing 5%, has grown five-fold; and, in general, for each 1% put into R&D there has been a 100% increase. Indeed, the economic pay-off on R&D dollars seems to average 100% per year for a 25-year period! And the return on each basic research dollar, especially in the life science area, is considerably greater. As between countries, the greater the fraction of GNP invested in R&D, the greater is the GNP per capita—about \$1000 per capita for every 0.5% of GNP put into R&D. The United States was long at the top, with an average of 1.1%; Russia, on a comparable basis, is now ahead, with 1.2%.

Total R&D funds, and those for basic research, reaching the life sciences in general or physiological science in particular are not easy to establish. The published data, by NSF and other agencies, as corrected by returns on the Survey questionnaires, suggest for 1953, in the life sciences, total R&D funds of \$280 million and \$55 million for basic research, with biology receiving \$55 and \$18, respectively. Another estimate for the same year, presumably on a broader base, gives \$125 million for basic research in life science. Neglecting the \$10 million allocated to miscellaneous areas, 76% of these

TABLE XII-4. SOURCES OF EXTRAMURAL FUNDS FOR MEDICAL RESEARCH.

	1947	1951	1952	1953
Amount (millions)	\$110	\$180	\$(36)	\$140
	%	%	%	%
Government	28	42	70	55
Industry	45	33	#	24
Other	27	25	30	21
	<hr/> 100	<hr/> 100	<hr/> 100	<hr/> 100

Less than .5%.
Sources: 1947(78), 1951(17), 1952 (BSIE data, Survey), 1953 (Survey questionnaire; total from 100 and 102 increased for industrial contribution).

funds was spent by academic institutions, 15% by government, and 9% by industry. The distribution of biologists is: academia, 72% (76% of biology Ph.D.'s); government, 16% (21%); industry, 12% (10%). Clearly, funds are spent in fairly close relation to the number of men. The lower ratio of money to men in industry probably reflects the smaller proportion of high level employees, as shown by the Ph.D. figures.

Physiological scientists reported spending \$57 million on research, nearly half the total basic research money available to all in life science. There is some unclarity in the classes of figures, but physiological scientists constitute one-third of biologists and devote over half their time to research, as compared to one-third for all biologists, so this amount is perhaps reasonable. When reduced to the individual, some striking relations appear. In the animal area, which is best supplied, the average investigator has available over \$14,000 in outside funds (the average PHS grant is \$14,000) and another \$9000 in intramural funds. Since one scientific paper costs on the average \$13,000, par is one paper per year per grant and 1.7 per man—the average number in questionnaire responses.

The total annual cost of research per scientist in 1953 was about \$24,000. From several sources the same rule emerges—research funds are divided about equally between salaries of professional personnel, salaries of non-professional personnel, and all other material and running costs. A single team might consist of the investigator (\$8000), technician plus secretarial, shop, and other part services (\$8000), supplies, etc (\$8000). For each person an average of 200 sq. ft. of floor space is needed; half for his own work space, half for supporting facilities—shop, library, animal quarters, etc. Such figures seem sufficiently general (space needs, for example, are alike for wet laboratory and for social research groups) to be helpful guides in budgeting a new research project and in seeking support for it.

Education

Funds for education in 1953 totaled over \$2.5 billion. Some 200,000 faculty members received \$800 million in salaries, an average of \$4000. If the average salary for science faculties was \$6500, the 62,000 science teachers would have received half of the total, which seems disproportionately high. In any event, all studies agree that academic rewards have plummeted over the past half century. Were the relative position of a senior professor to be restored to the 1905 level, his salary now should be well over \$25,000 (75). Institutions of higher learning require about \$4 billion for capital outlay and a like amount to endow salaries and other operating costs, if they are to function properly.

Each biology student requires about 50 sq. ft. of working space and, in 1953, needed nearly \$500 for adequate instruction and supplies: \$130 for

instruction, \$100 for materials, \$40 for upkeep of equipment, and \$200 for funding and upkeep of the plant. Actual expenditures averaged \$400, according to questionnaire responses from department heads; but the sample was biased toward larger institutions, so that actual performance was considerably below optimal.

The 75,000 students in biology in 1953 should have been supported by \$35 million. Estimates for 1960 show need for an additional \$7 million for annual expenses and another \$20 million for capital outlay. Department heads indicated in 1953 a need for added sums of \$4 million for running and \$10 million for building even in 1954.

Until education again becomes a major concern of this country, its needs will continue to outrun its support. The zeitgeist now favors comfort over achievement and passive entertainment over positive effort. Sport and sex ride high, and only a major convulsion¹ would raise brains to the status of bosoms or baseball.

EFFECTIVENESS

Training

If money invested in research generates the indicated rich rewards in new wealth and activities, funds should not become the bottleneck to the future except by gross mismanagement. This could, of course, occur with a narrow national policy, but only if the people will not grasp the vital need for education and research; and in this case the supply of men will also suffer. It is manpower that is now and will continue to be the limiting factor in the country's development.

At one time, manpower needs were really horsepower needs—for manual labor. Machines and fuels have taken over the supply of brute force and much of skilled manipulation; this is not a shortage. Machines have invaded the input domain, from simple aids for sensing to elaborate perception integrators; human eyes and ears are not at a premium. Machines are entering the heart zone of decision making and are taking over the more routine 'mental' tasks; bookkeepers and clerks could soon become dispensable. It may be that a time will come, as science fictioners love to tell, when machines take over or where only a few super-handlers are required to control them; but this age is not yet, and in setting goals and devising ways to meet them men are still essential.

Clearly, more men per se is not the solution—a large population expands consumption with production. The need is for better distribution and up-

¹ The sputnik rose into orbit while this volume was in press. It certainly led to an intensive and highly vocal re-examination of our present position and future goals. One might extend the title of the President's 'chins up' addresses and suggest as a slogan for the contemporary U.S., 'Double chins up!'

graded performance. It is beyond the province of this study to ask whether, indeed, the diversion of more men or more of the abler men from business or poetry to science is desirable; or, even if desirable for the national interest, whether the abilities and satisfactions of men are sufficiently interchangeable to shift effectively between trochee and trocar. Our conviction is that physiology serves society and satisfies its devotees and our assumption must be that more and better physiologists would be a good thing.

To a considerable extent this is part of the general problem of more and better scientists. This involves the improvement of public understanding of science as it really is—by an extensive program of adult education and by appropriate changes in schooling the young. But to some extent physiology and biology stand in competition with physical science for their share of the manpower crop; and it may well be argued that national policy in the future will be supported more and more via biological and psychological means and less by hardware, even including the ICBM with a nuclear fusion warhead. In war or peace, it is the minds of men that matter; our urgent task is to learn how the organism functions and, the supreme goal, how the human brain operates.

This Survey has reenforced the evidence that our youth receives inadequate education in science and that biology as widely taught is a travesty on the subject. Dynamic and living biology can and should be important in elementary school and up. This will require teachers who have themselves developed some guided curiosity and have at least enough subject area know-how to guide their pupils to valid sources of knowledge—nature, laboratories, libraries, other teachers. Such teachers will not result from routine training, they also must be exposed to the contagion of active physiologists or dynamic biologists.

As Amberson reported (2) after his teaching tour:

The college teacher of physiology is usually relatively isolated. He is often the only member of his department with any knowledge of our field. He is rarely a member of our Society, has not attended our meetings, knows few other physiology teachers, even in nearby colleges, and has little or no contact with the faculties in the universities and medical schools of his region. Those faculties have made little effort to keep in touch with him. He suffers from a relative dearth of source materials. With a few notable exceptions the colleges which I visited have rather meager library facilities in our field. Even if more abundant materials were available the physiology teacher would have little time to read. Under present conditions the textbooks must remain his major source.

The administrative orientation is also critical. Again, it is beyond the province of the Survey to enter the argument as to why Johnny can't read—although the general complaints about college and graduate students make it clear that he cannot write—but if science education is made too 'soft', hard-headed scientists will not be the expected product. High school science teaching, according to Brandwein (8), was concerned with science in the twenties

as a body of subject matter, in the thirties as an aid to understanding the environment, in the forties as a means of solving the problems of man and society, and in the fifties in terms of meeting a child's needs and interests. Textbooks used, teachers encouraged, instructions given, depend on the overall orientation of the school and school system; and so, ultimately, on public attitudes.

At college and graduate levels, the emphasis shifts some. As Wolfe and others have emphasized, nearly half of the high school graduates qualified for college do not continue; presumably (e.g. the Russian experience; 82, 89) largely on a financial basis.¹ Extension of scholarship programs, already so effective at the graduate level, to ensure that no able student falters from poverty, would clearly have a high pay-off rate. And general college students, like younger ones, mostly need more dynamic teaching of more dynamic biology.

Just what should be taught and how is actively in debate. Should college students be informed about the physiology of man, an organism of special importance to them; or be taught general biology, with a dynamic approach; or be presented with the still more analytic approach of general or cellular physiology, requiring some mastery of the physical sciences as well as descriptive biology? For students as a whole, the last is too much to expect; but dynamic biology is surely more truly educational, and not more difficult, than is human physiology. The latter can so easily become a cataloguing of facts with a hygiene overlay, rather than an invitation to intellectual exploration. A good course in general physiology, if at least available, would go far to exhibit the character of modern biology.

The manner of teaching is argued often, in terms of the passive or active role of the student, of lectures versus conferences, and of laboratory projects versus assigned experiments. This also involves the teachers' abilities and the question of combined or separate research and teaching, both as to skills and emphasis. Some evidence was presented (Chapter VI) that the personalities of the successful investigator and the successful teacher are not alike; yet teaching and research effectiveness and satisfactions did run together. Although physiologists are inclined to wish more time for research, even at the expense of teaching (and the pressures to leave the academic world entirely have been pointed out), any great shift in this direction will lead to infertility and a vanishing group. In any event, some kind of intellectual alertness of the teacher and intellectual breadth of the investigator must be maintained by one means or another.

So far as the student is concerned, the evidence is strong that active par-

¹ Dr. Wolfe informs me that the fraction of qualified high school students entering college has risen and now probably includes two-thirds of those in the top quarter. He also judges motivation, as well as funds, to be an important determinant for continuing, or not, into higher education.

ticipation in the educational process has most desirable results. Project teaching was warmly supported at the First Teaching Institute of the AAMC(3); Survey questionnaire responses favored the less structured and didactic type of teaching session; and remarkable results have been reported from allowing beginning college students to initiate true research projects in a physiology course(25, 26), or from apprenticing high school students to active laboratories for a summer(44).

The importance of a given school or even a given mentor in producing superior graduates has not been established. The distinguished records of pupils of certain institutions and men may well be the result of initial selection, rather than creation, of superior students. The study of American psychologists(12) suggested this interpretation; and the recent reanalysis of Knapp's data by Holland(40) strongly favors it in the case of science graduates. The competition between institutions for good students is high; only as the educational experience at one school is really superior to that at another is this justified. Such studies are most welcome; for the following statement, made a decade ago(27), is still all too valid.

Education of the young is probably, next to warfare, the most extensive undertaking of civilized man and, along with science, the most maintained one. The efficacy of research, and of battles, is consistently evaluated in terms of objective criteria; research processes are steadily modified in terms of their performance. Although some of the detailed techniques of education are being studied in this manner, the over-all impact of the educational experience on its subjects has received but scant attention. The continued debate about educational strategy is evidence that opinions regarding it are still formed on the basis of hunches rather than of knowledge.

The smaller group that becomes interested in physiological science will need also more chemistry and physics and mathematics—especially the newer mathematics of relation and process rather than of magnitude; the tools of set and game and information theory, of topology and stochastic processes, which will help supply future models of the architecture and events of living organisms. Such biology may recover the interest of the more able students, who now drift to other sciences at the graduate level—as evidenced by the drop in AGCT performance of biologists, below the science average, after the Ph.D. is reached(122). When they finish their training, a proper fraction of them—certainly an increasing rather than the present decreasing one—must be retained in the teaching function. The seed corn must not be consumed as food.

Too much easy money available to a young scientist may lead him away from teaching when he needs this experience and should make this contribution. It also helps clutter the literature with unnecessary articles, often of poor quality, which may even slow the advance of knowledge. Better results in research no less than in teaching would often result by giving time, not money—an early sabbatical to continue his own active learning experience,

after encountering the real demands of academic functioning but with relief from their routine performance. Government and industry will do well to insure a continuing supply of top men to train their successors; by endowed professorships (along the lines of Imperial Chemical Industries in England) and career teacherships (like the growing career investigatorships), by generally improved salaries, teaching facilities and assistants, and the like. Here, as in research productivity, any money spent on tools, space, and service to conserve the limited and expensive time of the professional is excellent economy. In animal physiology, especially, the large and growing gap between the income and prestige of medical practice and those of academic functioning is dangerously wide.

"He who learns from one occupied in learning drinks of a running stream. He who learns from one who has learned all he is to teach drinks 'the green mantle of the stagnant pool'." These wise words from the past century (Scott, Principal of Manchester College) apply from top to bottom and point the line of action needed. Suggestions for aiding teachers of science in high schools and colleges—workshops, academies, publications, society affiliations, and the like—have been made and will be gathered later. Perhaps the most important recommendation, offered even before the Survey evidence was available, has been made effective; a vigorous Committee on Education is functioning in the APS and interacting with like committees of the Academy-Council, the AIBS, and others—with fine support from the NSF, NIH, and other government agencies.

Facilities

Given a body of knowledgeable men, productivity still depends on the conditions under which they function. Time is the most critical commodity, and it is as wasteful to send a man on a boy's job as the reverse. Technical assistance is vastly better than it was, thanks to generous supporting funds, but it is not optimal in amount or quality. Whenever a scientist spends time on a job that could be delegated to one of lesser training, efficiency is lowered, at least immediately. Too complete a divorce of the scientist from his bench, of course, may erode his satisfactions and eventually his effectiveness; but few investigators profit from washing dishes or animal cages or even from sterilizing a pack or counting planchettes. Certainly, technical aid was the greatest felt need of the Survey respondents.

Even here, funds have often outrun personnel and a real need is for improved recruiting and training of technicians of many sorts. Students with college science who do not start or complete graduate work can be useful; but they, and of course ones with lower level training, can be made far more effective by appropriate specialized training in technology. Schools for biological technicians are becoming important, and far more should be done.

Time could also be saved and research greatly facilitated by other kinds of services. As the chemist sends out his microanalyses and the internist refers his patient for an X-ray, so the physiologist should have professional services available, on a local or regional basis, for his more standard procedures. He no longer makes most of his chemical or biological agents but still does most determinations or assays of substances in which he is interested. More services along the lines of labeled compounds and of standard animal supplies, including such special ones as timed pregnancies or recent hypophysectomies, would be highly rewarding. Centers should be created to which materials could be sent for quantitation of indicator substances—from tissue glycogen through blood amino acids to urinary steroids—without the individual investigator or laboratory having to set up and master each technique required. The service laboratories of medical centers, which have become indispensable, are a fair prototype. Happily, this problem is also receiving attention now from the Academy-Council, NIH and other groups. Less ambitious but still helpful would be a more organized and annotated body of information about existing services and supplies. 'Yellow page' directories and catalogues, by commodities rather than companies, would aid purchasing offices and users alike.

The main present limitation on effective research and teaching, for the existing work force, is space. New buildings or remodeled old ones are the plea of investigators and teachers alike; and the cries must increase as growth continues. In this region certainly, if less so for supplies and services, money is needed and in large amounts. Building funds begin to be available from agencies that earlier supplied only more immediate research support; a wise policy, belatedly become possible. The slogan, 'Brains not bricks', has perhaps been overplayed and had better be changed to, 'Brains and bricks.' A trained brain is still more precious and takes longer to produce than the working space it can use; the latter should not be allowed to become the limiting factor.

Organization

Science is not a mosaic of separate contributions, however much the individualistic scientists may think so; it is a cumulative and integrated intellectual structure built by collective mankind. It may be true that an idea occurs in a single brain, but only after enormous interaction with other brains and other ideas. Academic positions are preferred for the intellectual exchange, as well as the intellectual freedom, of the 'University atmosphere'; and men are attracted from one institution to another also by these riches.

The questions are not as to the value of professional interaction, but as to its magnitude and scope and conditions. How large a group of colleagues, and at what levels, is optimal? How wide a field should a man cover and

with what intensity? When does the acceptance of joint goals and the pooling of services become less an aid to efficiency than a hindrance to originality? Some evidence on these points has been presented in this study—experience in interdisciplinary research has proved pleasant to most; productivity and satisfaction is not greatest with most or least leadership and support, but at intermediate levels; certain ratios of subordinate personnel at different levels, and of men to materials, seem to recur and are presumably desirable—but the large questions remain. They were well formulated by Fenn in his talk at the Survey Symposium at Madison in 1954:

1. What is the optimum size for a research institution? Perhaps it could be said that we can write the equation for the answer but the constants of the equation remain undetermined so that a numerical solution is not possible. According to this equation the institution should be large enough to provide all the necessary services such as an electronics shop, glass blowing, photography, illustrations, carpentry, machine shop and library service so that the researcher need waste no time in mere drudgery. On the other hand, the institution should not be so large that the usual housekeeping problems cannot be handled by personal contact, but require increasing amounts of "red tape". The life of an institution can be strangled by too many reports in quintuplicate, order forms, salary forms, efficiency slips and committee meetings. Unicellular organisms obtain all they need by simple diffusion. Large organisms waste too much in communication, supporting and integrating mechanisms.

2. What is the optimum size for a research project? The project is assumed to be in an institution of optimum size. Here again we have an equation with constants which we cannot evaluate. The project should be small enough so that each individual member carries some real responsibility to the limit of his capacity and feels that his own originality and enterprise are both needed and appreciated. On the other hand it must be large enough to provide adequate cross stimulation and must include enough different skills and knowledge so that too much time is not wasted by the individual members in trying to operate effectively in fields where they lack competence. The best group leader is the one who can happily integrate the most people and lead them to a common goal. One man can *administer* any number of people but there is a limit to the number he can lead.

3. Is enough emphasis placed on the tools for research? There are two sides to this question also. We all know individuals who are referred to somewhat scornfully as gadgeteers. They like to perfect their methods and make new labor-saving devices but they accomplish no real research and make no discoveries. On the other hand it is distressing to recall all the hours many of us spent in chemical analysis before the flame photometer was perfected and the hours spent in counting radioactive disintegrations before the modern automatic instruments were available. When should one advise a student to wait a few years until some commercial firm has perfected an instrument which will do the contemplated job in one day of work? Should research supporting agencies make grants to universities or other large institutions to enable them to set up the necessary research service center or should each project grant carry special items to cover each of these necessary costs? Physiologists do not complain too bitterly about their research facilities but perhaps they should be taught to complain more. The whole history of physiology could be written in terms of new tools for research and such a history might have a great effect on the policies of an institution like the National Science Foundation.

Information

It has been argued that science will one day drown in its own output, as so nearly happened to the sorcerer's apprentice. When enough facts have

been embalmed in enough papers, it will become simpler to rediscover one in the laboratory than in the library; and, as Shaw replied to an admirer who was grateful to him for expanding his mind, the sage did not take responsibility for expanding it until it exploded. Scientific journals came into existence nearly three centuries ago. In half that interval they numbered 300 and abstract journals began. Now with 300 abstract journals (and 100,000 scientific periodicals), another critical point is upon us, and techniques for abstracting the abstracts are the order(64).

It is not by accident that a major wave of modern thought concerns information—its theory, the implementation of its communication, and its relation to organization and structure. With shrinking distances, accelerating tempo, and increasing numbers of men, interactions between man in general are vastly greater; those in the burgeoning domain of science are indeed near the critical concentration for an explosion. But this is a problem that transcends biology; and the present concern can be only with those agencies of communication at hand for physiologists—meetings and publications.

All agree that gatherings of grouped societies, as the Federation or AIBS, even of the larger individual ones, are now overwhelming. Fifty parallel scientific sessions in half a dozen scattered buildings, in a city bursting with several thousand registrants, who seek and elude one another in corridor tag, presents an image of Penguin Island or of Seal Rock. So pressures generate for smaller groups, restricted presentations, and new types of program. The small specialist symposia are widely appreciated by the invited participants, often more widely resented by the uninvited ones. Indeed, just to the extent that such meetings expedite rapid and significant exchange at a research front, those who are excluded may be handicapped—even when a monograph appears a year later. Large symposia or panel discussions at society meetings are perhaps a helpful intermediary solution; progressive subdivision of groups is certainly one that is occurring. In any event, this Survey showed that physiologists definitely prefer their information by written rather than by verbal channels.

The price of division, of course, is narrowness; and this unfortunately afflicts all vehicles and men, journals as well as societies. There must be optima for size of subpopulations and ease of interaction between them—of degree of 'cellulation'—for the evolution of social groups as for biological species(33); but their analysis remains for future research in behavioral science. It is futile to cavil at new journals, at more specialization, at separation of publications for results and methods and theories, at tighter space and editorial policy, at the flow of reprints and the flood in libraries; as more men do more research with more resources all this seems inevitable. New techniques of storing and finding information will be the answer—for a while—and physiologists are alert to reviews and handbooks, to information

coordination centers, to coding and microcards, to machine selection and tele-transmission(77a). The Survey has no basis for judgment as to the wise role of physiological societies in this area.

Milieu

Scientists, on the whole well selected and trained and well supported and institutionalized, may still fail of top effectiveness on the larger scene. Size and diversity and distribution of institutions, as of smaller work groups, must affect productivity of a locale or region. Malapportionment of teachers and students, men and money, facilities and ideas must lessen productivity. Insofar as areas of the United States are concerned, the data in Table XII-5 are instructive. (See also Tables VII-13 and VII-14 and *Physiology in the South*, Bach's Survey report to the Southern Regional Education Board, 4a.)

Finally, the temper of the time and people affects scientific productivity. Whether a nation suspects, tolerates, or prizes its scientists will deeply affect recruitment and morale. When unrealistic security and classification rules are imposed, progress suffers. If basic, long-range research is subordinated to immediate development, the future is starved and will be puny. An over-comfortable civilization does not generate pioneering on the endless frontier. Some pungent comments by Ruesch(73) on the rise of mediocrity in this country, and its relation to research in psychiatry, are worth attention.

TABLE XII-5. REGIONAL DISTRIBUTION OF PERSONNEL—%.

	Northeast	North Central	South	West	Total
Population ^a	26	32	29	13	100
Science Ph.D.'s employed ^b	34	44	10	12	100
Amer. Men. Sci. employed	34	26	25	15	100
NSF grants (number) ^c	34	31	17	18	100
Physiologists employed	28	30	26	16	100
Physiologists, APS members	28	30	26	16	100
Physiologists, top degree obtained	32	46	13	9	100
Physiologists, Ph.D.'s obtained	29	43	9	19	100
Physiologists, Ph.D.'s awarded	28	45	10	17	100
Physiologists, all grants (number)	39	24	18	19	100
Physiologists, all grants (dollars)	41	30	14	15	100
Physiologists, papers published	36	35	14	15	100
					All
Physiologists, citations per member	5.2	6.8	3.9	6.6	5.7
Students GRE score ^d	428	422	416	429	423

Sources: ^a(67); ^b(80); ^c(72); all others this Survey. ^d First-year graduate students in science. Note: Academic distribution as for whole population; industry heavy in Mid-Atlantic and East North Central; government heavy in South Atlantic.

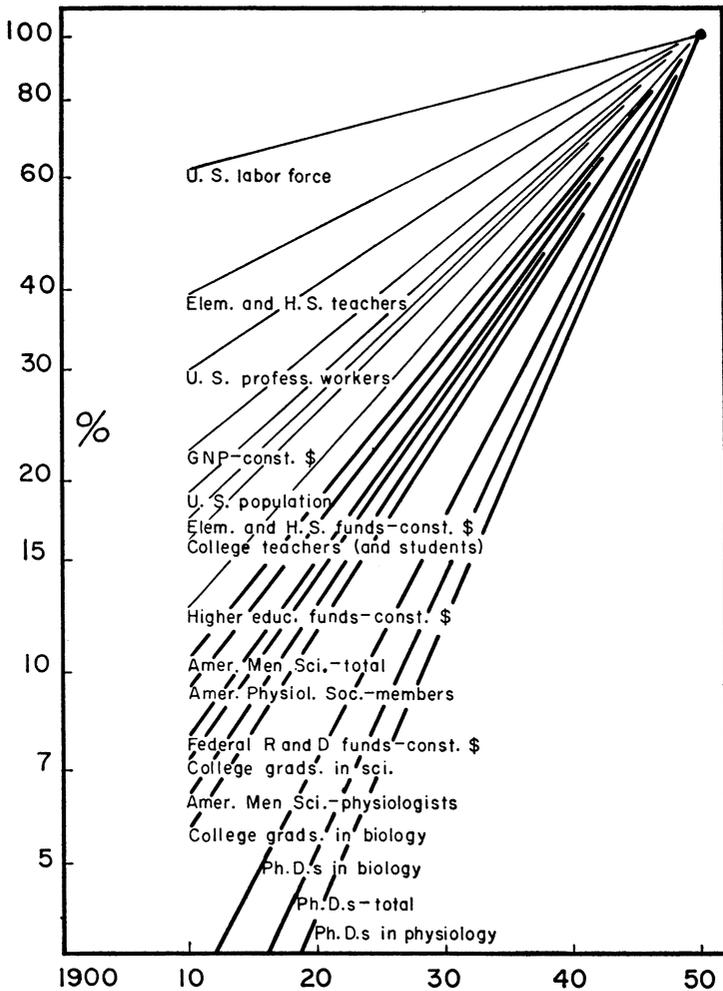


FIG. 9. Semi-diagrammatic graph of growth rates. Items associated with sciences (heavy lines) have increased more rapidly than others. (1950 values = 100%; but after straightening some curves distorted by the 1940-1950 war decade.)

THE FUTURE

Small excursions into the future have been made here and there in this volume, and more formal ones regarding men and funds appear in this chapter. Physiology has grown over the three decades to 1950 better than has the average science in terms of adherents, and definitely faster than all biology; Federation attendance has boomed thirty-fold (Table XII-3 and Figure 9). Within the discipline, shifts have been from animal physiology

and academia to bacterial physiology and industry; from neural, circulatory, digestive, and renal subspecialties to biochemistry, plant, and endocrine physiology; from metazoan organisms to their organs and cells and to unicellulars. Research support is more extramural and a larger fraction reaches medical schools and clinical departments. Physiologists are older and are moving from the Northeast to the South and, especially, the West; they spend more money and publish shorter papers.

Presumably such trends will continue for at least a modest period. But in part they are subject to control by physiologists and so are really unpredictable. If physiology must be defined by the men who call themselves physiologists, and the name in turn is related to the associations they establish—in departments, journals and, especially, professional societies—then physiology of the future is potentially in the hands of the physiology societies of today. As Galambos well put it in his Madison talk:

(Our profession) is adding each year in new Ph.D.'s alone between 5 and 10% of the total group employed. . . . We as a Society might well consider making regular and systematic study of these recruits. We should determine their number and also what kind of physiologists they are. Physiology 20 years from now will be largely what they want it to be and we can therefore have some of the future revealed to us by the relatively inexpensive method of studying them now.

Later he adds:

Somehow, American Physiological Society to me means the society of all physiology, both floral and faunal. If this is what it means to most of the present membership, I see some big changes coming in our selection criteria for members and in the make-up of our scientific programs.

Whether physiology, as a delimited sector of science reflected in human organizations, will swell or shrink is uncertain—and perhaps unimportant. It may evolve into new science forms, as the archesaurians into birds and mammals, but itself become a fossil on musty library shelves; it may become an eddy off the main stream of evolving biology and linger on like limulus, or gross anatomy; it may steadily change under its own name and impetus, as eohippus into modern horse; or it may permeate biological (and social) science and lose its identity—to gain the whole world and lose its own soul. Which course would most profit science and man?

On larger dimensions, however, intriguing thoughts are afoot. Price (64) sees science swelling along an exponential curve from about 1700, when the scientific revolution exploded man into the modern period, to the present. Publications in scientific journals, men in scientific societies, expenditure for scientific research have all risen exponentially, within an accuracy of $\pm 1\%$, increasing 5% to 6% a year and doubling in 10 to 15 years. Twenty doubles, in 2 to 3 centuries (say from 1700 to 1950), would mean a million-fold increase; and today, indeed, numbers of men, journals, and other indicia of scientific magnitude are all of the order of 10^5 to 10^6 . Other human activi-

ties, as poetry and politics, double only in 30 to 50 years; so science, doubling three times as often, is growing eight-fold faster.

Were this rate to continue another quarter millennium, there would be a thousand times as many scientists as the present world population; so it will not continue. As for other growth curves, this must flatten into a sigmoid or logistic form and approach an asymptote; and this change is just beginning. Only two doubling periods—25 years—from now, he estimates, is the inflection point when acceleration will turn into deceleration. The present shortages of the appurtenances of science, of facilities, teachers, investigators, mark the start of the critical pressures that will slow its growth; and even heroic measures could alter the course only over a few years.

The growing volume of science forces specialization and creates narrower and more rigid scientists, and these changes follow the same general time constant, doubling perhaps in fifteen years. But 'high level' advances follow the slower constant; so that scientific effort, in men, money, and the like, must grow as the cube to produce a linear increase in major scientific achievement—as the volume of a pyramid to its height. Such theory, Price emphasizes, offers a few decades of grace during which to adjust to the inevitable; to make policy decisions based on what is possible as well as wanted. But, he laments, "At present the writing can be seen on the wall, but it is no man's professional business to read it and take warning."

The story is persuasive and surely has much validity. West (119), however, looks even further in time and sees not a progressive but a cyclic process. He finds a recurring wave in science creativity, 164 years from crest to crest and, extrapolating from Greek and Arabic science (600 B.C. to A.D. 1300, with an eight-century gap from the nativity), places the next maximum at 1973 and a deep minimum at 2055. The first date is not too different from Price's inflection point; and West even finds the cycle for architecture to have twice the time constant for science, compared to the three-fold relation of Price (though he conceded that waves may have been missed by history). Finally, West gently mentions a possible relation to tree ring cycles and climate, cool favoring creativity. This story has much less conviction than the logistic one (see Kroeber's comment, ref. 119); but its very existence must temper our confidence in predicting, not in facing, the future. It is time to return to the microcosm of physiology.

RECOMMENDATIONS

The Survey ended with three million punches on sixty thousand cards and with a thousand tables in a veritable five-foot shelf of documents. Yet to pass from this mass of information to reasoned conclusions is not only difficult but often involves arbitrary decisions based on personal taste and perception. The more obvious findings simply confirm general expectations, and the

actions they point to have happily been initiated by now in many instances. The earlier survey(1) and committee(14) recommended to the American Physiological Society that: an Executive Secretary be appointed, a Committee on Education be set up, teaching sessions be initiated, the AIBS be supported, this Survey be made, and other actions be undertaken that have contributed to the present character of the Society. The Survey findings confirm their wisdom. Other recommendations, such as a widening of the membership base to include teachers and advanced students as well as established investigators, are under active consideration and gain support from present findings. Still other suggestions that arose from the Survey planning and early findings, mostly reported at the St. Louis, Atlantic City, or Madison meetings—such as regional meetings, grass roots' visits and interviews, grouping of AJP articles by field, workshops for teachers, a volume of laboratory experiments collected from teaching physiologists, a handbook of physiology—have also been developed and are in effect or being explored. Finally, as earlier mentioned, the existence of the Survey stimulated other studies and much interest; the mere requests to various industrial groups and individuals regarding the essays on applications generated active inquiry about physiology and considerable good will.

This report has presented the evidence and the considerations on which such recommendations rest; it remains only to itemize them and commend them to the thoughtful attention of appropriate men and groups: academic administrators, government agencies, professional societies, foundation officials, industrial executives, educators, publishers and producers, scientists, legislators, civic leaders. While they are of necessity the judgments of an individual rather than, as originally desired, the conclusions of a considerable group, they at least are a product of extensive communication, intensive thought, and expensive effort.

RESEARCH: Increase the supply of supporting personnel and services. Foster courses and schools for training technicians, from animal caretakers to animal surgeons. Channel students dropping premedical work into other service functions in biology. Expose students at high school levels and up to some experience in active investigation. Create regional centers to perform the more routine laboratory procedure for investigators.

Collect and release information on existing bibliographies in particular subject areas, both individual and institutional. Files of coded cards, with annotations and summaries, are especially important and might be reproduced for others on a fee basis. Aid in creating and coordinating separate codes would be invaluable. Collect and release information on suppliers of apparatus, supplies, living materials. Complete the *Handbook of Physiology* and keep it current by frequent revision.

EDUCATION: Continue strong support of the Committee on Education.

This Committee should cooperate with the Academy-Council Committee on Educational Policies, the AIBS Committee on Education, the President's Committee on Development of Scientists and Engineers (Bevis Committee), and other groups, such as the national associations of biology teachers and of science teachers. Thoughtful recommendations have been presented by many of these (e.g. 63, 38) and a recent report by Adolph for the APS Committee is presented as Appendix Q. Develop teaching materials: reading lists and sourcebooks of content material, with emphasis on principles, at high school and at college levels; collections of laboratory experiments for physiology students in more advanced courses; annotated lists of teaching films; a library of sound film lectures by outstanding physiologists, able to present effectively topics they master; a booklet describing graduate offerings in physiology; a journal of biological education.

Press for more integrated teaching of biology, with emphasis on principles and processes. The entire biology program of lower and intermediate education should be reexamined from this viewpoint, and standards raised appropriately to a hard-headed educational objective. Tougher college entrance requirements in biology, and science in general, would speed such changes; active participation in projects with living organisms would make them more meaningful to pupils.

Study college, graduate, and premedical programs in biology with a view to achieving more integrated and effective teaching in each, with more attention to general theory and to individual research. Particularly, college biology should be recast with far greater emphasis on general physiology. Medical schools should be prevailed upon to encourage rather than hinder this by their recommendations on programs leading to and in the premedical years; for preparation of pre-premedical students dominates much of biology in small colleges.

Improve the quality of high school and college science teachers: require more subject matter courses in teachers' training programs, especially some physiology for biology teachers; increase teachers' salaries, and put them on a twelve-month basis with a summer period devoted to enriching contact with active science and scientists—again with emphasis on the dynamic aspects in biology; further develop apprenticeships, workshops, travel grants, small research grants, and the like to supply such experiences; make these teachers feel part of physiology by meeting with them as individuals, by visiting lectures by professionals, and by offering some type of membership in professional societies.

Encourage more devotion to teaching by professional physiologists: continue the development of sessions on teaching, refresher courses, instructional materials, etc., at meetings of the professional societies; create post-Ph.D. 'internships' in college and university teaching; establish career teacherships

for superior teachers interested in contributing to the advance of physiological education; develop criteria of superior teaching performance and reward it with the rank and salary recognition given superior research performance.

PUBLIC RELATIONS AND RECRUITMENT: Establish a public relations function, office or official, preferably through the AIBS and Federation, which will cooperate with but not become part of activities of the AAAS as a whole. (Appendix S contains suggestions for a vigorous AAAS program.) Biology needs its own agency. The National Society for Medical Research now serves such a function, but only for animal physiology and to a limited extent.

Promote movies, syndicated news columns, magazine articles and, especially, television programs presenting science as an exciting intellectual experience. Physiologists have demonstrated skills in these media and industry has shown willingness to support science programs; a little active catalysis should yield large results.

Facilitate summer workshops, vacation institutes, and research apprenticeships for high school and college students; bring physiologists to the schools on lectureships, on film, or on airwaves. Movie shorts on career opportunities and filmed or taped lectures and, especially, round table discussions and arguments on significant problems and viewpoints in biology should be most effective.

Make graduate students welcome into professional societies in some appropriate form of membership. This contact for students and teachers would be greatly facilitated if regional or local meetings of the societies or area subdivisions became established.

FURTHER STUDIES: An office should be created, in the AIBS or at the NSF and with an advisory committee representing the appropriate professional groups, to maintain rosters and other data reasonably current, to make further studies on the Survey and supplementary materials, and to supply information to placement, public relations, publication, and other officials and to others seriously interested in the profession.

Some specific jobs are: 1) improve the definition of physiology, biology, life science, etc., so that the statistical bases used by NSF, NIH, NRC, ACE, Office of Education, Bureau of the Census, and other data-collecting agencies will be alike and translatable. 2) Interview supporting agencies and investigators to establish a more meaningful basis for defining pure and applied research. 3) Interview senior and junior authors of joint publications to identify the meanings of such authorships and the range of contribution of each participant. Since publications are the basis of many value judgments as to success, creativity, and the like, any improved insight in this area would be most helpful. 4) Extend the studies of elite and average physiologists, using more rigid criteria for inclusion in the select group; push all analyses bearing on the major matter of creativity—group size, breadth, organization, service,

leadership, freedom, etc. 5) Extend the analyses of physiological journal articles for time trends in the subject matter, institutions, procedures, and other important aspects of physiology. 6) Collect personal bibliographies and, if practicable, reprint sets of leading physiologists at death or retirement; and accumulate historical materials of institutions and departments. The aid of local men can be enlisted on this task; and a paper on the development of physiological science at the host institution would be an attractive addition to Fall Meetings. This was done effectively at the 1954 Fall meeting at Madison. Such materials would not only yield definitive genealogies but would greatly supplement the review of published literature in revealing the course of physiology over the decades. 7) Complete the Survey materials in scope by including: teachers of physiology who are now omitted, the research program of the Department of Agriculture, a fine analysis of plant and bacterial physiology in terms of subdisciplines, and appropriate control groups with which to compare the findings for physiology—noting why men did *not* choose to become physiologists as well as why they did. 8) Analyze subareas of physiology in terms of needs and support; explore the conditions in industry, especially in view of the satisfaction of those in it and the emphasis on research, reported by the questionnaire respondents, and of the contrasting image most physiologists have of the situation.

UTILIZATION: All worth of this Survey will be enhanced if the findings reach the proper human targets. Publication of portions or condensations or critiques of this volume (with reprints to all respondents to the questionnaire, were this possible) would increase its impact. If local groups of physiologists or biologists initiate formal discussions of this Report, repercussions will be extensive. New ideas will be generated, policies will be clarified, and administrators in academia, government, business, foundations, school systems, and elsewhere will be alerted to the considered opinions of a great profession.

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APPENDIX A

February 27, 1952

Dr. John Field
National Science Foundation
Washington, D.C.

Dear Dr. Field:

I take pleasure in submitting the enclosed proposal for a survey and inventory of physiological science to the National Science Foundation on behalf of the American Physiological Society. This is signed by myself as President and Dr. Lee as Executive Secretary of the Society and has been approved in principle by the Council of the Society and by an *ad hoc* committee of Past-Presidents of the Society.

For your records, the following brief review of the development of this proposal may be of value. You and I first discussed this informally (with Reynolds and Piori present) early in November 1951. Pursuant upon these discussions, I wrote you on November 14 and 15 outlining the project that the Society was interested in. You then invited me to meet with members of the staff of the National Science Foundation for most of the day of January 7 to explore the particular interest of the Foundation in a study of the sort envisaged. As a result of this meeting, and of further informal conversation between us, you sent me a letter on January 23 inquiring as to the Society interest in a number of points of particular concern to the Foundation. This led to the suggestion in my letter of January 29 that a meeting be called under Foundation auspices, and this was held on February 22. The Society was represented at this conference by Drs. Dill, Landis, Lee, Reynolds, Visscher and myself and the Foundation by you, Consolazio, Gaunt, Harwood and Wilson. The discussions that day and, by some of the group, the following morning helped to develop the more complete formulation that is now presented to you as a proposal. The Society representatives hope that the study contemplated would prove of real interest and value to the Foundation in terms of its own objectives; but we also recognize that this proposal is made entirely on the initiative of and in terms of the objectives of the Society and the judgment of its representatives.

Since I shall be out of the country for three months after April, it is most urgent (unless the Foundation prefers to delay the start of the study until Fall) that the main committee have at least one meeting of two full days before the end of April. Since it is always difficult to gather busy people, the initial invitation to members to serve and preliminary arrangements for dates of meeting should start at once. At the February 22 conference, the Foundation kindly undertook to finance and sponsor such a meeting without waiting for definitive action on the enclosed proposal. I should appreciate word from you to Dr. Lee approving the release of a letter to prospective committee members. A copy of such a presumptive letter is enclosed.

I am personally grateful to you and the Foundation staff for your great interest and constructive suggestions and hope that you will find it possible to finance both parts of the proposal as presented.

Sincerely,
R. W. GERARD, President
American Physiological Society

A PROPOSAL FOR A SURVEY AND INVENTORY OF PHYSIOLOGICAL SCIENCE

Submitted to the National Science Foundation for the American Physiological Society

By RALPH W. GERARD, President, and MILTON O. LEE, Executive Secretary

I. SIGNIFICANCE OF THE STUDY

The American Physiological Society, a professional society of American Physiologists, proposes to undertake a survey and inventory of physiological science, with special reference to the future welfare of the United States as served by science.

Physiology stands at the crossroads of biology, even of science as a whole. It utilizes the most detailed concepts and knowledge of mathematics, physics, chemistry and morphology; and its contributions, in turn, are central to clinical science and practice, animal husbandry and agriculture, psychology and psychiatry. The American Physiological Society alone does not fully cover this whole territory, but it proposes to form a committee to guide the study, on which will be individuals representing all aspects of physiology: general (including plant) physiology, human physiology, biophysics and biochemistry, clinical and other applied areas; academic, government, foundation and industrial interests; expertness in matters of publication and communication, administration, personnel and finance; and leadership in teaching and research. There is appended a list of persons who might constitute such a committee.

The American Physiological Society is interested in this study because it recognizes the importance to its subject, as well as to the nation, of a foresighted program of development. Science is perpetually changing, not only in content, but also in emphasis, organization, personnel and usefulness. These changes are but little understood, are uncontrolled, and are sometimes devastating. Granting that the forces operating may often be too massive to control and that any sort of imposed uniformity is unacceptable, it remains true that the forces may be modulated and that over-all objectives may be sought without violating individual freedom and initiative. There has been no serious stock-taking in physiology (if in any science) of present status and of past and presumptive future trends; nor any formulation of what may be the desirable directions of movement or of improved procedures for achieving them.

The American Physiological Society, in short, and like the Foundation, is deeply concerned with: (a) national and other policy for promoting research and education in physiology; (b) the impact of physiological science upon the national welfare, via medicine and related professions, agriculture and animal husbandry, industry, government, foundations and universities; (c) a survey of the existing and projected resources (finances, installations, materials, persons) and programs of research and teaching in physiology by educational institutions, industry and government; and (d) the present status, past development and projected trends of research content and practice and of teaching emphasis.

To obtain the necessary information and subject this to expert evaluation, we propose a two-phase "Physiology Assay." The first portion, planned for 9 months or less and requiring a budget of \$34,000, will formulate the full set of problems, collect and evaluate available data, and create basic instruments and procedures for further research. The second portion, planned for 18 months and

requiring a budget of about \$86,000, will carry out the actual research studies. In both portions, much contribution by committee members will be made, and from each portion should result definitive documents to be published. The details of these various phases are presented in the following sections.

II. SCOPE OF THE STUDY

Information is desired as to trends and status, past, present and projected, of physiology and related disciplines in the United States and elsewhere. Existing material will be collated and new studies made, and the findings will be interpreted critically and constructively. The following areas will all be surveyed and will be studied as intensively as resources permit.

A. *Historic background, present intellectual content and trends of physiology.* This will examine past teaching and research activities (perhaps by samplings of texts and journals), current scope and emphasis, and discernible trends (as the rise of scientific medicine and the shift of leadership from Europe to the United States). Attention will also be given to present and to desirable relations of "regular" physiology with other biological disciplines or subdisciplines (histology, cytochemistry, zoology, botany, comparative physiology, microbiology, general physiology, biochemistry, biophysics), and with applied science (medicine and other health professions, animal husbandry and agriculture, aviation, work and exercise physiology, "human engineering"). It may prove fruitful to note gaps and salients in the perimeter of research and so call attention of investigators to promising fields.

B. *Institutional aspects of physiology.* This will survey institutions or units concerned with teaching or research involving physiology and with the administrative organization and status of physiology. Attention will be given to departments of physiology, to physiological personnel and content placed in other departments, to the organizational place of physiology in educational (professional and liberal arts schools), industrial and governmental agencies, and to the proper relation of professional physiology to more inclusive national and international organizations in the scientific or governmental spheres (as the NRC, AIBS, AAAS, ICSU, UNESCO, WHO, FAO, U. S. government agencies—Defense, State, National Science Foundation, etc.).

C. *Personnel aspects of physiology.* This will inventory the present pool of students, teachers, investigators and administrators in physiology, with attention to their levels of competence, qualifications and conditions of employment, and will estimate presumptive future needs for such skills. Attention will be given to the factors which influence students into or from a career in physiology (popular glamour of various areas of science, scholarship and fellowship aids; expected economic and other professional support and personal rewards; exposure to competent teaching of the subject at all levels of education) and which move trained persons about in this discipline or which bring them from, or lose them to, other disciplines.

D. *Financial aspects of physiology.* This will inventory the sources, amounts and conditions of use of funds for teaching, research and administration in physiology, and will examine future needs. Attention will be given to the consequences of support by government, industry, academic institutions and public subscription; to the relation of funds to competent personnel and existing facilities; to the long-range correlation between support and output, both in understanding and in practical application (e.g. rise of longevity paralleling invest-

ment in biological science); to the conditions of support—long or short range, to groups or individuals; and to the distribution of funds among alternate subject areas and to any rationale for planned distribution.

E. *Educational aspects of physiology.* This will be concerned, in general, with educational activities in presenting physiology, or all of biology, to the public and to primary, secondary school and liberal arts college students, with the impact of such teaching and with ways of improving these activities; and, in particular, with the education and training of physiologists, biologists, physicians, veterinarians, dentists and other professional people requiring advanced training at universities, professional schools and on the job. Detailed attention will be given (by direct visit) to teaching standards, practices, facilities and outcomes, including: actual requirements for degrees (or positions); content and level of courses (or on-job training); physical facilities, such as space and equipment; teaching materials, such as textbooks and laboratory manuals, motion pictures, slides and charts; animal supply and care, and apparatus; teaching load, and principles and methods utilized to attain analyzed objectives; subsequent careers of the graduates of various schools with an effort to relate success in research or teaching to particular factors in the educational experience.

F. *Research aspects of physiology.* This will survey operating conditions under which research is carried out and may consider possible improvements. Attention will be given to: independent, cooperative and directed research, and the relation between senior and junior investigators, students and paid technical assistants; intended or accidental repetition or duplication of experimental work; material and morale conditions in laboratories at universities, institutes, industrial and governmental installations; the relation between teaching and research duties and the consequences of a shift to more emphasis on the latter; the visiting investigator and conditions affecting his research here and abroad; the significance of centers such as Woods Hole; the possible creation of centers for certain special technics such as electron microscopy, electronic calculators, or the use of labeled molecules; the problems of instrumentation, including standardization, aid in development and production, costs, and the relation between industrial and non-industrial suppliers and users.

G. *Publication and communication aspects of physiology.* This will inventory existing journals and other publications in physiology (including teaching), and will note publication ownership, policies, pressures, delays, circulations, costs, coverages, and problems in primary reports, monographs, reviews, bibliographies, abstracts, title lists and indexes. Attention will be given to the mounting problems of getting relevant information to users, of costs to individuals and institutions, of rapid communication between persons and rapid availability of documents at a distance from a center; and to possible solutions to these problems by new technologies and devices which supplement printing, such as in photoreproduction in facsimile and miniature, television, punch card and electronic sorting and selection, and documentation and information-coordinating centers.

III. Plan of Study

The projected study falls into two parts, a pilot phase and a definitive phase, which might partly overlap in time. The pilot phase, about 9 months in duration, will formulate the problems and methods, will find and collate presently available statistical data and other relevant studies, will make preliminary tests of procedures (through interviews and visits to departments by staff or commit-

tee members), and will draw such inferences and point such problems as seem indicated. The results of this phase may be published separately.

The definitive phase, about 18 months in duration, may begin as soon as clear practicable lines have been developed in the pilot phase. It will involve intensive attack on problems selected for their significance and feasibility. It is hoped that the results of the whole study, when published, will include not only factual information but also incisive evaluation and constructive suggestions.

The study will be organized with committees and executive staff and, if possible, will be located near the existing Society offices. A central committee, already identified, will give form to the study, separate the subject matter into fields appropriate to subcommittees or commissions, and select the members of these. Each commission will plan the studies in its field in appropriate detail. An executive director will devote full time to the execution of the study and will participate in all phases of the planning. He should be a scientist of stature and, once the outlines of the project have been established, should operate with maximal freedom. An alphabetic list of some possible executive directors is appended.

The central committee will have little occupation, after starting the commissions, until time for a final conference of physiologists and other interested experts (perhaps fifty altogether) to consider the results obtained by the study. Each commission will presumably spend some time in the initial planning of the study in its area and will later advise with the staff on the exact procedures to be undertaken. Commission members could well participate in the gathering of information. As results accumulate, the commissions may be asked to help interpret them; and all members will participate in the final conference. The executive director should participate in all phases of the survey, including planning and final publication.

If the desired person could be obtained as executive director for one year but not for two, he might serve part time during the pilot phase and later while material is readied for publication. Three of the men who might serve as executive director are on the central committee and a fourth, Dr. Orr E. Reynolds, may be available on a 6-months leave from the Office of Naval Research to carry out the fact-gathering portion of the pilot study and to assist in its other aspects.

INFORMATION ON THE AMERICAN PHYSIOLOGICAL SOCIETY

The American Physiological Society is the oldest and largest professional Society in North America in the broad field of physiology. It was founded in 1887 and incorporated in the State of Missouri in 1923. Its present membership of 1310 individuals includes professional physiologists located in universities, industrial organizations, government laboratories, institutes and foundations, engaged in teaching, administration and research covering the broadest aspects of basic and applied physiology.

The Society was instituted "to promote the advance of physiology" and has always regarded research in physiology as its primary objective. Its qualifications for membership are high, including the conduct and publication of meritorious original researches in physiology. Candidates for membership must be engaged in physiological work and are usually not elected until one to three years after their doctorate degree; consequently, the Society is of a highly professional character.

APPENDIX B

PERSONNEL

CENTRAL COMMITTEE

Ralph W. Gerard, *Chairman*,¹ University of Michigan
 Wallace O. Fenn, *Co-Chairman*,¹ University of Rochester
 Alan C. Burton, University of Western Ontario
 John Field, II, University of California (L.A.)
 David R. Goddard, University of Pennsylvania
 Robert S. Morison, Rockefeller Foundation for Medical Research
 Marion Parker,¹ U. S. Department of Agriculture
 H. Burr Steinbach,¹ University of Chicago
 Maurice L. Tainter, Sterling-Winthrop Research Institute
 Maurice B. Visscher, University of Minnesota
 Perry W. Wilson, University of Wisconsin
 Edward F. Adolph (1954), Eugene Landis (1953), and Hiram E. Essex (1955),
 Presidents, American Physiological Society (Ex Officio)
 Milton O. Lee, Executive Secretary, American Physiological Society (Ex Officio)

SUBCOMMITTEES

Research

Wallace O. Fenn, *Chairman*; David R. Goddard, *Co-Chairman*

Personnel

Robert S. Morison, *Chairman*; H. Burr Steinbach, *Co-Chairman*; Robert Galambos, Army Medical Service Graduate School; James Bonner, California Institute of Technology; Dael Wolfe, American Association for the Advancement of Science

Communications and Teaching

Maurice B. Visscher, *Chairman*; Alan C. Burton, *Co-Chairman*; Julius H. Comroe, Jr., University of Pennsylvania; Howard Meyerhoff, Scientific Manpower Commission; Raymond L. Zwemer, United Nations Educational, Scientific and Cultural Organization

Applications and Consequences

Maurice L. Tainter, *Chairman*; John Field, II, *Co-Chairman*; Leigh Chadwick, Army Chemical Center; George Irving, Jr., U. S. Department of Agriculture; Max Kleiber, University of California College of Agriculture; A. M. Lands, Sterling-Winthrop Research Institute; C. Ladd Prosser, University of Illinois; Robert E. Smith, University of California (L.A.) School of Medicine; Craig L. Taylor, University of California (L.A.) College of Engineering

History

John F. Fulton, *Chairman*, Yale University; I. Bernard Cohen, Columbia University; Hebbel E. Hoff, Baylor University; Morris Leikind, U. S. Armed

¹ Member of the Executive Committee.

Forces Medical Museum; Ilza Veith, University of Chicago; F. W. Wendt, California Institute of Technology

CENTRAL OFFICE PERSONNEL

Executive Directors

Orr E. Reynolds (May 1, 1952–Feb. 28, 1953),² Office of Naval Research;
L. M. N. Bach (March 1, 1953–June 30, 1954), Tulane University

*Consultants*³

Harry Borthwick, U. S. Department of Agriculture, Beltsville, Maryland (Plant Physiology); William G. Land, Research Consultant on Education, Washington, D. C. (Preliminary Organization, 1952, Survey Project 17, 1953; Draft of Final Report of the Survey, 1956)

Research Assistants

Betty Jane Lobdell, May 1952–June 1954; Sarah Sledge, 1954–55; Caroline Mayerson, 1954–55

Secretaries

B. P. N. Pederson, June 1952–March 1953; Joan Linfoot, March 1953–June 1954; Karen B. Morgan, 1954–55

General Assistants

Barbara Lancaster, October 1953–June 1954; Jerry Machalek, March 1953–January 1954; Jean McNeely, Summer, 1952, 1953, 1954; Margaret Bach, January–June 1954

² Part time from Nov. 1, 1952 to Feb. 28, 1954.

³ In addition to those whose services were utilized solely in connection with Survey Projects (see Appendix C).

APPENDIX C

SURVEY PROJECTS

1. College Catalog Study (III-D, 1–6)¹ (39)²
E. G. S. Baker, Drew University
Card coding by Central Office

Distribution of courses having physiological content by type of department. Based on sample of 124 institutions determined by Michigan Survey Research Center (1952–53). Report presented at the Teaching Session of the APS, April 1953.
- 2A. Survey of Popular Periodicals (III-D, 6–8) (40)
Alan C. Burton and R. H. Hayes, University of Western Ontario

Comparative study of the presentation of biological sciences in 1938 and 1951 issues of *Reader's Digest*, *Saturday Evening Post*, *Collier's*, *Scientific American*, and *Science*.

¹ Chapter, section and page reference to *Preliminary Report*.

² Reference number used in *Preliminary Report*.

Analysis of *Time* also made by Central Office.

- 2B. Science Writers Interviews (III-C, 5-7) (41)
L. M. N. Bach
Originally intended as a questionnaire to members of the National Association of Science Writers. Carried out as eight individual interviews.
- 2C. Public Opinion Poll on Health Education (III-A, 1-2) (42)
H. F. Kilander, New York University
Summary of trends of public knowledge of physiology in relation to school health education over a twenty-year period.
- 3A. Rorschach Study of Physiologists (III-A, 2-3) (43)
Anne Roe, Consulting Psychologist, New York, N.Y.
Analysis of data on physiologists from the study of eminent biologists reported in *Psychol. Monogr.* 64: No. 14 (Whole No. 331) (1951). Presented at the Survey of Physiological Science session at the Federation Meeting in Chicago, April 1953.
- 3B. Analysis of Progress Data on Physiologists Who Competed in Westinghouse Science Talent Search, 1942-1952 (III-D, 36-37)
Harold Edgerton—Richardson, Bellows, Henry, Inc., New York, N.Y.
Preliminary search of data indicated 150 possible physiologists of whom approximately 100 were likely to be working in the field. Analysis of data available abandoned because of budgetary considerations.
- 3C. Graduate Record Examination Scores Made by Physiologists (III-A, 3-4) (44)
Data provided by G. V. Lannholm, Educational Testing Service, Princeton, N.J.
Profiles based on scores of 102 persons, of whom 47 were found to have written theses judged physiological in content. Analysis and report prepared by the Central Office.
- 3D. Survey of Eminent Physiologists (III-B, 1-6) (45)
Central Office
Selection of eminent physiologists based on eight criteria resulting in 402 names satisfying two or more of the criteria, only one physiologist satisfying all eight. Non-identifiable data obtained from Project 18A, together with 400 in control group, in coded punch-card form. Analyses made and reported by Central Office.
- 3E. Study of Nobel Prize Recipients in Physiology and Medicine (III-A, 4-5) (46)
Betty Jane Lobdell, Central Office
Analysis of statistics in publications concerning the Nobel Prize winners.

- 4A. Genealogies of Foreign and American Physiologists (III-D, 8-10) (47)
Central Office: data also supplied by Carlos I. Reed, University of Illinois
- Analysis of Rothschuh's study of physiologists and the published *History of the American Physiological Society* and also of Dr. Reed's data made it possible to construct tentative institutional and personal genealogies for most departmental chairmen and presidents of the Society. This material is not sufficiently complete for publication.
- 4B. Essays on the Application of Physiology to Other Fields (III-D, 10-15) (48)
Central Office
- Essays of about 500 words each were solicited from specialists in 106 fields, with about 50% return. Mimeographed copies of the essays were circulated to the Central Committee and the Committee on Applications and Consequences.
- 5A. Teaching of Physiology and Biology in Iowa Schools (III-B, 9-13) (49)
Norma Hajek, State University of Iowa
- Questionnaire survey of elementary and secondary school teachers in public and private schools in Iowa regarding physiological content and emphasis in teaching, teaching methods, preparation of teachers, and evaluation of teaching effectiveness. Based on 86% returns of 13% secondary sample and 6% elementary sample. Duplicate coded punch cards provided for the Survey, in addition to report.
- 5B. Teaching of Physiology in Utah (III-D, 15-16) (50)
H. W. Davenport, University of Utah
- General survey of the teaching of physiology in colleges and schools, based on personal experience. Sample course outlines, examinations, and school statistics also forwarded to the Survey.
- 5C. Letter Regarding Physiological Knowledge of College Undergraduates Not Enrolled in Physiology Department Courses (III-D, 16-17) (51)
G. J. Millar, University of Saskatchewan
- Mimeographed and distributed to Committee members.
6. Physiological Content of Undergraduate Biology Courses (III-D, 17-19) (52)
Julian L. Solinger, Simmons College
- Based on visits to fifty colleges and interviews with 131 biology instructors. Analysis of examination material to determine the extent of physiological subject matter in general biology courses prerequisite to further work in that subject and general-education general biology courses indicated the proportion of physiology in each biology course and also the proportion of each physiological category treated in the course. Report presented at the Teaching Session of the APS, April 1953.

7. Study of Ph.D. Thesis Titles (III-A, 5-7) (53)
 Central Office: based on annual list of Doctoral Dissertations
 Review of titles of theses in Biological Sciences to identify those physiological in nature; application of Physiological Research Code; listing of personal and institutional data. Coded cards (approx. 1600) cover the years 1939-40, 1944-45, 1950-51, and 1951-52.
- 8A. Essays by International Physiologists (III-D, 19-24) (54). Presented at the XIX International Physiological Congress, Montreal, September 1953.
 M. B. Visscher, R. W. Gerard, Ilza Veith as *ad hoc* committee
 Published, under the title *Perspectives in Physiology*, by the American Physiological Society (\$3.00). Edited by Ilza Veith.
- 8B. Interviews With Physiologists (III-C, 2-5) (55)
 L. M. N. Bach
 Originally proposed as a major element of the Survey in addition to the Questionnaire, budgetary requirements prevented full exploitation of this source of data. On the basis of questions prepared in consultation with Michigan Survey Research Center, interviews were carried out with 42 faculty members or graduate students, chiefly in medical school departments in the South, Midwest, and East, although one commercial laboratory and three liberal arts college departments of physiology were included.
9. Supply House Questionnaire Study (III-B, 13A-16) (56)
 Central Office: Analyses by E. G. S. Baker, Drew University
 Following a survey of 36 of the 44 exhibitors at the Federation Meeting in Chicago (April 1953), questionnaires were sent to 188 firms engaged in supplying biologists and physiologists. Of the 104 replies received, 84 were usable for analysis.
10. Publishing House Questionnaire Study (III-B, 16) (57)
 Central Office: Analyses by E. G. S. Baker, Drew University
 Similar to Project 9. Of the Questionnaires sent to 81 publishers, 54 were returned and 50 were suitable for analysis.
11. Association of American Medical Colleges Questionnaire (III-B, 16-21) (58)
 Julius H. Comroe, Jr. (AAMC) and Central Office
 Questionnaires were prepared (with Michigan Survey Research Center assistance) for six different groups attending the First Teaching Institute of the AAMC devoted to the teaching of Physiology, Biochemistry and Pharmacology in the medical schools of the United States and Canada (Oct. 19-23, 1953). Data published by the AAMC as part of the report of the Institute (July 1954).
- 12A. Survey of Physiological Literature (III-D, 24-28; III-A, 7-8) (59, 60)
 Central Office, Ralph W. Gerard (see Appendix H): Analyses by Herbert Kelley, Tulane University

Project undertaken by Robert Grenell, Johns Hopkins University, for measuring the time trends in physiology based on an analysis of the *American Journal of Physiology*, the *Journal of Cellular and Comparative Physiology* and the *Journal of Neurophysiology* at five-year intervals, 1909–49. Approximately 1600 papers were analyzed and coded on punch-cards, from which analyses of data were made. In addition, data were obtained from Estelle Brodman of the Armed Forces Medical Library comparing citation frequencies in the *American Journal of Physiology*, the *Journal of Physiology* (Brit.) and *Pflüger's Archiven* for 1938–39, and similar listings were made for 1948–49.

12B. Abstracts Study (III-D, 28–29; III-A, 8) (61, 62)

Robert Grenell, University of Maryland, School of Medicine; supplement of data from Mary Nunez TenEick, Florida State University

An intensive study of the papers mentioned in Roman Kenk's *Bibliography of Cerebral Circulation* (1952) in relation to their geographical origin and their appearance in the *Annual Review of Physiology*, *British Abstracts in Physiology*, and *Excerpta Medica*. Reported in detail as part of the Report on the Pilot Phase of the Survey (Jan. 1, 1953). In addition, supplementary data were obtained from a thesis by Mrs. TenEick comparing the extent to which twelve selected physiological fields were abstracted in 1948 by *Biological Abstracts* and by *Physiological Abstracts*. These data were organized by the Central Office as a report of Project 12B-II (1954).

12C. *Annual Reviews* Citations Study (III-D, 29) (63)

Betty Jane Lobdell, Central Office

Citations of papers by APS, ASPP, and SGP members in the *Annual Reviews* of Physiology, Plant Physiology, Medicine, Psychology, Physical Chemistry, Biochemistry, Microbiology, and Nuclear Science for 1950, 1951 and 1952. Data reported as part of the Report of the Pilot Phase of the Survey (Jan. 1, 1953) and also separately.

12D. Editorial Policies and Publication Data (III-D, 30) (64)

Central Office: with the cooperation of Milton O. Lee and Sara Leslie (FASEB)

Data on 9 periodical publications in physiology collected. Report prepared by Central Office (1954).

13A. American Men of Science Study (III-A, 8–11) (65)

Central Office

Data for 1906–44 processed and coded in punch-card form, tabulated and data reported. Data from 1949 edition previously coded by ONR as part of a National Scientific Register project were extracted, with the permission of the National Science Foundation which had assumed title to the material, and relevant information included in the project report.

13B–13I incl. (Discontinued projects)

- 13J. Placement Service Record Analysis (III-D, 30-32) (66)
Central Office: with the cooperation of Letha K. Andervont, Director, FASEB Placement Service
Analysis of active and inactive records for the period 1949-54. Data recorded in punch-card form, from which report was prepared (1954).
- 13K-13L. (Discontinued projects)
- 13M. Study of International Fellowships in Physiology (III-D, 32-33) (67)
Central Office: with the cooperation of Joan Christie, Director, Central Card Index, Institute of International Education, New York, N.Y.
Data located on 352 different fellowships involving physiologists from the United States studying abroad or foreign physiologists studying in America. Information coded in punch-card form, and report issued in June 1954.
- 14A. Biological Sciences Information Exchange Projects in Physiology (III-A, 11-12) (68)
Central Office (Betty Jane Lobdell): with the cooperation of Stella Leiche Deignan, Director of BSIE
Approximately 4000 cards of physiological research projects, primarily medically oriented, were coded with BSIE data and also analyzed according to the Physiological Research Code (Appendix D), in punch-card form.
- 14B. Office of Naval Research Expenditures on Physiological Research (III-A, 13) (69)
Central Office: with the cooperation of Orr E. Reynolds.
Data based on three-years' expenditures, equated to one year and not identifiable as to source, were furnished by the Office of Naval Research, and coded according to the Physiological Research Code by the Central Office using punch-cards. Analysis of information reported.
- 15A. Report on Elementary and Secondary School Textbooks in Biology (III-D, 33-34) (70)
Ruth Rue, American Institute of Biological Sciences
Of a total of 444 book titles, 48 were judged to be in wide use as being on state-adoption lists. An analysis of physiological content and presentation was made for this group.
- 15B. Proposed Analysis of College Physiology and Biology Textbooks (discontinued project)
This project was to be carried out in cooperation with a New York publisher of scientific textbooks with the objective of providing analyses and indicating needed improvements in textbooks.
- 15C. Survey of Laboratory Manuals (III-D, 35-36) (71) (incomplete project)
Central Office: with the cooperation of Julius F. Comroe, Association of American Medical Colleges

Medical school laboratory manuals received by the First Teaching Institute of the AAMC were abstracted by recording the abstractor's (L. M. N. Bach) remarks. No further progress.

16. Chronology of American Physiological Society (III-A, 13-14) (72)
Betty Jane Lobdell, Central Office
Data obtained from the published *History of the American Physiological Society, 1887-1937* and from subsequent records of the Society.
17. Survey of the Teaching of Biology and Physiology at the Pre-College Level (III-A, 14) (73)
William G. Land, Consultant on Education
A study initiated in accordance with Section B of the report of the Subcommittee on Education and Communication, dated Aug. 13, 1952. Based on published materials and unpublished dissertations: covered enrollments in courses in science; changing objectives in the teaching of biology and physiology; trends in presentation; status, competence and preparation of science teachers; pre-college motivation toward vocations in biological and related sciences. The original report of 91 pages was condensed by L. M. N. Bach for committee distribution using the original title, *The Nurture of Physiologists to Come*.
- 18A. Attitude and Opinion Questionnaire (III-B, Sec. 1, 1-36) (74)
- 18B. Survey Research Center, University of Michigan: Charles F. Cannell, Robert Kahn, Seymour Lieberman, Consultants
The major effort of the Survey, resulting in the publication of two mimeographed volumes of percentage tables. Vol. I: Basic Tables; Vol. II: Summary Tables and Selected Relationships.
- 18C. International Physiologists Study (III-B, 6-9) (75)
Central Office: Maurice B. Visscher
A shortened version of the Attitude and Opinion Questionnaire was distributed to incoming registrants at the XIX International Physiological Congress, Montreal, Sept. 1953, and some 300 were later distributed through the secretaries of foreign physiological societies; 73 questionnaires representing 26 countries were returned at the Congress: 67 more were received prior to May 1954, when results were analyzed.
- 18D-18F. (Discontinued or incomplete projects)
- 18G. Questionnaire Study of Physiologists Teaching in Osteopathic Schools (III-B, 9) (76)
Central Office: with the cooperation of Irwin M. Korr, Kirksville College of Osteopathy and Surgery
Supplementary to Project 18A, 19 additional replies, of 24 names of physiologists teaching in osteopathic schools, were sent the major Attitude of Opinion Questionnaire. Responses were hand sorted by the Central Office.

- 18H. Departmental Chairmen Questionnaire (III-B, 21-24) (77)
Central Office

Sent to Physiology department chairmen in all institutions, also to Biology or Physiology department chairmen in a sample of institutions based on Project 1: total 331 departments in 124 academic institutions. Projections of the data to represent the total number of institutions of higher education were made in the report of the project. Different results were, however, used in the *Preliminary Report*.

- 19A-19C. (Discontinued or incomplete projects)

- 19D. Survey of Physiology Teaching Programs in Schools of Physical Therapy (III-B, 25) (78)

Helen Hislop and Norma Hajek, State University of Iowa

A questionnaire study covering 82% of the physical therapy schools in the United States. Reported at the April 1953 teaching session of the APS.

APPENDIX D

PHYSIOLOGY RESEARCH CODE

The following Survey Projects were coded: 7, 12A, 14A, 14B, 18A (see Appendix C).

I. *Experimental Variables*

1. Radiant energy (including locally applied heat)
2. Mechanical energy (including vibration; sound; pressure; acceleration)
3. Electrical energy (galvanic; faradic, including diathermy)
4. Physical-chemical (piezoelectric; electro-chemical; osmotic, etc.)
5. Pharmacological; toxicological; exogenous physiological
6. Biological (serological; immunological; macromolecular; cell fragments; viruses; surviving cells; organisms)
7. Physiological, endogenous origin (mechanical work load; metabolic imbalance; hypo- and hyperthermia; surgical ablations; alterations); pathology
8. Nutritional (including inorganic)
9. Psychological (including linguistic and sociological)
- X. Natural conditions (time)

II. *Type of Organism*

1. Viruses and rickettsiae
2. Unicellular (bacteria; yeast; protozoa; algae)
3. Molds and fungi
4. Plants, autotrophic nonvascular (larger algae; bryophytes)
5. Plants, vascular
6. Metazoa, invertebrate
7. Vertebrate, poikilothermous
8. Vertebrate, homeothermous
9. Vertebrate, human

10. Model or analog (*in vitro* studies of unspecified tissues)
 - X. Pathology (existing)
- III. *Structural Level*
1. Molecular
 2. Cellular particulates
 3. Cell
 4. Tissue (including blood and tissue fluids)
 5. Organ
 6. Organ system
 7. Organisms
 8. Groups of organisms
- IV. *Functional Responses in*
1. General properties of protoplasm
 2. Growth; differentiation; reproduction
 3. Metabolism; internal respiration; nutrition
 4. Reception; coordination; transmission; sensation (nervous system activities)
 5. Effector activity (e.g. motor, tropistic responses); support; protection
 6. General adaptation; immunity
 7. Circulation; external respiration; transpiration; translocation
 8. Ingestion; digestion
 9. Excretion; osmotic balance
 10. Environmental energy exchange (including photosynthesis)
 - X. Pathology (intentional)
- V. *Socio-Economic Orientation*
1. General scientific; educational; academic (pure) science
 2. Theoretical biology (including biometry)
 3. Psychobiology; sociology; anthropology
 4. Medicine; dentistry; public health and industrial hygiene
 5. Technology (environmental physiology; human engineering; military physiology)
 6. Agricultural sciences (veterinary medicine; animal husbandry; soil sciences; horticulture)
 7. Dual (2, 3)
 8. Dual (2, 4)
 9. Dual (2, 5)
 10. Dual (3, 4)
 - X. Dual (4, 5)
- O—Not known
 Y—Distribution through series (3 or more included in a major category)

APPENDIX E

REGIONAL CLASSIFICATION OF STATES (CENSUS BUREAU
CLASSIFICATION)

NORTHEAST

New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

Middle Atlantic: New Jersey, New York, Pennsylvania

CENTRAL

East North Central: Illinois, Indiana, Michigan, Ohio, Wisconsin

West North Central: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota

SOUTH

South Atlantic: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia

East South Central: Alabama, Kentucky, Mississippi, Tennessee

West South Central: Arkansas, Louisiana, Oklahoma, Texas

WEST

Mountain: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming

Pacific: California, Oregon, Washington

APPENDIX F
SURVEY OF
PHYSIOLOGICAL SCIENCES

Attitude and Opinion Questionnaire

October, 1953

This questionnaire deals with the type of work people engaged in the physiological sciences are doing and the conditions under which they are doing their work.

The questions have been designed so they can be answered simply, in most instances by a single check mark. Please check the answer which is most applicable to you. If you wish to make additional comments or notations, feel free to do so.

The value of the survey depends on the care with which you answer the questions. So please read each question carefully before you answer it. Whether the results of the survey give a true picture of the attitudes and opinions of those engaged in the physiological sciences depends on whether you answer the way you really feel.

The code number contained at the top of this page will be used by the Survey Research Center at the University of Michigan only to keep track of the questionnaires as they are returned.

The findings of the survey will be made available in published form to all those interested in the results.

Mail to:

SURVEY RESEARCH CENTER
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

ABOUT YOUR PROFESSION

1. If you were asked to identify yourself with a **general** field, which field would you select?

(Put a "1" in front of the general field with which you would primarily identify yourself. If you would also identify yourself with any of the other fields, rank as many of these as apply to you—"2", "3", "4", etc. If your general field is not specified in the list, write it in the space marked "other.")

- Agriculture (41)
- Anatomy (51)
- Animal or human physiology (11)
- Bacteriological physiology (21)
- Biochemistry (61)
- Biophysics (52)
- Botany (42)
- Clinical medicine (71)
- Home economics (53)
- Microbiology (81)
- Pharmacology (62)
- Plant physiology (31)
- Psychology (54)
- Zoology (55)
- Other (Specify): -----

2. Which of the following factors contributed to your entering this general field? (CHECK AS MANY AS APPLY)

- Secondary school teacher
- College teacher
- Graduate school teacher
- Parents or other family members
- Fellow-student or friend
- Interest in the content of the field
- Prestige of the field
- Monetary advantages in the field
- Supervisor
- Availability of a position
- Other (Explain below)

3. About how long ago did you get your first professional job in this general field? (CHECK ONE)

- 1 Less than 1 year ago
- 2 1 to 2 years ago
- 3 3 to 5 years ago
- 4 6 to 10 years ago
- 5 11 to 15 years ago
- 6 16 to 20 years ago
- 7 Over 20 years ago

4. Were you employed in any other professional fields before you entered your present general field? (CHECK ONE)

- 1 Yes
- 2 No

If yes, specify fields:

5. Were there any other professional fields that you seriously considered going into, but did not go into, before entering your present general field? (CHECK ONE)

- 1 Yes
- 2 No

If yes, specify fields:

6. What is your **field of specialization** within your general field? (For example, if your general field is in physiology, is your special field respiratory physiology, neurophysiology, photosynthesis, growth, metabolism, etc.?) (WRITE IN BELOW)

ABOUT PROFESSIONAL SOCIETIES

7. How many professional societies do you belong to (not including honorary societies such as Phi Beta Kappa or Sigma Xi)? (CHECK ONE)

- 1 None
- 2 One
- 3 Two
- 4 Three to five
- 5 More than five

8. Are there any professional societies you do not belong to now but would like to belong to? (CHECK ONE)

- 1 Yes
- 2 No

If yes, specify societies:

(THE REMAINING QUESTIONS IN THIS SECTION ARE TO BE ANSWERED BY THOSE WHO BELONG TO ONE OR MORE PROFESSIONAL SOCIETIES. IF YOU DO NOT BELONG TO ANY PROFESSIONAL SOCIETIES, PLEASE GO ON TO QUESTION 17.)

9. Which professional society do you consider your primary professional association? (If you feel closely related to more than one, please choose the one you identify with most.) (WRITE IN BELOW)

10. About how many years have you been a member of this society? (CHECK ONE)

1 Less than 1 year

2 1 to 2 years

3 3 to 5 years

4 6 to 10 years

5 11 to 15 years

6 16 to 20 years

7 Over 20 years

11. Have you held any offices or committee positions in this society? (CHECK ONE)

1 Yes, now

2 In the past, but not now

3 No, never

12. How do you feel about the scientific sessions of this society? (CHECK ONE)

1 Satisfactory as they are now

2 Some improvement needed

3 Much improvement needed

13. What comments or suggestions do you have about the scientific sessions? (WRITE IN BELOW)

14. Is presenting a paper a prerequisite to getting your expenses at society meetings paid? (CHECK ONE)

1 Yes

2 No

15. How do you feel about the membership requirements of this society? (CHECK ONE)

1 Satisfactory as they are now

2 Qualifications for membership not high enough—should raise membership requirements

3 Qualifications for membership too stringent—should make membership requirements more lenient

16. All in all, how do you feel about the way this society is run? (CHECK ONE)

1 Very satisfied

2 Fairly satisfied

3 Neither satisfied nor dissatisfied

4 Fairly dissatisfied

5 Very dissatisfied

ABOUT COMMUNICATIONS

17. How much do you depend on each of the following sources to keep up with advances in your field of specialization (i.e., the field you indicated in Question 6)?

(Check one box in EACH LINE)

	To a considerable extent	To some extent	To little or no extent
Journals -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Abstracts -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Annual reviews -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Monographs -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Society meetings -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Seminars, conferences, etc. --	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3

18. How adequate do you find each of these sources for keeping up with advances in your field of specialization?

(Check one box in EACH LINE)

	Satisfactory as it is now	Some improvement needed	Much improvement needed
Journals -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Abstracts -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Annual reviews -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Monographs -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Society meetings -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Seminars, conferences, etc. --	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3

19. How well do you feel you are able to keep up with advances in your field of specialization? (CHECK ONE)

- 1 Very well
- 2 Fairly well
- 3 Not too well
- 4 Not well at all

20. What are some of the problems you have in keeping up with advances in your field of specialization? (WRITE IN BELOW)

ABOUT YOUR JOB

21. Are you employed full-time, employed part-time, unemployed, or retired? (CHECK ONE)

- 1 Employed full-time
- 2 Employed part-time
- 3 Unemployed
- 4 Retired

(THE REMAINING QUESTIONS IN THIS SECTION ARE TO BE ANSWERED BY THOSE WHO ARE EMPLOYED AT THE PRESENT TIME. IF YOU ARE NOT EMPLOYED AT THE PRESENT TIME, PLEASE GO ON TO QUESTION 37.)

22. Are you employed in: (CHECK ONE)

- 1 An academic institution
 - 2 An industrial institution
 - 3 A government institution
 - Other (Specify):
-

IF EMPLOYED IN AN ACADEMIC INSTITUTION, ANSWER QUESTIONS 22a, 22b, AND 22c.

22a. Do you have tenure in your job? (CHECK ONE)

- 1 Yes
- 2 No

22b. Do you hold a faculty rank? (CHECK ONE)

- 1 Yes (Specify):

- 2 No

22c. What are the sources of your income? (CHECK AS MANY AS APPLY)

- Institutional budget
- Research grant or contract
- Fellowship
- Private practice or consulting
- Non-professional income

23. In what state is your institution located? (WRITE IN BELOW)

24. About how many years have you been employed in your present institution? (CHECK ONE)

- 1 Less than 1 year
- 2 1 to 2 years
- 3 3 to 5 years
- 4 6 to 10 years
- 5 11 to 15 years
- 6 16 to 20 years
- 7 Over 20 years

25. Prior to your current place of employment, have you ever worked in:

	(Check one box in EACH LINE)	
	Yes	No
An academic institution?..	<input type="checkbox"/> 1	<input type="checkbox"/> 2
An industrial institution?..	<input type="checkbox"/> 1	<input type="checkbox"/> 2
A government institution?	<input type="checkbox"/> 1	<input type="checkbox"/> 2

IF YOU USE ANIMALS IN RESEARCH OR TEACHING, ANSWER QUESTION 32a.

32a. Indicate below the kinds of animals that are most important to you in your research or teaching, and answer the following questions about each of them.							
Kind of animal	Are costs a problem?		Is quality a problem?		What are the sources? (CHECK AS MANY AS APPLY)		
	Yes	No	Yes	No	Pound	Dealer	Breed own
-----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
-----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
-----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3

33. How important are each of the following things to you in a job; which things do you want most in a job?

(Check one box in EACH LINE)

	Of utmost importance	Very important	Fairly important	Not too important
Having a job that has prestige in my profession -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
Good salary—earning enough to make a good living -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
Security—being able to keep my job as long as I want it -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
Freedom and authority to carry out my own ideas -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
Good chances for advancement in my profession -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
Good chance to use my skills and abilities -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
Having support and recognition from my superiors -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
Being with people who are congenial to work with -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
Opportunity to contribute to scientific advancement -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4

34. What are the things you like best about your present job? (WRITE IN BELOW)

36. All in all, how do you feel about your present job? (CHECK ONE)

- 1 Very satisfied
- 2 Fairly satisfied
- 3 Neither satisfied nor dissatisfied
- 4 Fairly dissatisfied
- 5 Very dissatisfied

ABOUT RESEARCH DUTIES

(THE QUESTIONS IN THIS SECTION ARE TO BE ANSWERED BY THOSE WHO ARE ACTIVELY ENGAGED IN RESEARCH AT THE PRESENT TIME. IF YOU ARE NOT ACTIVELY ENGAGED IN RESEARCH, PLEASE GO ON TO QUESTION 50.)

35. What are the things you don't like about your present job? (WRITE IN BELOW)

37. List the area of the research problem or problems you are working on at the present time.

37a. -----

37b. -----

38. Do you carry out your research as a member of a research institute or other research organization (exclusive of university departments)? (CHECK ONE)

- 1 Yes
- 2 No

IF YES, ANSWER QUESTIONS 38a, 38b, AND 38c.

38a. What is the name of your research organization?

38b. About how many professional people are employed in your research organization? (CHECK ONE)

- 1 5 or less
- 2 6 to 10
- 3 11 to 20
- 4 21 to 30
- 5 31 to 40
- 6 41 to 50
- 7 Over 50

38c. About how many levels of professional people are there in your research organization? (CHECK ONE)

- 1 1 level
- 2 2 levels
- 3 3 levels
- 4 4 levels
- 5 5 levels
- 6 6 or more levels

39. What is the source of your research funds? (CHECK ONE)

- 1 Allocation from funds within my institution
- 2 Contracts or grants from outside institutions
- 3 Both

If contracts or grants from outside institutions, are the sources: (CHECK AS MANY AS APPLY)

- Government non-military
- Government military
- Foundation
- Industrial or commercial
- Other (Explain below
-----)

40. Approximately what was the total amount of research funds that were available for research in which you were personally engaged during the past year? (CHECK ONE)

- 1 Less than \$1,000
- 2 \$1,000 to \$4,999
- 3 \$5,000 to \$9,999
- 4 \$10,000 to \$19,999
- 5 \$20,000 to \$29,999
- 6 \$30,000 to \$39,999
- 7 \$40,000 to \$49,999
- 8 \$50,000 or more

41. How adequate were the funds available for your research during the past year? (CHECK ONE)

- 1 Very adequate
- 2 Adequate
- 3 Inadequate
- 4 Very inadequate

42. How much responsibility do you have for obtaining your research funds? (CHECK ONE)

- 1 Complete responsibility
- 2 Major responsibility
- 3 A little responsibility
- 4 No responsibility

43. If you have any responsibility for obtaining research funds, how difficult do you usually find it to obtain research funds? (CHECK ONE)

- 1 I have no responsibility for obtaining funds
- 2 Very difficult
- 3 Fairly difficult
- 4 Not too difficult
- 5 Not difficult at all

44. How adequate do you find each of the following research facilities?

(Check one box in EACH LINE)

	Satis- factory as it is now	Some im- prove- ment needed	Much improve- ment needed
Laboratory equipment -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Living material (plants or animals) -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Supplies other than living material -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Storage facilities -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Laboratory space -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Repair and replacement facilities -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Technical facilities (histo- logical, photographic, etc.)	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Research assistants -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3

45. Is there a person who supervises your research?
(CHECK ONE)

- 1 Yes
- 2 No

IF YES, ANSWER QUESTIONS 45a AND 45b.

45a. Listed below are a number of things a superior or supervisor might do. How much does your superior actually do each of these things?

(Check one box in EACH LINE)

- | | To a con-
siderable
extent | To
some
extent | To little
or no
extent |
|---|----------------------------------|----------------------------|------------------------------|
| Provide leadership and guidance for my research | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 |
| Allow me freedom to do my job the way I think it should be done | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 |
| Obtain funds and facilities necessary for my research | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 |
| Recognize my skills and abilities | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 |

45b. How important is it to you for your superior to do each of these things?

(Check one box in EACH LINE)

- | | Very im-
portant | Fairly im-
portant | Not too im-
portant |
|---|----------------------------|----------------------------|----------------------------|
| Provide leadership and guidance for my research | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 |
| Allow me freedom to do my job the way I think it should be done | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 |
| Obtain funds and facilities necessary for my research | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 |
| Recognize my skills and abilities | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 |

46. How much freedom did you have in choosing the research problem you are working on at the present time? (CHECK ONE)

- 1 Complete freedom
- 2 A great deal of freedom
- 3 Some freedom
- 4 Not much freedom
- 5 No freedom at all

47. Approximately how many research papers have you had published (as author or co-author) during the past three years?

Number of research papers: _____

48. How much chance does your current job give you to do as good a research job as you feel you can do? (CHECK ONE)

- 1 Very good chance
- 2 Good chance
- 3 Fair chance
- 4 Not too good chance
- 5 Very poor chance

49. What are some of the factors that you feel are keeping you from doing a maximally effective research job? (WRITE IN BELOW)

ABOUT TEACHING DUTIES

(THE QUESTIONS IN THIS SECTION ARE TO BE ANSWERED BY THOSE WHO ARE TEACHING DURING THIS ACADEMIC YEAR. IF YOU ARE NOT TEACHING THIS ACADEMIC YEAR, PLEASE GO ON TO QUESTION 58.)

50. In what department or departments do you have your teaching appointment?

51. List the formal and informal course work in which you have some teaching responsibilities this academic year.

List each course by:

- a. Department
- b. Level: *undergraduate, graduate, or professional* (professional includes all medical)
- c. Subject matter of the course or part of course for which you are responsible

Department	Level	Subject matter
-----	-----	-----
-----	-----	-----
-----	-----	-----
-----	-----	-----
-----	-----	-----
-----	-----	-----
-----	-----	-----
-----	-----	-----
-----	-----	-----
-----	-----	-----

52. How adequate do you find each of the following teaching facilities?

(Check one box in EACH LINE)

	Satis- factory as it is now	Some im- prove- ment needed	Much improve- ment needed
Lecture facilities -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Demonstration facilities ----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Audio-visual aids -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Textbooks -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Laboratory manuals -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Laboratory equipment -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Living material (plants or animals) -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Supplies other than living material -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Storage facilities -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Laboratory space -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Repair and replacement facilities -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Teaching assistants -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3

53. Course material might be taught in a number of ways. As things stand now, in the courses you teach, how much are each of the following methods used?

(Check one box in EACH LINE)

	To a con- siderable extent	To some extent	To little or no extent
Lectures -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Laboratories -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Audio-visual aids -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Demonstrations -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Discussions or seminars ----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3

54. How much do you feel each of these methods of teaching should be used?

(Check one box in EACH LINE)

	About same as used now	More than used now	Less than used now
Lectures -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Laboratories -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Audio-visual aids -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Demonstrations -----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
Discussions or seminars ----	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3

55. How much chance does your current job give you to do as good a teaching job as you feel you can do? (CHECK ONE)

- 1 Very good chance
- 2 Good chance
- 3 Fair chance
- 4 Not too good chance
- 5 Very poor chance

56. What are some of the factors that you feel are keeping you from doing a maximally effective teaching job? (WRITE IN BELOW)

57. Do you teach any students who are working for a Ph. D. in the physiological sciences? (CHECK ONE)

- 1 Yes
- 2 No

IF YES, ANSWER QUESTIONS 57a, 57b, 57c, AND 57d.

57a. How good physiological scientists do you feel most of these students will make? (CHECK ONE)

- 1 Very good
- 2 Good
- 3 Fair
- 4 Not too good
- 5 Poor

57b. What is there about their **past or present training** that might keep them from becoming good physiological scientists? (WRITE IN BELOW)

57c. What is there about the **students themselves** that might keep them from becoming good physiological scientists? (WRITE IN BELOW)

57d. Do you feel that a course in general physiology should be taught as a prerequisite for graduate students in the physiological sciences? (CHECK ONE)

- 1 No
- 2 Yes, should be taught at the undergraduate level
- 3 Yes, should be taught at the graduate level

EDUCATIONAL BACKGROUND

58. Approximately what was your **over-all** grade average in your **undergraduate** work? (CHECK ONE)

- 1 A
- 2 A--
- 3 B+
- 4 B
- 5 B--
- 6 C+
- 7 C
- 8 Lower

59. If you have a Ph.D. or Sc.D., who was your thesis supervisor?

His name: -----

His department (at that time): -----

His major activity (at that time): (CHECK ONE)

- 1 Teaching
- 2 Research
- 3 Administration

60. In which subjects would **further** training have been **particularly** helpful to you in your profession? (CHECK AS MANY AS APPLY)

<u>Subject</u>	<u>Specify kind</u>
<input type="checkbox"/> Physics	-----
<input type="checkbox"/> Chemistry	-----
<input type="checkbox"/> Botany	-----
<input type="checkbox"/> Zoology	-----
<input type="checkbox"/> Biochemistry	-----
<input type="checkbox"/> Psychology	-----
<input type="checkbox"/> Mathematics	-----
<input type="checkbox"/> Technique training	-----
<input type="checkbox"/> Other (Specify):	-----

61. List below when and where you obtained each of your academic degrees, and the field in which you obtained them.

<u>Degree</u>	<u>Year</u>	<u>Institution where obtained</u>	<u>State</u>	<u>Field</u>
Bachelor's	-----	-----	-----	-----
Master's	-----	-----	-----	-----
Ph.D. or Se.D.	-----	-----	-----	-----
M.D.	-----	-----	-----	-----
Other (Specify below)	-----	-----	-----	-----

BACKGROUND INFORMATION

62. Your age (at last birthday): -----

63. Your sex:

- 1 Male
- 2 Female

64. Are you:

- 1 Single
- 2 Married
- 3 Widow, widower, or divorced

65. Number of dependents (excluding yourself): -----

66. If born in the United States, in what state were you born? If not born in the United States, in what country were you born?

67. Where did you grow up? (If you grew up in more than one place, check the one where you spent most of your time.) (CHECK ONE)

- 1 On a farm
- 2 In a small town—under 10,000 people
- 3 In a medium-sized town—10,000 to 100,000 people
- 4 In a large town or city—over 100,000 people

68. What was your father's occupation while you were growing up?

69. What is your military status at the present time? (CHECK ONE)

- 1 On active duty in the armed forces
- 2 Reserve status
- 3 No military status

70. What was your professional income last year? (CHECK ONE)

- 1 Less than \$3,000
- 2 \$3,000 to \$3,999
- 3 \$4,000 to \$4,999
- 4 \$5,000 to \$5,999
- 5 \$6,000 to \$6,999
- 6 \$7,000 to \$7,999
- 7 \$8,000 to \$8,999
- 8 \$9,000 to \$9,999
- 9 \$10,000 to \$14,999
- 0 \$15,000 or over

APPENDIX G

PERCENTAGE DIFFERENCES REQUIRED FOR STATISTICAL SIGNIFICANCE AT .05 LEVEL OF CONFIDENCE IN COMPARING GROUPS OF VARIOUS SIZES (Q, II, 185).

N	25	50	75	100	150	200	300	400	600	800	1000	1500	2500	3500
25	28	24	23	22	21	21	21	21	20	20	20	20	20	20
50		20	18	17	16	15	15	15	14	14	14	14	14	14
75			16	15	14	13	13	12	12	12	12	12	11	11
100				14	13	12	11	11	11	10	10	10	10	10
150					11	11	10	9	9	9	9	8	8	8
200						10	9	8	8	8	8	7	7	7
300							8	7	7	7	6	6	6	6
400								7	6	6	6	6	5	5
600									6	5	5	5	4	4
800										5	5	4	4	4
1000											4	4	4	4
1500												3	3	3
2500													3	3
3500														2

Example: If 1100 academic physiologists and 270 industrial physiologists are to be compared, a difference should be at least 8% if it is to be regarded as statistically significant in that there are only five chances in a hundred that the difference is due to chance.

APPENDIX H

May 28, 1953

TO ALL COMMITTEE MEMBERS:

Survey of Physiological Science

The accompanying outline of the Literature Search Project is sent for your information and advice. It presumably contains all suggestions that have been made for the use of this source of information, and has received more detailed contributions from Grenell, Bach and Veith in particular. The final formulation is mine.

Suggestions of any sort will be welcomed, including the names of any person who might wish to undertake the project. Suggestions as to appropriate journals to include or omit, on the sampling plan, on details of procedure, and particularly on items to be added or omitted, will be especially welcome. Would you please send your comments to Bach by the middle of June.

Cordially,

R. W. GERARD

MEMORANDUM ON THE LITERATURE SEARCH PROJECT

INTRODUCTION

The search of the published journal literature is conceived as one of the several important methods to be used in answering certain questions about physiology; not as a study of problems of publication. It thus stands with the roster and like statistical materials, the interview and questionnaire approach, and other avenues to information, and it can be applied to any of the fields of interest of the Survey. Its major utility, however, would seem to be for identifying and describing significant trends in physiology, for comparing these with trends in other areas of science, and for helping interpret the causes and consequences of these phenomena.

Inevitably, some of the information gained by a study of the journal literature will require coordination with information obtained by other methods. Some points of necessary coordination are indicated below. Conversely, considerable information regarding publications as such is best obtained in other ways than by examination of the publications; this area of study is indicated below, but is regarded as essentially outside the proper scope of the literature search method. Finally, a certain amount of miscellaneous information might be gleaned from the published articles with relative ease and should be obtained for whatever independent objectives would be served.

The main questions to be answered by the literature search, then, are:

- Ia. Changes in the scope of the subject, in relative emphasis on its subdivisions, and in disciplines that have splintered off and become new entities.
- Ib. Factors responsible for these changes, and consequences of them.
- IIa. Information on research productivity of men and institutions and their changes with time.
- IIb. Factors responsible for the rise and fall in productivity.
- IIIa. Information concerning publications, primarily obtainable from the journals.
- IIIb. Information concerning publications, primarily obtainable from other sources.
- IV. Miscellaneous information.

THE GENERAL PLAN

A. *Journals to be examined*

These should include: Representative samples from various phases of physiology, probably limited to the English language and mainly to United States publications, such as: *American Journal of Physiology*, *Journal of Cellular and Comparative Physiology*, *Journal of Physiology*, *Physiological Zoology*, *Plant Physiology*. (Should *Pflüger's Archives*, *Archives International de Physiologie*, the *Scandinavian Archives of Physiology*, be included?)

The sub-specialty journals in physiology should be represented by such examples as: *Circulation*, *Endocrinology*, *Neurophysiology*, *Blood*, *Journal of Chemical Education*.

Closely related disciplines could be represented by: *The Journal of Biological Chemistry*, *Journal of Pharmacology and Experimental Therapeutics*, *Journal of Clinical Research*. (? *Journal of the American Medical Association*, other jour-

nals in zoology and in botany, *Proceedings of the Society of Experimental Biology and Medicine*.)

Journals in other areas of science to serve as controls might include: *Journal of Morphology*, *Taxonomic Index*, *Journal of Entomology and Zoology*, *Journal of Comparative Neurology*. (The appropriate journal in psychology and in physics and any other suggestions in biology?)

Finally, such early or general journals might prove useful as: *Proceedings of the Royal Society, B.*, *Transactions of the American Philosophical Society*, *Nature*, *Silliman's Journal*.

B. *Time samples to be taken*

It is probably impracticable and unnecessary to make a complete study of any journal, even our own *American Journal of Physiology* (AJP). On the other hand, sampling one year in ten or even in five might fail to give the necessary continuity. It is suggested, therefore, that one or more issues be examined for each year. Thus, on a weekly, every 12th issue might give an appropriate sample, on a quarterly, every 4th issue (or even the first half of such issue), on a monthly, one, two, or four issues spread through the year—depending on the importance of the journal in question. (Whether it would be safe to choose the same month, or months, for each year or whether it would be necessary to rotate through the calendar to avoid seasonal bias, would require a small sampling study.) Besides intensity of sampling, there might be a difference from journal to journal in the items examined.

C. The information to be sought will be indicated below in the detailed proposals; and it will be indicated for each item whether it is an entirely objective one, requiring little more than copying and tabulating, or whether some scientific judgment will be needed in obtaining the information. The former (coded obj.) can presumably be obtained by clerical help, the latter (coded judg.) would require the background of an advanced graduate student, at least.

D. A number of the items to be gleaned from the literature will be of little significance until correlated with information obtained from other sources. In some cases the nature of this correlative information is obvious; in other cases it is still obscure and must be thought through and sought for more completely; in a few cases it is indicated in the detailed plan below.

E. *Operational aspects*

The work had probably best be done in Washington, in contact with the Central Office, although Chicago is not excluded. It is difficult to judge ahead of time how long it will take to do a single issue of a single journal in the desired detail. On the assumption that a college graduate in biology, serving as secretary, could cover the objective information in the equivalent of three volumes of the AJP per day, and that a Ph.D. or post-graduate in physiology could make the further judgments involving material in one volume per day—entirely arbitrary guesses—and assuming the study starts with the year of founding of the AJP, the following times would be involved, approximately:

AJP—assumed average of 2 volumes a year for 70 years, but only one issue of the six per volume examined, gives an equivalent of 23 volumes, about one month's work for the Ph.D. and one week's work for the secretary. Assuming that other journals average half the duration and half the yearly volume of the AJP, and will be studied on the average half as intensively, eight other journals would also require comparable units of time. Since about 24 other journals

might be used, and allowing a little extra time for correlation, the study looks like a full-time job for the Ph.D. for a long summer period or for half a year at most; and looks like a one- to two-month job, full-time, or a quarter-time job for the long summer on the part of the secretary. The cost should then be approximately covered by the \$1500 tentatively budgeted for this item.

THE DETAILED PROJECT

- Ia. A. What are the changes in the scope of physiology, in the relative emphasis given its subdivisions, and in the splinters that have become separate disciplines?
 1. List all the titles of articles in terms of sub-fields of physiology—compare the changing ratios between them. (Judg.) It will be interesting to relate these results to others on laboratories of origin, to memberships in various societies, to financial support in particular areas, etc.
 2. As evidence of splintering of new fragments, and as a control on false evaluation of changes in emphasis on a given subspecialty within physiology, due only to new publication outlets, it will be necessary to note the founding (and the demise, if necessary) of all journals reasonably related to physiology. This should include date of origin, names of editors (to check with society memberships, institutional positions, and previous publication interests), stated *raison d'être* and editorial policy. (Obj.?)
 3. It may or may not prove practicable to estimate the percent of physiology published in clearly physiological journals as compared to adnate journals. (State journals, anatomy, chemistry, etc. Relate authorship to roster classification.) (Judg.)
- B. How is the literature of physiology changing (other than in its allotment to particular subdivisions) in total volume, in omissions or repetitiousness, in primary and secondary publication, and the like?
 1. What is the total number of articles and of pages published per year? (Obj.) (How does this relate to number of workers, institutions, and support?)
 2. Similar quantitative information, comparing original articles with various types of review and other derivative publications. (Obj.) (Particularly useful information for comparison would deal with how individual scientists go about finding and organizing the literature in a subject, for teaching or research purposes. Such information should be obtained by the I and Q technique—interview and questionnaire.)
 3. How does the space given to results compare with the length of the total article? Does the introduction of more figures and tables correlate with shorter presentation? (Obj.) (The ratio of discussion to total length of paper, and the absolute length per paper, might be expected to decrease as the rigor of the subject improves. Compare below.)
- C. How have ideas grown in physiology and how has it increased in precision of measurement and rigor of analysis?
 1. How many mathematical formulations appear per paper. (Judg.) (This might be further pushed to analysis of the use of calculus,

differential equations, vector analysis, La Placeian functions, Boolean algebra, etc.) The use of physicochemical equations and concepts (thermodynamics, quantum theory, etc.) could be similarly studied. It might also be possible to relate the degree of quantitation to the sub-field of physiology involved and to the nature of the approach. A more sophisticated evaluation of the significance of the concepts and rigor used might be made by a qualified scientist. [Math—maybe M—— would take on an evaluation (not just a counting) of the use of math]

2. What is the experimental precision of the data obtained and to what extent are the results handled in a statistically sophisticated manner? (Judg.) Increasing precision could involve a decrease in standard error of given measurements, decrease in the absolute magnitude of the measurable quantities, decrease in the size of the sample needed for measurement, and the like. Sophistication in experimentation might be indicated by statistical adequacy of samples used and of handling of the resultant data, precise definition of experimental conditions and relevant parameters, etc.
 3. Perhaps the main lines of development of ideas can be traced with reasonable safety in terms of literature references in recognized classical contributions or in critical and semi-historical reviews. Thus, one might start with a recent paper marking a new departure, follow back through that to the contributing ideas and the papers in which these appeared, and so on. This is perhaps the most demanding problem of the entire study and might prove too subjective to do at all, or might be possible only if a personal study is made by a mature and wise physiologist.
- Ib. What are the factors responsible for these changes in physiology and what consequences flow from them?
- A. How important is the introduction of a new technique? Examine papers for methods used, note the speed and magnitude of spread in the use of a new instrument (oscilloscope, flame photometer), material (hamster, giant axone, iodoacetate), intellectual tool (chelation, pH, volume conductor theory). (Obj. and Judg.)
 - B. How important is the influence of an individual or an institution? Information here will also be relevant to the later question regarding research productivity. Papers must be examined for laboratory of origin, for senior and junior authors (the extent of multiple authorship may prove to be an index of increasing complexity of methods and problems, of size of research groups, of interdisciplinary approach, etc.), and for the tendency of students to stay in the field of interest of their teacher and to use his approach. (Obj.)
 - C. How important is the influence of support and opportunity in particular areas? The acknowledgments for fellowship aid or research financing accompanying many publications will give some clue to this (for example; neuromuscular studies supported by poliomyelitis funds, high altitude studies supported by aviation funds), but coordination should also be possible with data from our other sources on research and fellowship support. (Obj.) The institutions of origin should also be studied in relation to the creation of new posts, the building of new laboratories, the endowment of new projects, and the like. It would

also be desirable to obtain correlations with the creation of adequate publication outlets and the improved availability of information (technical journals, such as *Review of Scientific Instruments*, *Stain Technology*; company publications, RCA Tube data sheets; handbooks, *Beilstein*, *Tabulae Biologici*). Comparable correlations would be desirable on the technical side: the improved supply of standardized animals (the Wistar rat, genetically pure mouse strains, hypophysectomized rats, bacterial type cultures), standardized equipment (oscilloscopes and amplifiers, Warburg vessels, spectrosopes), and other commercial resources (Eastman's chemicals, Abbott's tracer-labelled molecules, etc.).

- IIa. What is the history of the rise and fall of productivity of individual men and laboratories? Many of the data asked for above are also relevant here. Additional attention should be given to the laboratory of origin of articles, in terms of geographical location (including country of origin), type of institution (university, college, government, etc.), and position of the laboratory in the institution (department of physiology, of zoology, clinical origin, industrial research laboratory, etc.), teaching or non-teaching, size of the group, sharpness of focus on a given area, etc. (Obj.) Authorship should also be related to other personnel studies (rosters, Ph.D. lists, society memberships).

It may prove much easier to obtain the necessary data for such studies by collecting lists of publications from individual laboratories and men, at least for the more recent decades of the study, than by a search of the journals themselves. In any event, such individual bibliographies should be most valuable supplementary material and should reveal a good deal about the rise and fall of productivity, shifts in focus of interest, numbers and fates of students, consequences of a change in direction of a group, etc. They would also show changes in journals used as publication outlets in various areas. A good many complete bibliographies of important scientists have been published, and many laboratories, particularly in earlier years, published annual volumes of collected papers which should be available in the major libraries or in the older departments of physiology collections. (Obj.) (Scientific 'genealogies' have been prepared for some European laboratories [Rothschuhs, Needham] and material is available [Reed] for similar ones to be prepared for U. S. ones.)

- IIb. What are the factors responsible for changes in productivity? Much of the material relevant to these questions has already been indicated under IIa). Especial attention here should be given to the kinds of students attracted to a department, teaching and other obligations, research facilities, and the like. (Judg.) But probably the greatest interest will attach to the personal and anecdotal material concerning individual teachers and leaders, available in historical studies, reminiscences by older men, and 'scuttlebut' from informal bull sessions, as well as the more formal results obtained by interviews with appropriate individuals.

- IIIa. Information dealing more particularly with publication matters, most easily obtainable by the study of the journal literature itself, could include:

Overlapping and duplicate publication (Judg.)

Editorial policies on inclusion of papers dealing with methods, theories, reviews, etc. (Obj.)

Actual growth of journals, in terms of volumes per year, papers per volume, and pages per paper (Obj.)

- Frequency of reference to articles in a given journal by articles in other journals (Obj.)
- Delay in publication (Obj.)
- [Society membership of authors (Obj.)]
- IIIb. Information concerning publications, primarily obtainable from other sources than the literature search:
- Number of journals in each area, circulation of each, cost per page (relate data on cost of publication of research to cost of performing that same research).
 - Rejection rate.
 - Comparison of subsequent usefulness (judged by amount of reference to the article) of articles which were barely accepted for publication compared with those accepted eagerly.
 - How are journals valued by contributors and by users; which ones are given first choice of a man's articles and which are subscribed to by preference?
 - How intelligible to readers in one field are articles in another field or specialty?
 - What are individual satisfactions and dissatisfactions with existing channels of primary publication?
 - What new outlets are desired. Should there be more encouragement for publication of negative results and unsuccessful experiments?
 - What is the availability of various journals in representative libraries and how extensively are they use?
 - How complete is the coverage by review journals, by area, and of the literature within a given area? How heavily have reviews been substituted for study of the original literature?
 - What indexing services exist, how complete are they, and which journals publish regular or special current or cumulative indexes, book reviews, and the like?
 - A comparable study of abstract journals, including the completeness of coverage, the degree of discrimination in covering only important articles, the availability of abstracting services to scientists, the areas of overlap and relative attributes of the different abstracting services, etc.
- IV. Miscellaneous information. Suggestions are particularly in order as to miscellaneous items that might be picked up in the course of the literature search. An example is the kinds and numbers of animals used in physiological research and the changes in these over the years.

APPENDIX I

REPORT OF THE SURVEY OF PHYSIOLOGICAL SCIENCE ¹

Chicago, Illinois, April 9, 1953

Chairman: R. W. GERARD

The Survey: Orientation

R. W. GERARD, University of Michigan

- I. A study of physiology is a social study
 - A. Undertaking the survey required expertness. Skepticism and disapproval characterized the general attitude at first.
 - B. Physiology is a part of a large culture. We must face up to such an obligation. If physiologists don't do something about their status in the community, it will disintegrate.
 - C. Reactions to the Survey are generally cooperative. Cooperation may be inspired by differences of opinion, but the end result is the same; they are obtaining material they want. Enthusiasm within the Society is also great.
- II. Objectives of the Survey
 - A. To serve *physiology* in a narrow sense
 - 1. People who are members of physiological societies
 - a. Survey is a status survey
 - b. Improvements in research, teaching, etc.
 - B. To serve *biology* as a whole
 - 1. Improving status and import: this can be achieved by public education
 - 2. Recruitment: examining the biology which reaches high school students and making the laymen biology conscious
 - 3. Practical results: biology is not supported as it should be; the date of the biology building on your campus is indicative of this status
 - C. Service to *science* as a whole: on the technical level, communications, including publications, are being studied, on the basis of quantity and quality of original papers, as well as by citations to these works
 - D. Service to the *country* on a technical level
 - 1. Appraisal of scientific manpower through scientific registers, rosters and original data is being made
 - 2. Allocations of resources, numbers and locations of personnel, and present and future sources of personnel also are being studied
- III. Survey results will be used by
 - A. Individuals
 - B. Medical colleges
 - C. National Science Foundation

¹ These summaries were made by L. M. N. Bach.

- D. Ourselves
- E. 'To whom it may concern'
 1. Interested people
 2. People who can act, i.e. people who can do something about the situation
- IV. Historical background of the Survey
 - A. The NSF agreed that the APS is preferable to the government in making such a study, for it is the scientists themselves who are most acutely aware of the problems in their field
 - B. What fraction of science is the Survey covering?
 1. About $\frac{1}{10}$ of all science
 2. $\frac{1}{4}$ to $\frac{1}{3}$ of biology
 - C. Survey committee members include physiologists in academic institutions, government and industry; the Survey is in contact with the American Psychological Association, Biochemists, American Association of Medical Colleges, American Association for the Advancement of Science, American Institute of Biological Sciences, and the National Research Council
- V. Divisions of the Survey
 - A. Pilot phase
 1. Definition of objectives
 2. Development of instruments or methods
 3. Testing of methods
 - B. Definitive phase (just begun)
 1. Analyses
 2. Special studies
 3. Trends in various countries
 4. Doing it all over again, properly
- VI. What of the future of physiology?
 - A. It is shrinking as a formal discipline
 1. It *could* result in dissension and splitting of groups
 2. It *could* become stagnant
 3. It *could* continue to evolve, retaining its own name and characteristics
 4. It *could* permeate all of biology
 - B. Answers to these questions are important because changes will occur; and wise action is possible *only* on the basis of information

The Survey: Operations and Results

L. M. N. BACH, Tulane University

- I. Dr. Orr Reynolds, who was Executive Director of the Survey's Pilot Phase, has returned to the Office of Naval Research
 - A. As pilot of the Good Ship Survey, he guided it past the riptides, shoals and jagged rocks to the boundaries of the ocean of physiology
 - B. Now the ship has been turned over to a Captain who must sail this ocean
 1. Using rather indistinct charts and collection of data, he must make an effort to determine the nature of the ocean

2. Many small samples, from which the composite whole will be derived, include
 - a. The depth lines—questionnaires
 - b. Loran and Sonar—oral interviews
 - c. And from these the nature of the ocean will be reconstructed
 - C. If we sail into your sea, bay or inlet in quest of provisions, we hope that the greetings and salutations characteristic of physiologists will be extended to the weary navigators
- II. Collection of information during the definitive phase will include *descriptive statistics*—data alone are not as important as knowing *why* data exist
- A. Primary and secondary school textbooks (Rue)
 1. Science books—biological sciences slighted in favor of earth sciences
 2. Health education books—some physiological function and some physiological bases of health rules
 3. Biology books—socio-economic aspects of biology and inter-animal relationships—very little physiology; nervous system and digestive system occasionally treated and usually surprisingly well
 4. Authors—mostly in education or public school systems
 5. Physiology in general poorly presented, if at all
 6. Collect names and positions of authors and find out why they wrote books
 - B. Personnel rosters (AMS, NSR)
 1. Distribution among specialties; total number of physiologists
 - C. College catalogue studies—course distribution in 12 top ranking institutions producing Physiology Ph.D.'s; in Dr. Baker's study, for example, an average 2.5 undergraduate courses appeared to have physiological content
 - D. Distribution of funds among different specialties in physiology (BSIE information) to determine
 1. Why funds are distributed as they are
 2. Sources of funds
 - E. *Annual Review* citations—a measure of the productivity of individuals
 - F. Abstracting and literature statistics (Grenell)
 - G. Society memberships and distribution of members
 - H. Popular literature analysis—in Dr. Burton's preliminary report on *Reader's Digest*
 1. Twice as much applied biology and applied physics as pure appeared
 2. Coverage in 1951 was 68% biology and 32% physical
 - I. Films (Root Committee) and a list of 65 film sources (H. S. Mayerson)
- III. Many special projects also are under way
- A. Motivation study:
 1. Dr. Roe to follow in Symposium
 2. Dr. Edgerton—Westinghouse Talent Search
 - B. Physiology content of biology courses
 1. Dr. Solinger—reported at teaching session
 - C. Data available for study of background of high school biology teachers in New York State
 - D. International aspects and 'elder statesmen' from other countries—hope to take advantage of International Congress
 - E. Historical trends—Fulton Committee
 1. Instruments

2. Literature
 3. Schools
 4. Societies
- IV. Interview—Questionnaire
- A. Sampling of institutions and people
 1. Note differences and similarities for sampling purposes
 2. Advantage of visitations—observations
 3. Physiologist vs. personal interviewer—to be combined in one
 - B. Exhibit; questionnaires and pamphlets to be handed out at end of session
 - C. Kinds of students: general, science, biology, botany, zoology, psychology, pre-medical, medical (and ancillary—pharmacy, dentistry, osteopathy, veterinary, optometry), graduate medical, basic science (anatomy, physiology, biochemistry, pathology, pharmacology), agriculture, bacteriology, nutrition, engineering, law
 - D. Faculty—from graduate teaching assistant to full professor
 - E. Administrators—curriculum directors (major advisors), project directors, department chairmen, research directors, deans
 - F. Investigators—graduate students, graduate degree seekers, post-graduate investigators, research assistants, associates and principal investigators
 - G. Policy makers—government and foundation boards, councils, panels, academic boards, etc.
 - H. Special groups:
 1. Societies—members, officers and committees
 2. Publications—text, monograph, review and original paper authors, editors
 3. Publishers
 4. Apparatus companies
 } have distributed questionnaires here at meeting
- V. Survey results
- A. They will appear as
 1. Descriptive statistics
 2. Personal attitudes within profession
 3. Professional attitudes
 4. Factors in working environment
 - a. Satisfactions and dissatisfactions
 - b. Directions and lost and founds
 - c. Motivations—trends
 - B. They will serve as guides to those who desire guidance
 1. Academic administrations (institutions)
 2. Private and government agencies
 3. Professional societies
 4. Individuals (students, curriculum directors)

Personality Patterns of Experimental Biologists

ANNE ROE, New York City

- I. By way of beginning I must express my indebtedness to the human guinea pigs who participated in my studies of 64 scientists through
 - A. Their life histories

- B. Discussions of their work
- C. Tests
 1. Intelligence tests
 2. Rorschach tests
 3. T.A.T.
- II. Differences between physical scientists and biological scientists in general, with special reference to physiologists
 - A. Information from biologists' histories
 1. They consider other people a necessary nuisance; they prefer institutionalized relationships
 2. They are shy, over-intellectual
 3. They have close friends
 4. They 'date' late
 5. They exhibit parental respect
 6. 5% of the physical scientists are divorced, whereas 40% of the biologists are divorced
 7. They exhibit a predominance of rational control
 8. The most eminent group appeared well balanced; the next less eminent group seemed pedantic, slack
 9. As a whole, they are a non-aggressive, but stubborn group
 - B. Intellectual aspects
 1. Modes of thinking: biologists and experimental physicists possessing a high degree of visual imagery, rely upon it heavily
 - C. In intelligence tests the range enormous
 1. In the eminent group it was 130 and up with a top of 210 (I.Q. of 130 is superior)
 2. Intelligence factors
 - a. In biology geneticists are higher in math than in verbal abilities
 - b. In botany and the physical sciences, the scientists are high in verbal ability
 - c. These don't necessarily demonstrate any means, but rather factors that produce the scientist
- III. Motivations—why does he behave as he does?
 - A. The group as a whole is composed of hard workers
 1. Those who reached the top worked all the time and were dedicated to their work
 2. Putting the whole self into the job indicates the presence of a dynamic emotional drive; and it often also indicates flight from emotional problems
 - a. The death of a parent at an early age often seems to be the involving factor in this group
 - b. The profession also can be resorted to as an escape from emotional problems
 - B. Motivation is important in selecting students because their attitudes influence their outlook on work
- IV. Uses of this information
 - A. A means of determining how to get more physiologists, etc.
 - B. A help in shifting presentations
 - C. An indicator of how much time is spent above and beyond the requirements

- D. An aid in the selection of people contemplating the field as a career
 - 1. Does he want freedom or direction?
 - 2. How much initiative does he have?
- V. The moment of decision of life work in physiology is that time when an individual realizes that he can do research; we must not forget, however, that concepts of a mature personality are influenced by our own self-ideal(s)

Physiology in Education: Undergraduate and Graduate

ORR E. REYNOLDS, Office of Naval Research

- I. The conflict which exists between undergraduate and medical students exists probably because of a failure of communication
- II. Problems of undergraduate departments
 - A. The Ph.D. candidate apparently is not as good raw material as the medical candidate
 - 1. Medical students are larger in number
 - 2. Prestige is in favor of the medical student
- III. How should physiological students be trained?
 - A. Perhaps the problem goes back to the elementary school
 - B. At present our primary concern seems to be that of graduate teaching when, in reality, a large proportion of students do no graduate work
 - C. Publicity is a must
 - 1. Publicity for physiology probably is no different from any other advertising; the same techniques probably can be used successfully
 - 2. We must obtain an appreciation of the problem from influential people who can do something about it, particularly those people having contacts with undergraduate courses

Physiology in Education: Professional Schools

J. H. COMROE, JR., University of Pennsylvania

- I. The Survey of Physiological Science deals with *all branches* of physiology; the Association of American Medical Colleges is also doing a Survey which will include all medical education through graduate work
 - A. The two surveys will cooperate
 - B. Their reports will not conflict
- II. Purposes of the AAMC Survey
 - A. What it is *not*
 - 1. It is *not* a dean's institution
 - 2. It is composed of members from
 - a. Physiology
 - b. Pharmacology
 - c. Biochemistry
 - B. It is a series of teaching institutes in which the responsibilities of the medical faculty will be appraised
 - 1. To produce good doctors
 - 2. To encourage future teachers

3. To present and explore new knowledge
4. To implement community service by bringing people and ideas together for the exchange of ideas
- C. Representatives are to
 1. Confer with each other
 2. Confer with students
 3. Present the composite of these ideas to the above groups during these 'exchange of idea' sessions
- III. Help is needed in the following areas
 - A. Content of courses: Chairman—Acheson
 1. Correlation
 2. How devised
 - B. Interrelationships: Chairman—Landis
 1. Is teaching carried over into medical schools?
 - C. Recruitment of teachers: Chairman—Abraham White
 1. Where are teachers coming from?
 - a. According to Dr. Waterman, it is only 38% of what it was 3 years ago
 - b. Only 3% of dental students are interested in teaching and research
 2. Methods of recruiting
 - a. Teach learning techniques (Hall)

<ol style="list-style-type: none"> 1. Learning techniques 2. Evaluating techniques 3. Students and methods 	} numbers used
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 - b. Control results will show us
 1. How we can know one method is better than another
 2. Whether teachers are involved and, if so, how much?
- IV. The cooperation, help, thinking, and experience of everyone here are vitally needed

Dr. Gerard called for questions from the floor

- I. *Dr. George Wakerlin* (Head, Dept. of Physiology, University of Illinois): "Money is a big problem in the lack of students. \$5,000 is about all a young instructor can expect; the entire group is underpaid. This should be publicized, and I would like to see salary data publicized for the general public."

Dr. Gerard: "Such publication would involve a time curve and the physiologist's worth to society. We must convince the public that it is worth while to pay us more. This is one reason for the importance of increasing our status."

- II. "Your motives are laudable, but I think that a questionnaire can be dangerous. It should be carefully designed and distributed."

Dr. Bach explained the method of questionnaire development—"To illustrate the thoroughness and success of such planning, we have had a big return on a questionnaire distributed to the instrument makers having exhibits at Chicago."

Dr. Comroe explained more fully the methods of obtaining needed information from medical schools. The direct interview method, in which assigned delegates will conduct personal talks with faculty members, will be the most used.

- III. "How do we select men to enter the field of physiology? Many applications are received from disappointed medical students. If the applicant has an ordinary science record and is rejected from medical school, is it safe to accept him as a graduate student in physiology?"

Robert Johnson: "One-half of the students in physiology are frustrated medical students. Our policy is to let them in the first year, then flunk them out. It is a policy more-or-less of survival of the fittest. In general, the source of teachers in mammalian and general physiology is not from medical schools. It is increasingly the Ph.D.'s who turn to teaching. Education in graduate school is important for this reason."

APPENDIX J

REPORTS OF SUBCOMMITTEES AND OUTLINES OF PROGRAMS

Subcommittee Plans Formulated at New London, Conn., July, 1952

Central Office Arrangements Presented at Bar Harbor, Me., July, 1953

J-1 Subcommittee on Personnel

ATTENDANTS: Robert S. Morison (M), H. Burr Steinbach (S), Dael Wolfe (W), Robert Galambos (G)

CONSULTANTS: Ralph W. Gerard, Milton O. Lee, Orr E. Reynolds

REPORT OF SUBCOMMITTEE ON PERSONNEL

INTRODUCTION

Importance of people in science

- a. As producers of new knowledge
 - b. As producers of new people
 - c. To perform various services needed by society
- Quality and quantity (in that order) of people more critical than any other factor—money, equipment, organization. Emphasize danger that committee reports and 'national plans' will over-rate money, equipment and organizational patterns because these are obvious and easier to talk about.

METHODS OF STUDY

To be filled in later.

- I. Present status and trends—this should be a purely factual statement along following lines
 - A. How many people call themselves physiologists?
 1. Now
 2. 5, 10, 15, and 20 years ago
(Present, 5 and 10 years ago can probably be obtained from national rosters, or more laboriously from AMS)
 3. Are the people who called themselves physiologists 5, 10, 15, 20 years ago still in the field, or is there a trend away into other areas—biochemistry, clinical medicine, administration, etc.?

B. What is the present distribution of physiologists?

1. By field:

a. General	a' Respiration
b. Invertebrate	b' Circulation
c. Vertebrate	c' Nervous system
d. Mammalian	d' Endocrine
e. Human	e' Other
2. By type of activity
 - a. Proportion of time spent in teaching
 - b. Proportion of time spent in research
 - c. Proportion of time spent in applied technology
3. Type of institution employed in:
 - a. Government laboratories
 1. Agriculture
 2. USPHS
 3. Armed Forces
 - b. Industry
 - c. Educational institutions
 1. Schools
 2. Colleges
 3. University departments other than medical schools
 4. Medical schools

C. How is the supply in relation to needs?

1. Vacant posts in organizations listed in preceding paragraph.
2. Age distribution of professors, associate professors, etc. Cf. Hinsey's AAMC article.
3. Estimate of posts which may become available as certain fields develop to meet newly recognized needs (e.g. need for more behavior physiologists as basic science for psychiatry).

Other suggestions needed to round out this section.

II. Where do physiologists come from and why?

A. Factual data (broken down into 5-year age classes)

1. Geographical origin
 - a. Is this in roster data?
 - b. *American Men of Science*
 - c. Sample study?
2. Trained where?

a. Small colleges	}	—roster probably adequate for this
b. Universities		
c. Medical schools		
d. Other		
3. Socio-economic origin

a. Occupation of father	}	—sample study
b. Income group of father		
c. National origin father and mother		
4. How able (in relation to those entering other fields) are people entering physiology?
 - a. Standing in class
 - b. Intelligence tests, AGCT, graduate record exam., etc.

B. Motivation towards a career in physiology

This is probably the most important section of the report and the

hardest to get accurate information about. Very little helpful information is likely to be found in the rosters or other standard reference books like *American Men of Science*. Probably, we will have to rely on intensive interviewing of a small but well drawn sample. It would be desirable if this sample could be large enough to yield significant differences (if there are any) among 10-year age groups for the past 40 or 50 years. Also by quality of work done—do 'good' physiologists have different reasons for going into physiology than mediocre or poor ones?

This section might begin with an essay, necessarily rather speculative, on the personality structure of the creative scientist, with special reference, if possible, to physiology. Three or four psychologists, Harry Murray and Donald McKinnon for example, might be asked to submit memoranda summarizing the available material and setting forth their guesses as to what personality characteristics condition the choice of a scientific career and make for success and satisfaction. Such an essay might be interesting in itself and in any case would add a rather new note to a committee report of this type. Furthermore, it might help to set up hypotheses for intensive testing by the interview procedure.

It is not suggested that it would be possible or even desirable to draw up a character sketch of the ideal or typical physiologist. Obviously a field which has benefited from as diverse talents as those of Cannon, Carlson, Erlanger, H. M. S. Evans, Fulton, Gasser, Homer, Smith, and Wiggers needs a pretty large least common denominator. Nevertheless, it may be useful to inquire whether or not the scientific career offers unusual opportunities to people with more than usual amounts of certain personality traits. If so, how can such people be made aware of the opportunities and so drawn into socially important and personally satisfying careers?

Some reasonably objective data may be accumulated by inquiry of our sample as to when and how they made up their minds to go into physiology and to stay in it despite offers to go into clinical work, become deans, and so forth. Equally important, some attempt should be made to find out why biochemists, physicians, administrators or what have you did *not* go into physiology.

(Some attempt could be made here to find out how many people go into physiology because they couldn't be admitted elsewhere, e.g. medical school.)

The two most obvious incentives to take up a particular career are money and status. Monetary compensation can be accurately analyzed in considerable detail and might be done as follows:

Salaries by age groups and by academic title certainly for the past 30 years and if possible for the last 50. These should be corrected for changes in the cost of living and taxes, and *compared with income of other occupations* such as medical practice, clinical research, law, public accounting, highly skilled labor.

In addition, there might be some discussion of age of marriage and child-bearing in relation to salaries in the lower brackets. One has the impression that men in the 25-35 age range have more family responsibilities now than was the case 20 or even 10 years ago. Though probably good from the general social standpoint it may be a considerable negative incentive in considering a scientific career.

Analysis of status, glamour, prestige and so forth is much more difficult. It seems reasonably obvious that physiology has less prestige, at least in the public mind, than medical practice, biochemistry, physics or psychology. It may have somewhat more than entomology, or physical anthropology. One way of getting objective data on the matter would be to ask a representative group of college students when they first heard of physiology and what it means. (A representative list of 10–15 other scientific specialties should be dealt with in the same way for comparison.)

There is reason to believe that outstanding teachers have a great influence in steering students towards particular fields. How is physiology fixed in this respect? At the undergraduate level? At the graduate and medical school level?

Are outstanding men being drawn into research posts in government, industry, and institutes like the Rockefeller Institute, which keep them from contact with the oncoming generation?

This could be approached by analyzing starred *Men of Science* (physiologists) by teaching positions in 1920, 1930, 1940, and 1950. (Other suggestions needed.)

Submitted by ROBERT S. MORISON

Central Office Arrangements, L. M. N. Bach

I. A. 1–2.

- a. Definition of a physiologist
 1. Criteria are based largely on society membership, self-classification and field of the Ph.D.
 2. These criteria include
 - a. Membership in Canadian Physiological Society, APS, SGP, ASPP
 - b. Stated first competency in physiology in
 1. SAB
 2. APA
 3. Membership in physiology section of BSA
 4. In other biological societies where physiological competency is indicated
 - c. 1st competency in the principal physiological codes in
 1. 1948 *American Men of Science* study
 2. 1952 National Science Register
 3. Names solicited in 1944 Adolph survey
 4. Names solicited in 1945 Visscher survey (for the Armed Forces)
 - d. Names of all Ph.D.'s whose theses are judged physiological regardless of the department from which the degree was obtained: 1948–52
 3. Name and address of each individual derived from the above sources are placed on an index card. Each card shows all of the sources (a-e) of any one name.

4. Self-classification as a definition
 - a. Answer to Q. 1 in questionnaire
 - b. Author of physiological paper as a definition (literature survey): this is not being used as a name source, since too many names would be missed with only 5-year intervals being used for the literature survey. On the other hand, the proportion of authors' names classified in AMS listings as physiologists for appropriate years can also be determined.

Enumeration of Physiologists

Over 7500 names (without duplication) were culled from the sources (2a-e above). A very cursory examination of the returned questionnaires shows about 30% of the respondents select physiology (animal, plant or bacteriological) as their first choice. Any other choice means that the respondent is *not primarily* a physiologist. On this basis there are: 2250 professional physiologists; 5250 'fringe' physiologists.

Of the latter figure it is estimated about 200 cannot fit any definition (in their own terms) of a physiologist past or present. So the fringe population drops to 5050 and 200/7500, or about 3% represents the degree of 'impurity' of our population.

NSR, AMS and Adolph Survey names were used as sources of names. BSIE grants personnel and 'American Colleges and Universities' were not used because for the former the criteria were not considered rigid enough and most of the physiologists' names were probably duplicated as derived from other sources. In the latter case names are not listed. A spot check of 10-12 large medical school physiology department faculty lists showed that perhaps 1 of 6 names was missed, that is, was not in the list of 7500 names to which questionnaires were sent. These people, however, were usually very new M.D.'s or Ph.D.'s who just appeared on the staff for the first time. There were also a few 'non-joiners' and 'roster non-respondents' of older questionnaires. These mixed names probably would total no more than 50 or 75. It would have proved difficult to obtain their names in any event by the time the questionnaires were mailed.

4. Trends

- a. The population surveyed by Adolph in 1945 has been completely covered in our questionnaire mail out. It is intended to study the changes in this population in two ways:
 1. The same group will be pulled from the present population and compared on responses to identical questions between 1944 and 1953.
 2. A group of the present population, comparable in its current characteristics to the Adolph population (or some part of it), as existed in 1945, can be measured with reference to a variety of properties (e.g. Were instructors paid as well relative to assistant professors in 1945 as they are today?).
- b. *American Men of Science* study. The AMS issues for 1906, 1910, 1921, 1927, 1933, 1938, 1944 and 1948 are being analyzed (for later coding and punching) for the following information
 1. Name
 2. (Year of AMS issue)—(date of birth) (=age)
 3. Marital status
 4. Number of children

5. Age at Ph.D.
6. Institution of Ph.D.
7. Position(s)
8. Institution(s)
9. Research interest
10. Issues of AMS in which name appears
11. * Names

From this study it will be possible to trace the shifts in origins, age groups, family responsibilities, educational backgrounds, institutional relationships, research emphasis and eminent names at roughly 5-year intervals for 40 years. All of these factors can be interrelated within card groups for or between various yearly groups.

B. *Classifications suggested*

- a. 1st, 2nd, and nth choice of self-classification as a physiologist; see questionnaire Q. 1.
- b. Other areas in which he classifies himself—questionnaire Q. 1.
- c. General field—Questionnaire Q. 1 (11, 21, 31)
- d. Special field—Q. 6
- e. Employing institution—Q. 22
- f. Subclassifications—possibly by Q. 38a & 50
- g. Expenditure of time—Q. 28
- h. Years of degrees—Q. 61
- i. Undergraduate major and school—Q. 61
- j. Postdoctoral training—this will require a separate analysis of available fellowship records
- k. Other correlations—these will be developed. While much of the above could also be obtained in varying degrees from other existing records in our hands it would seem that the most accurate, complete and consistent information can be obtained from the questionnaire itself with the least effort. For these reasons the additional sources are not mentioned as they will not be used for the above.
- l. Productivity
 1. Questionnaires are being grouped in terms of the number of citations in *Annual Reviews* for each of the respondents. Quality of research and names in *Who's Who* as criteria of productivity are too difficult to assess for validity at this time. In the questionnaire we can relate number of citations and/or citation for eminence (see 2—below) against amount available for research Q. 40.
 2. Citation for eminence—we are planning to solicit from ca. 200 physiologists the names of 10–25 physiologists in the U.S. and Canada who they feel are making the most important contributions to their field today, together with the reasons for their selection. The 200 names selected as judges are picked from the following sources:
 - a. Members of the Central Committee
 - b. Members of the editorial boards of the various physiological journals
 - c. Officers and council members of the APS, ASPP, and SGP

- d. A group of about 150 having the greatest frequency of citations in all the *Annual Reviews* series 1950-52

The nominated names will be grouped according to:

- a. Frequency of nominations
- b. Areas of physiological interest
- c. Nature of reasons for selection

These groups will be measured by a variety of characteristics against a comparable group from the residue population

1. Classification by field—Q. 1, 6, 32a, 37 & 51 for 'general' invertebrate, vertebrate, mammalian, human, respiration, circulation, nervous system, endocrine, etc.
2. Type of activity
 - a. Teaching and research—Q. 28 questionnaire
 - b. Applied technology—coded reply to Q. 37 (physiological code—5th digit stands for socio-economic orientation; where 5th digit appears as 3, 4, 5 or 6 (sociology, medicine, technology and agriculture)

3. *Institution employing*

- a. 1. Government laboratories—Q. 22
 - Agriculture—Q. 38a (or address of respondent)
 - U.S.P.H.S.—Q. 38a (or address of respondent)
 - Armed Forces—Q. 38a (or address of respondent) or Q. 39 & 22
2. Industry—Q. 22
3. Educational—Q. 22
 - a. Schools—Q. 50 (or address of respondent)
 - b. Colleges—Q. 50 (or address of respondent)
 - c. Non-medical schools—Q. 50 (or address of respondent)
 - d. Medical schools—Q. 50 (or address of respondent)
 - e. Shifts between institutions—Q. 25
 - f. Age factors—Q. 3, 24 & 62

C. *Supply and Need*

1. Vacant posts—institutional analysis—to be done with analysis of Federation Placement records and Burnice Larsen in Chicago
2. Age distribution according to academic rank—in questionnaire Q. 22b answers related to Q. 62 answers
3. Estimates of posts needed for new field demands can only be gauged by measuring increased diversity of addresses from AMS study as related to
 - a. Current addresses of physiologists
 - b. Answer to questionnaire Q. 38a, 50, 51
4. Shortage of physiologists
 - a. Absolute shortage gauged by:
 1. Federation Placement record analysis
 2. Relation between questionnaire answers to Q. 3, 4, 22, 24, 35, 44, 49, 52, 56
 3. Number of physiology fellowships vacant
 - b. Relative shortage (of good men) gauged by:
 1. Graduate record examination comparisons
 2. Questionnaire answers to Q. 57a, b, c, 58, 56, 44, 45a, b, 49

3. Potential questionnaire to administrators (e.g. departmental chairmen)
 4. What are ex-physiologists now doing? Relate answers to questionnaire Q. 4 to 6 (or Q. 1) & 37. (When answers to Q. 4 or Q. 61 indicates previously a physiologist)
 - c. Above criteria measure demands. Needs very difficult and can only be approached from trend analysis (possibly AMS study).
- II. A. 1. *Origins*
- a. Geographical—questionnaire (Q. 61, 66 & 67)
 - b. For trends—AMS study
2. *Training*
- a. Answers to questionnaire Q. 59, 60 & 61—information relating to undergraduate school, major and graduate major; fellowship files
3. *Socio-economic origin*
- a. Answer to questionnaire Q. 68; age from Q. 3, 61 & 62
4. *Ability*
- a. Graduate record examination
 - b. Q. 58 answer in questionnaire
 - c. Fellowship distribution study
 - d. Starred AMS names, present-eminence-nomination study, and citation frequency
 - e. Nobel laureate winners
 - f. Will check on ACOE tests, GRE scores and physiology Ph.D.'s
- II. B. *Motivations*
1. Personal interviews are not projected because of budgetary limitations
 2. Anne Roe's study has information on eminent physiologists
 3. Answers to questionnaire Q. 2, 4, 5, 34, 35, 33, 45b, 49, 55, 56, 57, 58, 59, 60 & 68 will provide some information
 4. Reasons cited by people originally solicited as physiologists in questionnaire study who are not now physiologists as to why they are not
 5. Comparison of income, degree and rate of income change for physiologists for 1945 (Adolph), 1948 (AMS), 1951 (NSR) and 1953 (our questionnaire Q. 70) against Bureau of Labor Statistics on cost of living index and incomes of other professional and non-professional groups for those periods. Family characteristics, geographic origin and place of training are being noted for physiologists in AMS study from 1906 to present.
 6. Distribution determination between academic and non-academic physiologists as related to AMS starting or nomination for eminence (currently) will be made to see if students have contact with sufficient number of eminent physiologists.

J-2 Subcommittee on Research

ATTENDANTS: Wallace O. Fenn, David R. Goddard, Julius Comroe

General Questions

1. The first question the Committee considered is what sort of information

concerning physiological research would be useful to the NSF, the physiologists themselves, and to other organizations?

2. What mechanisms are available to obtain information; that is, studies of published literature, interviews, or information in the hands of the U. S. Public Health Service, of the U. S. Department of Agriculture, or other studies already carried out?

3. What individuals should be added to the Committee?

4. What kind of report do we expect to write and what sorts of information do we believe should be included in that report?

No effort was made to answer the questions in detail at this time.

I. *Specific proposals*

A. Content of physiological research

What problems are in active study; information to be obtained primarily from the literature study

B. Trends and fashions in physiological research

1. As influenced by new techniques or new apparatus
2. As influenced by special men or schools
3. As influenced by war or defense research
4. As influenced by foundation granting policies, or by Public Health Service grants
5. As influenced by industrial research or by grants from industry

C. Types of research

1. Basic
2. Applied
3. Programmatic and developmental

D. Kinds of research

1. Mammalian
2. Clinical
3. Higher plants
4. Microorganisms
5. Invertebrate, including insects
6. Physiological psychology

E. Approaches to research

1. Endocrine research
2. Nutritional research
3. Metabolic research
4. Sensory research (including behavior and tropisms)
5. Neurological and nerve
6. Respiratory
7. Circulatory
8. Electrolyte, diffusion, permeability
9. Etc.

II. *Institutional organization*

A. Location of laboratories in which physiological research is carried out

1. Physiology departments in medical schools
2. Clinical departments in medical schools
3. Research hospitals
4. Departments of zoology and of botany
5. Departments in schools of agriculture
6. Agriculture experiment stations
7. USDA laboratories

8. Public Health Service laboratories, and AEC laboratories
 9. Research institutes
 10. Industrial laboratory
- III. *Tools for research*
- A. Availability of required facilities
 1. Laboratory
 2. Library
 3. Apparatus
 4. Shops and electronic shops
 5. Photographic equipment
 6. Animals and animal quarters, plants, greenhouse and gardens
- IV. *Costs of research*
- A. Sources of funds
 1. Institutional
 2. Foundations
 3. Government subsidy, i.e. Public Health Service, ONR
 4. Government contract
 5. USDA: industrial grants
 6. In industrial laboratories
 - B. Salaries
 1. For professional staff
 2. Technicians and assistants
 - C. For supplies and current expense
 - D. For apparatus expense
 - E. For experimental animals and plants
- V. *Freedom to do research*
- A. Freedom in the selection of the problems
 1. How far are the professional men free in the choice of their problems?
 2. To what extent is the choice dictated by the institution, the department, the source of funds or other considerations?
 - B. Time for research
 1. What fraction of time of the professional men is available for research?
 2. What are the competing sources for the time of the professional personnel?
 - a. Teaching
 - b. Institutional administration
 - c. Professional societies
 - d. Government agencies; such as, USPH, NSF, ONR, Department of Defense, etc.
- Submitted by DAVID R. GODDARD
- VI. *Training for research*—belongs perhaps under Personnel but could be considered tentatively here also
- A. Variations in the Ph.D. requirements in different schools
 - B. Ph.D. after M.D.
 - C. Training of M.D. as preparation for research

- D. Need of better liaison with chemistry, physics and biology (Linus Pauling says that physiologists and biochemists are ten years behind the liberal arts departments in chemistry and physics)
- E. Types of Ph.D. in physiology—specialties in
 1. Medicine
 2. Physics
 3. Chemistry
 4. Biology
 5. Mathematics
 6. Psychology
 7. Pharmacology
 8. Biochemistry
- F. Should physiology make special effort to bridge the gaps
 1. Between physiology and medicine (or leave this to medicine)?
 2. Between physiology and liberal arts departments?
- VII. *Minimum requirements for a self-sufficient research unit*
 - A. Importance of being the right size; what is optimum size? Can a school be too small for proper use of a \$10,000 research grant? Can it be too large?
 - B. Research environment
 1. Other active departments
 2. Experienced consultants
 3. Travel opportunities
 4. Industrial contacts
- VIII. *Role of Research*
 - A. In education
 - B. In hospitals
 1. Ratio of laboratory to bed space in different institutions
 2. Optimum ratio
 - C. In military labs
 - D. In clinical practice
 - E. In industry
 - F. Percentage distribution between these different types of laboratory

I suggest that this boils down to the following *types of investigation* (among others), for each of which there might be a special subcommittee to formulate the details of the study

1. Literature survey
2. Applications survey
3. Catalogue survey
4. Institutional survey by a large committee of members, each one willing to answer questions concerning his own institution
5. National Roster survey

Submitted by WALLACE O. FENN

Central Office Arrangements, L. M. N. Bach

The first series of 'General Questions' beg themselves, so to speak, since:

1. The fund of information concerning research which is useful to NSF, physiologists themselves, and to other organizations, must depend upon

the way in which the information which we are collecting about research can be classified into categories of usefulness.

2. Mechanisms for gathering information do include the published literature and BSIE. The only immediate USPHS information relating to research not already collected by BSIE relates to fellowships and research personnel information. The Personnel Subcommittee has not recently expressed any urgent desire for this and specific information probably can be approximated in other ways. The USDA is practically unapproachable at this time due to reorganization. However, for intramural government research information, we have located the names of all physiologists, animal and plant, who work for government institutions. We have requested BSIE to solicit project information from these people through their agency. With the approval of their Executive Committee, we hope this will be done. In addition, relationships between questionnaire answers 22, 38a, 39 and 40 will give intramural government research fund information insofar as physiology is concerned.
- 3-4. Relating to additional committee members and the manner of writing the report are not in my province as regards 3, while 4 is being accounted for by Ralph Gerard's chapter outline.

I. Specific proposals

A. Content—Problems in active study; these are being coded and classified by title from

1. The literature survey
2. Analysis of research grant reports from BSIE
3. Physiological thesis titles for the Ph.D. regardless of department obtained
4. Research interests expressed in the questionnaire—see Question 37
5. Research interest expressed in the International Questionnaire

B. Trends and fashions

1. Effect of new techniques or apparatus; this is being handled approximately somewhat as follows
 - a. Literature survey—indication of 'level of sophistication' of 'physical or chemical approach' in the Methods section of the paper; this does not specify items of equipment or technique but gives some idea of the level of technical approach. These levels could be related to
 1. Laboratories of origin
 2. Area of research interest
 3. Particular journal
 4. Particular time
 5. Source of funds
 - b. Supply House Questionnaire

Question 5—'list items sold most consistently'

Question 6—'list items in increasing demand'

Question 7—'list items in decreasing demand'
 - c. It was hoped that visits to physiology laboratories in the course of interviewing would complement the above but budgetary restrictions prevent this approach.
 - d. In our questionnaire, questions 34, 44, 49 and 60 might bear on this area when the absence of knowledge of new techniques

- or apparatus is quite serious. These answers will be related to question 37.
- e. Dr. Morris Leikind of the Armed Forces Museum of Pathology had suggested a review of history of instrumentation. This has not, as yet, been followed up.
2. Effect of special men or schools
 - a. In our questionnaire questions 38a, 59 and 61 related to Q. 37. The frequency of *Annual Reviews* citations for each respondent and his nomination by peers as a significant contributor to one field as named in all questionnaires in reply to Q. 59 and in each individual case to Q. 37, 38a and 59.
 - b. Information from international questionnaire relating to name of thesis director.
 - c. Distribution of physiology Ph.D. theses according to institution and department as related to nature of thesis problems.
 - d. Analysis of the Rothschild genealogical tables and tables of physiological problems and investigators names running from ancient times to 1926.
 - e. Project analysis (BSIE) relating institutional and personnel information to nature of project.
 3. Influence of war on defense information
 - a. Literature survey—footnote information relating military source of funds, and/or laboratory designation as military to nature of research described in paper.
 - b. Project information from BSIE relating military source of funds to nature of project.
 - c. From our questionnaire relation of question 37 to 38a, 39 (govt.-military) and 22 (to get intramural-extramural relationships).
 - d. Is all AEC supported work 'defense work'? If not which part should be defense?—impossible to determine at this point unless we can devise some index from BSIE information!
 4. Foundation policies and government agency grants
 - a. Literature survey—relate nature of problem to footnote sources of funds.
 - b. BSIE project analysis—relate sources of funds to nature of projects.
 - c. Questionnaire—relate question 37 to question 39 (and 22 for intramural government information).
 5. Industrial grants—See a, b and c in (4).
- C. Types of research
1. Basic research
 2. Applied research

In the physiological research code, provision is made in Section (digit) V for socio-economic orientation of any problem to which the code is applied. Thus numbers 1 and 2 (Pure Science and Theoretical Biology) relate to basic research, whereas numbers 3, 4, 5 and 6 (Psychobiology and Social Sciences, Medical Sciences, Technology and Agriculture). Thus all research areas investigated to which the code is applied can be classified as basic or applied;

there are: Literature survey, project (BSIE) analysis, Ph.D.; thesis title analysis, and questionnaire (Q. 37).

3. Programmatic and developmental research
 These can be identified only in the following manner
 - a. Certain projects listed with BSIE and falling in our project analysis are listed as programmatic or developmental. (continuation)
 - b. In the literature survey the consistency of coding of the nature of the problems in the papers covered can be related to any given laboratory and fund source. The existence of such consistency within any given relationship may be counted as programmatic or developmental.
 - c. The coded consistency of subject matter from any one laboratory in the Ph.D. thesis study over the years may indicate the existence of programmatic research.
 - d. In the *American Men of Science* physiologist study extending from 1906, principal research interests of each physiologist is being noted and the consistency of this interest over the years as well as the relationship between his name in the questionnaire Q. 59 with Q. 37 will be noted.

D. Kinds of research

All research problems coded from (1) questionnaire Q. 37; (2) literature survey; (3) BSIE project study; and (4) the Ph.D. thesis study are coded to take into account each of the variables suggested as follows: (the five digit code used is represented in columns.)

	Experimental Variable	Type of Organism	Structural Level	Functional Response	Socio-economic
8 = homeothermous 9 = human					
1. Mammalian				8,9	
2. Clinical					4
3. Higher plants		5			
4. Microorganism		2			
5. Invertebrate		6			3
6. Physiol. psychol.	9				

E. *Approach to Research*

1. Endocrine	7			2,3,5	4
2. Nutrition	8			3	
3. Metabolic	7			3	
4. Sensory				4,5	
5. Neurological				4	
6. Respiratory				7	
7. Circulatory				7	
8. Electrolytes			4	1	

Points in D & E are also coded in the questionnaire for Q. 6 which will be related to answers to Q. 37.

II. Institutional organization

- A. The location of the suggested laboratories is being handled as follows
 1. Departmental address distribution can be determined from the collection of 7500 cards listing the names and addresses of physiologists.

2. Answers to Q. 38a in the questionnaires.
3. Distribution of departments from the Ph.D. thesis study.
4. Analysis of the address distribution in the project analysis (BSIE).

III. Tools for research

A. Availability of facilities

1. Answers to Q. 44 related to distribution of problems represented in answers to Q. 37 in our questionnaire, will bear on this; Q. 60 (technique training) may also bear on this. The adequacy of library facilities can be measured by relating answers to Q. 37 to the answers to Q. 17, 18, 19 and especially Q. 20 where library inadequacy will appear if it is a serious matter. Similarly the answers to Q. 35 and Q. 49 should bear on this.
2. Additionally an analysis of the subscription lists of the various physiological journals will point up the adequacies and inadequacies as far as institutions are concerned.
3. We had hoped to gain our most pertinent information along these lines during the interview tours but budgetary restrictions again prevent this from being done.

IV. Costs of research

A. Sources of funds

1. Intramural versus extramural sources can be determined by relating answers in the questionnaire to Q. 22 and Q. 38a to answers to Q. 39. The nature of the sources of extramural sources can be measured by the answers to Q. 39. These can be related to the various types of problems as indicated in Q. 37.
2. An analysis of the BSIE projects will show the distribution of sources for various types of research problems and different laboratories.
3. Footnote information in the literature survey will give indications as to the source distribution which can be related to laboratories and types of research.

B. Salaries

1. Professional staff—this can be determined for professional staff members who are physiologists and who respond to the questionnaire by relating the answers to Q. 70 with answers to Q. 37, 38, 22c and 28 (100% research e.g.). We will not be able to determine salary sources for non-physiological professional personnel and technical personnel except whatever breakdown we can get from the sort of analysis which may be completed for ONR projects. We will also endeavor to obtain similar analyses from BSIE.

C. D. & E. Funds for Supplies, Equipment, Plants and Animals

This sort of analysis we *may be* able to get from

1. ONR contract analyses
2. BSIE project analyses

V. Freedom to do research

- A. Choice of Problems—This will be specifically answered by the replies to Q. 46 & Q. 49 in our questionnaire. This can be related to answers to Q. 22, 26, 27, 33, 34, 35, 38, 38a and 45. These relationships will also spell out the factors bearing on freedom of choice as related to (e.g.): institution, department, source of funds.

B. Time for research

1. Fraction of time available for research—answers to questionnaire Q. 28 and 29.
2. Sources of competing time—teaching, administration ('other' in Q. 28 will bring out society and government sources of time demands). Q. 28 and 29 answers in questionnaire as related to Q. 11 (society demands e.g.).

VI. Training for research

A. Variations in Ph.D. requirements in different schools

1. This should be available from the catalogue survey where we get graduate school bulletins and can be related to the distribution of Ph.D. theses and graduate record examination grades according to institutions.
2. Relationship between answers to Q. 61 and the answers to Q. 58, 59, & 60; which areas of interest etc. can be determined by answers to Q. 61 and by relating year of M.D. or year of Ph.D. to institutions named and to answers to Q. 6.

B. Training of M.D.'s for research

1. In the questionnaire those who answer Q. 61 to the effect that only an M.D. degree has been obtained can be related to those who have both an M.D. and Ph.D. with respect to field of Ph.D. and field of Bachelor's in terms of distribution of answers to Q. 60, 49, 45a, 45b and 20.
2. In the AMS study, fellowship distribution for M.D.'s as compared to Ph.D. or Ph.D.-M.D. combinations can be determined.

C. Liaison with chemistry, physics and biology—the answer to this will largely be determined from

1. Study of prerequisites for physiology courses in the catalogue study.
2. The kinds of laboratories and institutions relating to levels of chemical, physical and mathematical sophistication in method approach and in result analysis will be determined in the literature survey.
3. In the questionnaire answers to Q. 60 related to fields for the Bachelor, Master and Ph.D. in Q. 61, and answers to Q. 57a, 56, 49 and 20 will bear on this.
4. Local visits during interviewing could have been helpful but are not possible because of budgetary restrictions.

D. Types of Ph.D.'s in physiology—specialties

As nearly as can be determined this refers to the field of the Ph.D. now in physiology.

This can be actually determined on a distribution basis in the questionnaire by relating the answers to Q. 1 (only those who are physiologists!) to the field expressed for the Ph.D. in Q. 61 and the variety of fields noted in answer to Q. 4.

E. Bridging the gap between

1. Physiology and medicine
 - a. May best be answered by analyzing the expressed opinions encompassed in the AAMC Teaching Institute.
 - b. Relating nature of research, type of journal and laboratory of origin in the literature survey.

- c. Relation of questionnaire answers to Q. 37, 38a, 50 and 51 and respondents departmental addresses.
 2. Physiology and liberal arts departments
 - a. Answers to Q. 56 and 57 in questionnaire
 - b. Answers to Q. 50, 51 & 61 in questionnaire
 - c. Analysis of course distribution and requirements in the catalogue survey.
- VII. Minimum requirements for Research Unit
- A. Optimum size in relation to size of grant
 1. In questionnaire relationship between answers to Q. 35, 38, 38b, 38c, 39, 40, 41, 44, 48, and 49.
 2. Comparison between characteristics of institutions named in questionnaire in response to Q. 38a with frequency of papers in literature survey and citations of respondents in *Annual Reviews*, may be drawn.
 - B. Research environments
 1. Other active departments
 - a. Departmental address distribution of respondents who fill out section on research in questionnaire.
 - b. Analysis of answers in questionnaire to Q. 38a.
 - c. Analysis of distribution of departments in literature survey.
 - d. Analysis of distribution of departments in BSIE project analysis.
 2. Experienced consultants—answers in questionnaire to Q. 17, 18, 20, 45a & 45b may bear on this.
 3. Travel opportunities—questionnaire answers to Q. 14, 17, 18 and 20.
 4. Industrial contacts—answers in questionnaire to Q. 49 if this is a real problem.
- VIII. Role of research in
- A. Education
 1. Textbook citations of recent original work could be used as an example.
 2. Questionnaire answers to Q. 17, 18, 20 & 28, proportion of all respondents who answer both section on research and section on teaching, relation of answers to Q. 51 to Q. 6 & 37, answers to Q. 52, 56 and relation between answers to Q. 59 and 51.
 3. Analysis of laboratory manual exercises and research emphasis in institutions by relating answers to Q. 37 for staff members of those institutions.
 4. In the supply house questionnaire, answers to Q. 11, 12, and 13.
 - B. Hospitals
 1. Ratio of laboratories to bed space
 - a. This can be measured by analyzing physiologists who answer research part of questionnaire on the basis of clinical addresses noting the bed space (data which we have).
 - b. In the literature survey hospitals or clinical distribution cited can be related to bed space.
 - c. Similarly in the BSIE project analysis.
 2. Optimum ratio—relate in questionnaire for persons in category B-1-a (supra) the answers to Q. 41, 44, 48 & 49.

- C. Military laboratories
 1. Form literature survey relate frequency and types of problems originating from military laboratories as compared to other.
 2. Similarly from BSIE project analysis.
 3. Relate answers in questionnaire to Q. 22 with answers to Q. 28, 29, 38a, 39, 41, 44, 46, 49 and 69.
- D. In clinical practice
 1. See (B) above except additionally relate in questionnaire answers to Q. 1 (clinical medicine) Q. 6, 61, 37, 44, 47, 48 & 49.
 2. In the literature survey the appearance of
 - a. Physiological papers in clinical journals from
 1. Clinical departments
 2. Physiology departments
 - b. Papers in physiological journals from clinical departments
 3. In the AMS Study, physiological research by M.D.'s holding clinical appointments.
 4. In the BSIE project analysis, M.D.'s and clinical departments in which physiological research is being done.
 5. In the catalogue analysis the physiological course distribution in clinical departments, undergraduate and post-graduate.
- E. In industry
 1. Analysis of physiological research laboratories in the listed industrial laboratories—actual and potential.
 2. In the literature survey, proportion of papers coming from industrial laboratories.
 3. In the questionnaire answers to Q. 22, 28, 29, 37, 38a, 40, 41, 44, 45, 46, 47, 48, & 49.
- F. Proportion of different laboratories can be determined from
 1. The literature survey—laboratory origin of paper.
 2. BSIE project analysis.
 3. In the questionnaire answers to Q. 22, 28, & 38a.

J-3 Subcommittee on Communications and Teaching

ATTENDANTS: Maurice B. Visscher, Alan C. Burton, Raymund Zwemer

1. Education: Information should be obtained about extent and quality of
 - A. Public education in physiology
 - Magazines
 - Newspapers
 - Radio
 - TV
 - Movies
 - B. Course work in high schools and colleges
 - Physiology (general, human, cell, plant, comparative)
 - Biology
 - Biophysics
 - General science
 - Physical education
 - Hygiene or health science

- Anatomy
- Botany
- Zoology
- Psychology, etc.
- C. Education of professional groups other than physiologists
 - Medical students
 - Dentists
 - Veterinarians
 - Medical auxiliary group
 - Nursing
 - Pharmacy
 - Dietetics
 - Medical technologists
 - Physical therapists, etc.
 - Agricultural specialists
 - Animal husbandry
 - Agronomy
 - Plant pathology
- D. Education of professional physiologists and allied groups
 - General physiologists
 - Plant physiologists
 - Comparative physiologists
 - Biophysicists
 - Microbiologists
 - Biochemists
 - Botanists
 - Zoologists
 - Pharmacologists
 - Clinical physiologists (medicine, etc.)

Information desired for each group above

1. Where is the physiology being presented, under what name?
2. Who is presenting it and what is his training?
3. How much time is devoted to physiology?
4. What techniques of teaching are used—lectures, laboratory, demonstrations, motion pictures, seminars, library assignments, conferences?
5. How many students are taught?
6. How have items 1-5 changed over last 50 years?

Possible sources of information

For Group A

- Magazine survey (Burton)
- National Society for Medical Research
- Consult librarians

For Group B

- National Science Teachers Association
- National Education Association
- U.S. Office of Education
- American Council on Education
- Association of College Teachers
- Westinghouse Scholarship Contest
- Catalogs and bulletins of schools and colleges

For Group C

- Council on Medical Education, AMA
- Association of American Medical Colleges
- American Association of Dental Colleges
- Veterinary College Association
- Other professional school associations
- Opinion poll in medical group, including medical undergraduates, residents and practising physicians
- Other opinion polls in perhaps three additional groups: plant physiology, medical auxiliary, etc.

For Group D

- Compilation of reports to be solicited from heads of departments in which graduate instruction in physiology is carried out. Information to be asked concerning requirements for graduate degrees, including background requirements in mathematics, physics, chemistry, morphology, etc.
- An analysis of relationship between background training and subsequent activities of a group of 100 randomly selected physiologists would be useful.
- It is suggested that symposia on the subject be organized at the Chicago and Montreal meetings and that at the latter foreign scientists be brought to present information.

2. Communications

A. Publications

1. Journals of primary publications
 - a. Journals devoted 100% to physiology—items of information desired
 - Pages per year
 - Cost per thousand words
 - Numbers of subscribers (both library and individual)
 - Length of papers
 - Delays in publication
 - Rejection rates
 - Comparative data over a period of years and for North American and foreign publications
 - b. Other journals publishing original physiological data
 - The same information is desired plus the percentage of the journal devoted to physiology
2. Secondary and tertiary publications
 - Reviews
 - Abstracts
 - Bibliographies
 - Indexes
 - Microfilms
 - Monographs
 - Motion pictures, etc.

We will wish to know the numbers of publications in the various categories, their completeness, cost, promptness, reliability, circulation, among other items of information.

Specific questions which were asked deal with the effect of editorial policy upon publication habits of scientists, such as the publication of numerous short papers rather than a small number of comprehensive

papers; the effect of research support policy upon publication habits in the same regard; the financing of secondary publications, particularly abstracts and indexes; the effect of security requirements upon publication of physiological information; the effect of industrial secrecy on distribution of physiological information; the statistical study of time trends in volume of published material.

B. Personal relationships, including scientific organizations, societies, meetings, symposia, etc.

1. Information desired

Number of organizations

Number of meetings

Number of persons attending

Character of the program in North America and in other parts of the world

Time changes over the last 50 years

2. The information is desired for organizations which are primarily physiological and organizations in fringe areas. Also considered of interest is information concerning organizations with occasional physiological papers or symposia such as those of professional, medical, and other societies and post-graduate courses of various sorts.

3. Financial aspects of organization and meeting activities

Sources of funds for travel

Provision for income tax refunds

Policies of employing institutes and granting agencies with regards to travel subsidy

4. The financing of scientific societies in physiology

A study of the financial structure and sources of income over a period of years seems desirable.

5. Qualifications for membership in physiological societies of various sorts in various parts of the world in comparison with qualifications in other scientific societies is desired.

The problem of general or associate membership or membership and fellowship was raised.

The importance of society membership to persons who are primarily teachers and to advanced undergraduate and graduate students was raised.

6. International interpersonal relationships

A study should be made of the mechanism of affiliation of scientific societies in international scientific unions in various countries. In the United States most natural science societies are not directly affiliated with international unions. The affiliation is through the NRC with no official connection for the society of major interest. The U.S. scientists have not participated very actively or effectively in international scientific unions.

Is the mode of affiliation an impediment to effective action?

What types of activities are most important for the proposed IUPS to engage in? This question might be approached by looking into the record of other international scientific unions to ascertain which types of activities have been most useful and most successful.

3. *General Comments*

In conducting studies it was generally agreed that as much use as possible should be made of work going on in other agencies and organizations bearing on questions raised. Cases in point are the abstracting survey by *Biological Abstracts*; the studies in the Library of Congress; the compiled information of the AMA, etc.

Submitted by MAURICE B. VISSCHER

Central Office Arrangements, L. M. N. Bach

I. Education

A. Public education

1. Magazines

- a. An analysis of *Reader's Digest*, *Saturday Evening Post* and *Collier's* has been completed by Dr. Burton. We plan to supplement this with *Life* and *Time* magazines.
- b. Interviews with medicine and science editors of *Time* and *News-week* are anticipated.

2. Newspapers

- a. Interviews are planned with Alton Blakesley, J. Q. Maisel, etc., and Watson Davis of Science Service.
- b. An analysis of the *New York Times* magazine section and the *American Weekly* is planned.

3. Radio and television

- a. It is anticipated that interviews with network program directors can be arranged.

4. Movies

- a. It is hoped that some background for the reasons behind the Disney movies, the March of Time and other documentaries can be assessed by interviews.

5. There should also be mentioned the 'chronic' public opinion poll conducted by Dr. Holger Kilander of New York University in which questions dealing with physiology have been asked. He has carried out this poll over some period of years in order to assess the extent of public information on matters of health education.

B. High school and college education in physiology

1. The catalogue survey will show the distribution of physiology courses among various departments.
2. The answers in the questionnaire to questions 50 and 51.
3. The high school course work in physiology will be analyzed:
 - a. From Dr. Hajek's questionnaire in Iowa which is sent to high school biology teachers
 - b. Dr. Davenport's analysis of the high school presentation of physiology in Utah
 - c. W. G. Land's report on the physiological training of high school biology teachers and the nature of the course work in high school
 - d. J. Solinger's report on the content of undergraduate course work in biology
 - e. Examples of secondary education problems in Canada (Summaries of (c), (d) and (e) are enclosed)

- C. Physiological education of professional groups not in physiology
 - 1. Catalogue survey
 - a. Number of students
 - b. Kinds of students
 - 2. Answer in questionnaire to question 51
- D. Education of professional physiologists
 - 1. See our questionnaire questions 57, 57a, 57b, 57c and 57d
 - 2. Catalogue statements of prerequisites in graduate schools
 - 3. Where is physiology being presented and under what name?
 - a. Catalogue survey (Baker)
 - b. In the questionnaire answers to questions 50 and 51
 - c. Data from the AAMC Teaching Institute
 - 4. Who is presenting it—his training?
 - a. Answers in questionnaire to questions 1, 6, 58, 59, 60 and 61 as these relate to various answers given in questions 50 and 51 as well as 22, 22a, 22b, 23, 24 and 25.
 - 5. Time devoted to physiology
 - a. From the questionnaire the relation between answers to questions 51 and 28 will give an estimate
 - b. Can be coupled with the actual time calculations determined in
 - i. Baker's catalogue study
 - ii. Land's report
 - c. Data from the AAMC Teaching Institute
 - 6. Techniques of teaching
 - a. Answers to questionnaire in questions 52, 53 and 54 related to answers to questions 50 and 51
 - b. Data from the AAMC Teaching Institute
 - 7. Number of students taught
 - a. Catalogue survey may give some data
 - b. Land's report may give some data
 - c. A separate questionnaire to department chairmen may be prepared
 - 8. Change over 50 years
 - a. Unless this appears in the international essays, it will not be obtained from 'elder statesmen' interviews in the U.S., since this project has been dropped. There are no other good sources known for this.
- II. Communications
 - A. Publications
 - 1. Journals both physiological and para-physiological
 - a. Pages per year, length per paper, publication delays, comparative data
 - i. The literature survey form is coded to record each of the above factors for every journal every year (at five-year intervals) and every paper.
 - b. Cost per word, number of subscriptions and rejection rates
 - i. Interviewing and/or short questionnaires to appropriate managing editors will account for the above.
 - 2. Secondary and tertiary publications
 - a. Reviews
 - i. Number—to be determined

- ii. Completeness—to be gauged from replies in questionnaires to questions 17, 18, 19 and 20
- iii. Cost—to be determined by approach to managing editors
- iv. Promptness—(see ii)
- v. Reliability—(see ii)
 - (ii), (iv) and (v) could have been more effectively determined during interview visits but budgetary restrictions prevent this.
- vi. Circulation—from managing editors
- b. Abstracts
 - i. This study has been completed with an analysis of the bibliography for cerebral circulation
 - ii. Number of abstracts—to be determined
 - iii. Completeness—gauged from answers to questions 17, 18 and 20; also from cerebral circulation bibliography analysis
 - iv. Cost—to be determined from managing editors
 - v. Promptness and reliability (see iii)
 - vi. Circulation (see iv)
- c. Bibliographies and indices—(see (b) (ii), (iv) and (vi) and questionnaire answers to question 20)
- d. Microfilm—answers to question 20 in the questionnaire and information as to numbers, cost and circulation from
 - i. Armed Forces Medical Library
 - ii. American Documentation Institute
- e. Monographs
 - i. Numbers—question 5 in the Publishing House questionnaire
 - ii. Completeness—gauged from answers to questions 17, 18 and 20
 - iii. Costs—not available
 - iv. Promptness and reliability (see ii)
 - v. Circulation—questions 2, 3, 4, 5 in Publishing House questionnaire as related to number of respondents replying in our questionnaire to questions 17, 18 and 20
- f. Motion pictures
 - i. Numbers—we have some lists which show selection numbers (e.g., only 'suitable' films, not all). We could poll the distribution to get further information regarding numbers, as well as cost and circulation.
 - ii. Promptness, reliability and completeness must be gauged for
 - a. Answers in our questionnaire to questions 52, 53, 54 and 56;
 - b. AAMC Teaching Institute information
 - iii. We have statements of editorial policies of all pertinent journals and can relate these to types, lengths and frequency of papers in any one journal. The sources of fund support also will be determined, all this in the literature survey.
 - iv. The financing of abstracts and indices will be taken up with managing editors.
 - v. The effect of industrial secrecy and security requirements will be measured by—
 - a. Approaching managing editors

- b. Answers to question 49 in our questionnaire if this is a serious problem. These answers will be related to the answers to questions 22 and 39.
 - vi. Statistical time trends are being accounted for by taking all articles in all pertinent journals for one whole year at five-year intervals.
 - vii. We forgot to ask in our questionnaire—"What journal(s) do you read most often?"
- B. Personal relationships
 - 1. Number of scientific societies
 - a. Number and variety will be measured by relating answers to question 9 to those in question 1 in our questionnaire.
 - b. We have ascertained the distribution of physiologists among all of the biological societies so far as membership alone is a criterion of interest or activity.
 - 2. Number of meetings and number of persons attending
 - a. These data have been collected for the FASEB.
 - b. Availability of the records of other societies will determine the extent to which we can add to this.
 - 3. Character of the program in North America and time changes in the last 50 years will be derived from
 - a. FASEB history abstracted in this office
 - b. Perry Wilson's article on the Bacteriological Physiology Section
 - c. Additional information from other groups or sources
 - 4. Financing
 - a. Sources of travel funds—to be gauged from relating questionnaire answers to questions 9, 17, 18, 19, 20, 22c, 35, 39, 40, 41, 48, 49 and 70
 - b. Personal interviewing would have been most valuable here but budgetary restrictions prevent it
 - c. Policies of employing institutions and granting agencies as regards financing travel
 - i. By separate questionnaire to department chairmen or administrators
 - ii. By examination of policies of a sample of granting agencies
 - d. Society financing
 - i. Consultation with society secretaries
 - 5. Membership qualifications
 - a. An examination of relationships between answers in the questionnaire to questions 1, 6, 7, 8, 9, 10, 11, 15, 17, 18, 20, 22, 22b and 22c will bear on this matter
 - 6. International relationships

This can be touched on only briefly by

 - a. The analysis of responses to the international questionnaire
 - b. Scattered correspondence
 - c. The historical essays

J-4 Subcommittee on Applications and Consequences

ATTENDANTS: Maurice L. Tainter, *Chairman*; John Field, II, *Co-Chairman*;
Craig Taylor, Max Kleiber, Robert E. Smith, Leigh C. Chadwick

M. L. Tainter attended organization meeting in Washington, sponsored by R. W. Gerard and 7 others. According to Tainter the scope of panels was not clearly stated at the Washington meeting. Presumably this panel is to explore utilization of manpower in the *functional life sciences*. However, the personnel panel appears to have this role. Overlap probably not serious. Our study is a two-phase one. A qualitative planning phase to be followed by a quantitative phase (data collecting). The work to be done by the Washington staff (collection and statistical treatment of data).

We as a panel may well discuss fields in which (1) physiology can be applied and (2) physiology should be applied, but is not at present.

Our first problem is to define more sharply our area of interest. To get at this let us consider:

1. A list of fields of biological and medical science in which physiology was and/or is applied
2. On estimate of the trained manpower now available in these fields
3. An estimate of the 'ideal' manpower requirements of these fields
4. The areas in which physiological sciences should be used but is not now used
5. The desirable combinations of training for such inter-disciplinary fields as biophysics, engineering physiology, bioclimatology, child development and the like

C. Taylor suggested that the Committee consider the problems of education for inter-disciplinary training (e.g., physiology and engineering, biophysics, where a man has almost two majors).

Under these general headings let us consider such matters as:

- a. The funds now available for research in physiology
 1. From Federal agencies
 2. From universities
 3. From industry
 4. Other sources
- b. Impact of physiological knowledge upon our culture
 1. Wealth created by physiology
 - a. Planting industry, largely developed by plant physiologists
 - b. Use of antibiotics in stock feeding
 - c. Use of riboflavin in feeding chickens
 - d. Mineralization in improving corn and other crops
 - e. Increase in life span contributed by insulin

These considerations may also be of interest to the education panel, and to others. Our interest should be weighted in terms of the interest of other panels. Refer this to Gerard and Reynolds.

Other fields to be covered? We will probably 'shake down' after consultation with the other committees.

To introduce historical perspective let us change our listing.

FIELDS OF APPLICATION PAST AND PRESENT

Look for journals, societies, and organizations in these fields. Areas in which application of physiology is made.

Rough List

1. Animal nutrition
2. Plant nutrition
3. Animal breeding (applied genetics)

4. Plant breeding
5. Human nutrition, including dietetics
6. Veterinary medicine
7. Animal production
8. Industrial physiology and hygiene (industrial fatigue)
9. Industrial toxicology

Interpolation—O. E. Reynolds (3:20 p.m.).

Define the field (Central Committee) of interest of subpanel
Reasons field is important

In what areas was science brought to bear on World War II. How many were physiological (records of OSRD). Washington office can do this.

Reynolds suggests the group get information from

1. RDB about what is going on in the Department of Defense
 2. USDA—for agriculture
 10. Applications of environmental physiology
 - a. Aviation physiology
 - b. Submarine physiology
 - c. Tank physiology
 - d. Bioclimatology (acute and chronic studies)
- (cf. *White Settlers in the Tropics*—Price)

Investigators need training in meteorology as well as physiology

11. Exercise and work physiology (physiology of exercise)
12. Engineering physiology—human engineering as design physiology
13. 'Health physics'—training in radiation monitoring at Oak Ridge, etc.
14. Biophysics
15. Biometry and actuarial physiology
16. Health education (e.g. physiological aspects of sanitation, etc.)
17. Public Health physiology
18. Conservation (fisheries, Fish and Wildlife Service)
19. Applications of physiology in agriculture
20. Insect physiology and toxicology
21. Plant physiology—(the basic field)
22. Parasitology
23. Physiological psychology—normal and pathologic
24. Medical physiology
25. Pharmacology
26. Dental physiology
27. Pathological physiology
28. Optometry
29. Physiological anthropology
30. Zoo-physiology (physiol. zoology)
31. Cellular physiology
32. Pharmacy
33. Pharmaceutical physiology
34. Food technology
35. Microbiological physiology
36. History of physiology
37. Biochemistry
38. Child development (usually given in home economics)
39. Human developmental physiology

M. L. Tainter proposes we take over list of titles and expand where necessary to clarify.

Cost estimates—Washington Staff

Estimate costs from manpower estimates available in the several fields, taking into account mean salaries at the several academic levels and assuming 50% overhead costs.

Breakdown—How much time does the academic man spend in lectures and in the laboratory?

Documentation of the value of basic research in physiology and related sciences

Some points to consider.

1. Years of life saved by 'invention' of X-rays may exceed loss of life in all wars since 'invention' of X-rays. Could any radiologist give us an estimate here?
2. Development of air-conditioning industry
3. Development of hearing-aid industry
4. The decrease in percentage of deaths from wounds in recent war
5. The decrease in deaths per 1000 per year from disease in armed forces
6. Increase in life span
7. Economic contributions of shock therapy

Reynolds suggests we think of

1. Good example case histories
2. Ways in general of demonstrating impact of physiological advances; e.g., graph of increase in life expectancy vs. research expenses. What interesting and valid correlations can we dream up?
3. Case histories which M. Leikind might work up in detail. Include M. L. Tainter's lecture on the "Golden Age of Medicine." Craig Taylor's lecture (in reverse) on contributions of engineering to health. Ralph Gerard's lecture "Two centuries of biology. From spirits to mechanism."

Members of the committee will send material to O. E. Reynolds and to John Field (as secretary) for such case history illustrative material.

We should also note contributions of biology to physical sciences; e.g., Galvani, Volta—frog studies. (Cf. Fulton: "Muscular contraction and reflex control of movement." Material in chapters on bioelectric phenomena—introduction.)

NOTE:

Analyses of trends in content of physiology through patterns of publication in, for example: *Am. J. Physiol.*, *J. Physiol.* (London), *Trans. Faraday Society*, *Phil. Trans. Roy. Soc. Series A, B*, *Proc. Roy. Soc. Series A, B*

The subcommittee suggests that the Washington office carry out a survey to determine trends in the fields on the subcommittee's list of fields of application or utilization of physiology.

Submitted by ROBERT E. SMITH

Central Office Arrangements, L. M. N. Bach

1. Biological and medical science fields in which physiology was and/or is applied
 - a. Analysis of the distribution of types of appointments held by physiolo-

- gists in the AMS study (1906–1948) may tell the variety of fields of application which did exist.
- b. Analysis of the (1945) departmental addresses used in the Adolph study will give similar information.
 - c. Analysis of the departmental addresses used in the NRS (1951) will give similar results.
 - d. Analysis of the departmental addresses and the answers in our questionnaire to questions 38a, 50 and 51 will give information as to current areas of application.
 - e. Analysis of BSIE project information will tell something of the current departmental and institutional distribution of funds for physiological research and thus those areas currently involving physiology.
 - f. Catalogue analysis project will show the distribution of physiology teaching efforts in various departments.
 - g. Departmental addresses given in the study involving physiological theses for the Ph.D. will show the emphasis in various non-physiology departments (e.g. psychology, horticulture, etc.).
 - h. Literature survey—types of departments which publish physiological papers
 - i. Analysis of Federation Placement Service showing jobs open in various types of institutes and departments
2. An estimate of the trained manpower now available in these fields. Depending on the definition of 'trained' (which we will assume means Ph.D. level) we can state that we have about 7500 names fitting the criteria of 'professional' physiologists. These can be broken down into all sorts of categories and fields from answers to questionnaire questions 1 and 6. We fell down in the questionnaire by not asking in question 57 "How many Ph.D. candidates do you have?"—to give some estimate of trained potential for the future. However, this may be covered by measuring the trends in the Ph.D. study over the years (through 1952) and predicting the future.
 3. 'Ideal' manpower requirements of these fields
Only by analyzing jobs open in the Federation Placement Service and statements in the questionnaire in reply to questions 35, 49 and 56 can any information be brought to bear on this topic. A contemplated questionnaire to administrators may approach this problem. See also form letter and check list of names for essayists.
 4. Areas in which physiology should be used
We have gone through the industrial laboratory listing and have made judgments as to what areas not now employing physiologists (biologists) could use them. Plans to capitalize on this information by questionnaires aimed towards directors of such laboratories are being considered.
 5. Desirable training for inter-disciplinary fields (biophysics, engineering and physiology, etc.)
 - a. Biophysicists who reply to the questionnaire will provide information along this line by answers to questions 60, 61, 57a, 57b, 56 and 49. Biophysicists as indicated in question 1 (52) and other combined interests as defined in answers to questions 1, 6, 37, 51 or 38a.
 - b. Questionnaires sent to administrators in academic institutions sounding out their estimates of the need for physiology in various curricula are being contemplated.

6. Funds for physiological research
 - a. Federal agencies; b. universities; c. industry; d. elsewhere
 - i. From footnote information in the Literature Survey
 - ii. From analysis of BSIE projects as to fund sources
 - iii. From answers to questionnaire questions 22, 38a, 39 and 40
7. Impact of physiological knowledge on our culture

The role of plant physiologists in planting, antibiotics, in stock feeding, riboflavin in chicken feeding, mineralization in crops, insulin and life span all as factors contributing to our wealth. It would seem that these are matters of judgment by experts in each instance. So many economic factors enter into the realization of these physiological approaches to practical problems that the cost and effort of all the various physiological contributions to any one area is impossible to sift out. It would seem imperative, if this information is to be obtained, that we solicit from acknowledged experts in each of the above and possibly additional areas their assessment of the part physiological science played in each of these advances as compared to all the other factors involved. See form letter and check list of names of possible essayists.
8. Fields of suggested application; past and present

In the fields of animal and plant nutrition, plant and animal breeding, human nutrition, veterinary medicine, animal production, industrial physiology and hygiene and industrial toxicology we can determine the following factors:

 - a. Contributions from laboratories relating to these fields to the physiological literature—Literature Survey
 - b. Journals in these fields—extent to which physiological problems are represented (if time and funds permit)
 - c. The extent to which physiological research funds are devoted to these areas from:
 - i. Analysis of BSIE project information
 - ii. In questionnaire relationship of answers to question 40, with answers to questions 37, 38a, 1 and 6
 - iii. Footnote information relative to grants in the Literature Survey
9. Societies involved
 - a. Answers to questions 8 and 9 in the questionnaire
 - b. Society membership as reflected in our source data for names and addresses of physiologists (all society membership rolls have been collected)
10. Organizations
 - a. Answers to question 38a in questionnaire
 - b. Departments from
 - i. Catalogue analysis
 - ii. Answers in questionnaire to questions 50 and 51
 - iii. Departmental address analysis

PHYSIOLOGICAL SCIENCE AND WORLD WAR II

Department of Defense

This is being approached by

- a. Requesting BSIE to obtain project information from all physiologists with government addresses (including military)—distribution of type of problems and types of agencies can be determined (This just fell through!)

- b. By relating in the questionnaire questions 40, 22, 38a to 39 and selecting those respondents with military addresses
- c. In the Literature Survey by grouping articles from military laboratories

The above source procedures would also apply to USDA material where possible.

The variety of applications of environmental physiology and the special application of physiology in exercise, engineering, biophysics, aviation, submarine and tank, conservation, physiological anthropology, etc. can only be measured practically to the extent that 7500 different physiologists are involved in this wide variety of fields.

- a. This can be determined from answers in questionnaire to questions 1, 6, 8, 9, 37, 50, 51, 59 and 61 and from an analysis of the departmental addresses of the respondents.
- b. Distribution of physiological course work from the Catalogue Survey
- c. Laboratories of origin in the Literature Survey

Cost estimates in various fields in relation to manpower.

Analysis of questionnaire responses to question 70 as related to answers to questions 1, 6, 22, 22b, 22c, 37, 38a, 39, 40, 50 and 51.

Breakdown—responses in questionnaire to question 28 as related to answers to questions 22, 50 and 51.

The value of basic physiological research as incited examples: X-ray-longevity, air-conditioning, etc. (*vide supra*)—see form letter and check list of essayists.

Names of physiological experts in these fields would be valuable to us as well as cited case histories which were promised! An attempt has been made with the essayist check list.

Contributions of physiology to physical science can be cited from histories of science. Volta, van't Hoff, etc.

Trends in physiological literature are being considered in the Literature Survey.

The preparation of a 'brochure' such as mentioned in the minutes of the Second Meeting of the Subcommittee might well take the form of essays contributed by outstanding physiological authorities in the various specialty fields indicated. See form letter and essayist check list.

Sources of information relating to demand for physiologists which are as yet unexploited include the Mellon Institute and Bernice Larsen of Chicago.

Enclosed, please find a list of suggested fields of application together with suggested consultants or essayists and type of form letter which might go to them.

APPENDIX K

LIST OF MATERIALS COLLECTED BY CENTRAL OFFICE, MAY 28, 1953

1. Brochure
- 2-4. Minutes Central Committee meetings 1-3
5. Minutes Executive Committee meeting 1
6. Minutes Central Committee meeting 4
7. Minutes Executive Committee meeting 2
8. Minutes Executive Committee meeting 3
9. Report of Research Subcommittee
10. Report of Communications and Teaching Subcommittee

11. Report of Applications and Consequences Subcommittee 1
12. Report of Applications and Consequences Subcommittee 2
13. Report of Personnel Subcommittee
14. Report of Trends and Perspectives (History) Subcommittee
15. Summary of all decisions reached at all meetings
16. Grouped priority ratings of all interest areas
17. Financial statement
18. Present and *proposed* budget
19. Outline of status of Survey
20. Reports on status of special projects
21. Report on progress of Michigan Survey collaboration
22. List of institutions solicited for names and covering letter
23. Questionnaire to supply houses and follow-up letter
24. Questionnaire to publishers and follow-up letter
25. Summary sample list
26. Questionnaire soliciting participation of Federation members
27. Deans' questionnaire on salaries (for AAMC)
28. Medical school teaching questionnaire (for AAMC)
29. Notes—International Congress and Essayists
30. Listing of topics for Literature Survey
31. Status of various personnel rosters
32. Status of various project rosters
33. Outline of FASEB Symposium (Chicago)
34. Report on Analysis of Secondary Textbooks (Rue)
35. Report on Motivation of Physiologists (Roe)
36. Consolidation of History of FASEB (Lobdell)
37. Code Books for the Survey Questionnaires (Michigan Survey Center).
(See Appendix T, page 368.)

The above and certain other materials of the Survey, including a full set of punched cards, are in the office of the American Physiological Society, 9650 Wisconsin Avenue, Washington 14, D.C., and may be made available under appropriate arrangements.

APPENDIX L

PLANNED TABLE OF CONTENTS OF REPORT

Foreword

- I. Summary and general conclusions
- II. Introduction (setting of the study)
 - Gerard:* General considerations. This study—origin, objectives, plan, personnel, documents
 - Bach:* Other studies—in physiology, in related areas or comparison areas, on special phases (annotated bibliography in Appendix).
 - Levin:* Interest of NSF in this for a National Science Policy
- III. Historical highlights (important events, people, places)
 - Veith:* Growth of physiological science in USA (North America): men (individual leaders, following), centers, societies, publi-

- cations. Fragmenting from medicine and anatomy and into biochemistry, clinical science, etc. Relation to Europe and other continents.
- IV. Definition of area of study (research design and methods of the Survey)
- Bach: Reynolds:* Identification of physiological science—content, research
 Identification of physiologists (core and fringe)
 Relation to other areas in biology and in application (medicine, agriculture)
 Delimitations in time and coverage
 Institutional aspects—teaching, research, government, industry, organizations, societies
 Sampling—procedures, validity, extent, etc. for each of the major tools—I. and Q., documents, rosters and other statistical sources. (Should there be an appendix with *full lists* of the men, places, books, research grants, etc; or only with names of the lists and their sources?)
 Other details of design and procedure for each tool
- V. The midcentury picture (facts, detailed data, tables)
- Morison: Galambos:* Physiologists (the population)—who, where, activities, salaries, sources, attitudes, desires. Compare elite and others.
- Goddard:* Institutions
 Departments, societies, committees, international
- Parker:* Funds, space, services, equipment, assistance, animals and plants
- Lee:* Activities, organization (internal and in the whole institution)
- Wilson:* Education
 Courses—number, content techniques, level and hours
- Comroe:* Students—number, training, attitudes, career
 Teachers—origin, competence, attitudes, turnover
- Adolph:* Facilities—live plants and animals, costs, equipment
Prosser: Attention in decreasing order to: graduate, professional, college, high school levels
Actual output
- Fenn:* Research
 Relative activity in subdivision and specialties
 Funds, costs, animals (vivisection problems), equipment, services, instruments, commercial resources and suppliers, purchasing and personnel practices
Actual output
- Visscher:* Communication
 Journals, secondary publications, books
 Meetings, travel, symposia and monographs
Actual output
- Tainter:* Application
 Kinds of activity, of users, of person in applied

- physiology (medicine, agriculture, biology, industry, etc.)
 Employment machinery, job satisfaction and turnover, salaries
 Present and projected relation of supply and demand
Actual output
- Burton:* Public relations
 Presentation in mass media, especially use of TV and movies; problems involved
 High school (and college) experience with biology (and physiology) of non-biologists
 Attitudes to biology (and physiology) of lay public and especially of community leaders (business, administration, finance, political, technical)
- Reynolds: Bach:* Finances
- VI. Comparisons (setting of physiology; factual)
Bach: With other field in many of above topics
 Medicine, agriculture, taxonomic biology, psychology, physics, chemistry, mathematics
 With other times—trends in physiology; in comparison with other and for many topics, and when possible projected into the future
- VII. Causal factors (correlations, interpretations)
Field et al.: Conditions determining, *on a comparative basis*
 Number and quality of men entering and leaving physiology (and its sub-fields)
 Quality and amount of research production in physiology and especially between sub-fields
 Utilization of physiology and physiologists
 Status of physiology and of biology as a whole in the respect of students, professional men, educators, administrators, community leaders, the lay public
- VIII. The future (recommendations)
Gerard: Conference
 Trends
 in teaching, research, application, etc.
 Goals
 optimal, realistic at present
 Recommended actions to
 Societies
 physiological and wider scientific groups—NRC, AAAS, AMA, etc.
 Educational administrators and their organizations—AAMC, NEA, ACE, etc.
 Government Agencies—NSF, PH, ONR, USDA, SGO
 Foundations and commissions
 Publishers and documentation groups—BA, ADI
 Instrument companies and associates
 Individual teachers
 Individual investigators

APPENDIX M

ROSTERS—INFORMATION AVAILABLE, PUNCHED; STATUS

I. *American Men of Science*

- †*1. Name
- 2. Home address
- †*a3. Employment address
- 4. Permanent address
- 5. Other names (professional, publication, maiden)
- 6. Place of birth
- †*7. Date of birth
- †*8. Sex and marital status, date of marriage, and children
- 9. Citizenship
- †*b10. Academic training and specialization, undergraduate and graduate institutions, state located, dates of attendance, earned degree, date awarded, major and minor fields of specialization.
 - 11. Honorary degrees, institution, type of degree, date awarded
 - 12. Doctoral dissertation—title, major professors
 - 13. Postdoctoral fellowships (topics, institutions, names of fellowship, \$ value)
- †*c14. Professional history
 - Job title, name and location of employer, dates, duties (includes present position)
- †*15. Present annual professional income
 - Regular annual salary (ranges); additional annual professional salary; sources of additional professional income
- †16. Professional scientific societies (name, year of election, present grade of membership, major offices held and dates)
- 17. Chief specific fields of research
- 18. Bibliography of publications to show unique trend of competence and also diversity
- †*19. Patents, inventions, completed developments
- †*20. Employment as scientist by government agencies or on contract or development projects
 - AEC, OSRD, NDRC, JRDB, Army, Navy, Air Force, NACA, Bureau of Standards, USPHS and others. Employment as civilian or as military, employment status as directly with agency or by contractor with agency.
- †*21. Military and civilian service with armed forces—time, nature and place of service (with serial number)
- †*22. Modern foreign language facility—reading and speaking knowledge in orders of abilities.

23. Other attainments and achievements (honorary, extra-professional, etc.)
- *24. Knowledge of foreign countries and resources
25. Avocations, hobbies, special skills
- †*cd26. Fields of specialization (checked in order of 1st through 5th competency)
-
- *a. Place of employment punched only according to state.
- *b. Undergraduate institution not coded (therefore not punched); punching includes University of highest degree, nature and date of highest degree only.
- *c. Agreement between present employment and field of specialization.
- *d. Fields of competence punched for 1st, 2nd, and 3rd and consider a. experience and b. function.
- * Items punched.
- Underlined items appear in published AMS.
- † Items coded.
3. Institution, city and state coded.
 7. Month and year.
 8. Sex, single or married; if previously married, now div., sep., or wid.
 9. Native, naturalized, alien to be naturalized, alien not to be naturalized.
 10. Academic institution, state, dates, earned degrees, date of degrees.
 14. Present job title, employer, and nature of job.
 15. Regular annual salary, additional annual salary, and sources of additional annual salary.
 16. Belong to societies or not.
 19. Patent, etc., anything or not.
 20. Past participation, present participation, or no participation in gov't act.
 21. If in service, World War II, presently in reserve, type of service
 22. Foreign language—read or speak; how well.
 23. Field of specialization.

The status of the AMS roster is as follows:

1. The collection of AMS punched cards were arranged through ONR and the first competencies in the physiological sciences (40 categories coded by Dr. Reynolds) were tabulated and run. Discrepancies in the tabulation total and the punch run total invalidated (?) this effort. Hand tabulations (rather than IBM) have been made on 2nd and 3rd competencies.
2. A formal order for a new set of AMS cards was placed with NSF in January. These cards were punched as indicated by the starred items in the above list.
3. These cards are undergoing sorting for 1st, 2nd, and 3rd competencies and removal of duplications at the present time by Mr. Ballard of the NRC IBM machine room with the completion of such sorting set for May 30.
4. Valid to 1948.
5. About 4000 cards involved.

II. *National Scientific Register*

- * 1. Name
- * 2. NRS serial number

- * 3. Date of survey
- 4. AMS (?)
- 5. 'National Emergency' (?)
- * 6. Date of birth
- * 7. Sex
- * 8. Citizenship (4 possibilities as with AMS listing)
- 9. Country of birth
- *10. Marital status (married or single)
- 11. College and postgraduate training
- * a. Location
- * b. Major subject codes
- c. Minor subject codes
- d. Years attended
- * e. Earned degree (highest) or extent of pre-baccalaureate training.
(if doctorate, what kind coded)
- *12. Modern foreign language facility codes
- *13. Foreign travel and residence codes
- 14. Honors and prizes
- 15. Professional publications
- *16. Memberships in fields of science
- *17. Military status—status, branch of service, grade or rank
- 18. Present employment
- * a. Industry code
- * b. State where employed (code)
- * c. Major employment specialty
- * d. Function within employment specialty
- * e. Range of professional income (total)
- * f. Length of experience in field
- * g. Fields of specialties (1st, 2nd, 3rd competencies)
- * h. Function in held of specialization

* Items punched and coded.

The status of the NSR roster is as follows:

1. The NRS cards have been provided by the NSF on the basis of 63 NSR specialty codes as of March 4.
 2. 30,000 such cards are at the NRC-IBM room with another 10,000 to be delivered about June 10 due to delay in coding and punching through NSF contractors.
 3. Duplicates are to be deleted and tabular run comparable (as nearly as possible) to the AMS tabulation is to be done by NRC-IBM.
 4. 40,000 cards involved valid through 1951.
-

III. *American Physiological Society Questionnaire—NRC for War Department 1942-46 (M. B. Visscher)*

1. Name
2. Address
3. Date of birth
- * 4. Formal non-physiological education—highest degree
- * 5. Formal physiological education—highest degree

- * 6. Formal education since February 1, 1942—highest degree
- * 7. Experience—present work status
- * 8. Experience—type of work between February 1, 1942 and September 1, 1945
- 9. Experience—prior to February 1, 1942
Employer, dates, descriptive title of work
- 10. Experience from February 1, 1942
Employer, dates, descriptive title of work
- 11. If now a student, (1946) state courses, anticipated degree, and length of time to go
- 12. Specific experience with any military department—branch, rank or grade, nature of experience
- 13. Selective service—reason for deferred status if any, entry into service, branch of service, length of time, rank at entrance and exit, educational experience in service
- 14. Nature of military service and comments

* Items coded.

Status:

- 1. About 300 forms in our possession (from Dr. Lee).
- 2. Cards probably punched but not yet located.
- 3. Valid in 1946.

IV. *American Physiological Society Questionnaire—1945* (E. P. Adolph)

Part I

- * 1. Highest degree obtained
- * 2. Special training outside of degree work or employment
- * a. Amount
- * b. Subject
- * c. Place
- * 3. Year in which
- * a. Doctorate awarded *or*
- * b. Entered professional life
- * 4. Shift between physiology and related fields (not specified)
- 5. War-time dislocation
- * a. Nature of shift
- * b. Permanence of shift
- * 6. Identification with physiology or paraphysiological field
- 7. Teaching
- * a. Nature—physiological, para-physiological, or non-physiological
- b. Type of student
- * 1. Major teaching effort directed towards
- * 2. Other types taught
- * c. Number of months teaching
- * d. Attitude towards efficiency of teaching
- * e. Types of handicaps in teaching
- 8. Attitudes toward research situation
- * a. Satisfactory
- * b. Types of handicaps in doing research
- * 9. a. Society membership
- * b. Age elected

- *10. a. Marital status
- * b. Children (number)
- * c. Total number of dependents
- *11. Sex
- 12. Income
 - * a. Total income—range
 - * b. Professional income only—range
 - * c. Part of income derived obtained as professional physiologist
- 13. Rank or title
 - * a. Are you employed in an institution using academic titles
 - * b. Rank or title held in 1940? in 1945?
 - * c. Located in dept. of physiology or in another dept., in 1940? 1945?
- *14. Are there provisions in your present employment for retirement with pay or an annuity?

Part II

- 1. Name
- * 2. Place and date of birth
- * 3. Present address
- * 4. Present position and employing institution
- 5. Percentage of your working time given to the following:
 - * a. Teaching
 - * b. Research
 - * c. Administration
 - * d. Other duties
- 6. Teaching
 - * a. Title and general subject matter of courses you teach, semester hours, number of students, number of instructors
 - b. Criticism of subject-matter or methods of physiology *or*
 - c. If you teach another subject for which physiology is a prerequisite, what criticism do you offer on the adequacy of students' preparation in physiology
- 7. List associates who are physiologists but not members of the Society
- 8. Express ideas on improvement of publication facilities, on meetings, on new fields of employment that might be opened to physiologists, on the obligations of physiologists to society, or other pertinent topics
- 9. Budget
 - * a. Annual funds for work in physiology in 1940? in 1945?
 - b. Percentage devoted to
 - * 1. Salaries
 - * 2. Teaching
 - * 3. Research
 - * 4. Other uses
- 10. Personnel
 - a. Salaried persons other than technicians in physiology
 - * 1. Number in full-time research
 - * 2. Number in teaching and research
 - * 3. Number in teaching only
 - b. How many students work in your unit
 - 1. Majors
 - 2. Minors
 - 3. Total

- * c. Are your technical helpers adequate in number and quality?
- d. If not, is deficiency due to
 1. Lack of money
 - * 2. Lack of available trained personnel
 3. Lack of both
 4. Other difficulty
- e. Comments on quality and number of advanced students and research workers available

* Items coded and punched.

Status:

1. 1043 cards loaned to us by Dr. Adolph. Valid through 1945.
 2. 50% return from circularization of lists taken from AMS, NSR, and Scates-Trytten Doctoral lists.
-

V. *NIH Fellowship Files*

1. Number.
- * 2. Name
- * 3. Legal residence
4. Place and date of birth
5. Citizen
- * 6. School applied from
7. Type applied for
- * 8. Degrees held
9. Years required
10. Veteran—dependents
11. Screening action (qualified, disqualified, deferred)
12. Final action (approved, disapproved, deferred)
- * 13. Type of award
14. Stipend
15. Effective date
- * 16. Department
- * 17. University
18. Sponsor
- * 19. Field of study
20. Subfield 1
21. Subfield 2
22. Termination date
23. Problem statement
24. Current address
25. Liberal arts school of origin
26. Academic or clinical
27. Publications
28. Follow-up (present position) 6–8 months after termination

* Items punched.

— Underlined items to be entered in new forms.

Status:

1. There are a total of some 4700 cards, including duplications.
2. All are inactive except the following groups:
 - a. 690 active cards

- b. 300 cards in process not yet granted
 - c. 300 cards in process not yet in duty
 - d. 300 applications—only post-doctorates and exclusive of foreigners.
3. This effort began in 1938 with the Cancer Institute and became full activity in 1948.
 4. Separate from all this, on all NIH grants there is available a curriculum vitae on all personnel involved in grants; the MSIE does not have this information.
-

VI. *NSF Fellowships*

- * 1. Name
- * 2. Present address: street, city, state
- 3. Permanent address: street, city, state
- * 4. Fellowship applied for—1st year, intermed. year, terminal year, postdoct. year
- * 5. General field (e.g.—Biol. Sci.)
- * 6. Specialized field
- 7. Major dept. (current or last)
- * 8. Educational inst. (current or last)
- * 9. Educational inst. (next)
- *10. Sex
- *11. Year of birth
- *12. Select. Serv. Class.
- *13. Names of individuals submitting confidential reports
- *14. Marital status
- *15. Number dependent children
- *16. Degrees earned
- *17. Date received or expected (each degree)
- *18. Educational institution and state (each degree)

* Items coded and punched.

Summary:

1. IBM punches start in Spring of 1953–54; 52–53 will be prepared.
 2. 600 such cards in files.
 3. Records have been broken down for: distribution in field of study, state of permanent residence, institution currently attending.
-

VII. *NRC Fellowships*

1. Name
2. Permanent address
3. Birth date
4. Marital status
5. Educational history
6. Field
7. Institution
8. Scientific advisor
9. Program
10. Started fellowship (date)
11. Terminated fellowship (date)

12. Ph.D. date
13. Research topic
14. Stipend received during fellowship
15. Travel during fellowship
16. Tuition and fees paid
17. Grant to institution of fellowship
18. Present position and date assumed
19. Present address

Summary:

1. All records back to 1919—on microfilm and alphabetically.
 2. Total of 13,000 applicants for NRC, NSF, AEC, etc.
 3. Dr. Lapp at NRC is working with this type of data to use for information to Foundations.
-

VIII. *Science Doctorate Listings* (Trytten Studies) (Scates)

- * 1. Name
- * 2. Serial number AMS
- * 3. Serial number NRC
- * 4. Sex
- 5. State and census division of birth
- * 6. Year of birth
- * 7. Doctor's degree, institution, location, year of award, age when received
- * 8. Master's degree, institution, location, year of award, age when received
- * 9. Bachelor's degree, institution, location, year of award, age when received
- * 10. Years elapsed between getting bachelor's and getting doctor's
- * 11. Major field of doctorate (29 categories)
- * 12. Major occupational specialty (600 categories)
- 13. Place of present employment (state, metropolitan according to census division; for other educational and research centers; and for foreign areas).
- * 14. Type of employment (type of employer)
- * 15. Source of information (tabulator, e.g.)

* Items coded and punched.

Summary:

1. 20,000 names through 1936–1948 (Scates via ACOE).
2. Checked against AMS files and NRC fellowship files.
3. 15,000 names period 1936–1945 (Trytten via NRC)—(probably overlapped or duplicated by 1).
4. Checked against "Doctoral Dissertations Accepted by American Universities" compiled by the Association of Research Libraries, NRC fellowship files, registrar lists, manpower surveys carried out by 33 scientific societies, and AMS files.
5. Includes Canadian doctorates.

Status:

1. Trytten reports that new cards are being punched to contain the above indicated data combined from Scates, NRC, and NSR, and revised and completed into a continuing project.
2. Cards should be ready by summer of 1953.

IX. *Federation Placement Service—Positions Sought*

1. Name
2. Home address
3. Telephone number
4. Age
5. Married or single
6. Dependents
7. Sex
8. Citizenship
9. Signify specific location desired or indicate willingness to go anywhere in U. S.
10. Education—degree, year, institution, field; majors and minors
11. Fellowships—year, institution, field
12. Experience (from present-back) organization, address, dates, title of position
13. Position and field desired
14. Date available
15. Salary
16. Special fields of interest

Summary:

1. 300 current cards available.
 2. 500 inactive (1½ years back) cards available.
 3. Files cleared out every 2 years due to lack of space.
 4. Source is combination of cards and application forms.
-

X. *Federation Placement Service—Jobs Available*

1. Name
2. Address
3. Date position is available
4. Position
5. Requirements for job
6. Field of work and duties
7. Range of salary

Summary:

1. Current jobs—500 cards available.
 2. Inactive—1000 cards available.
-

PROJECT ROSTER

I. *Bio Sciences Information Exchange*

1. Type of listing
- ** 2. Project identification ^a (prefix, number, continuation, supplements)
3. Supporting agency
4. Title of project
- * 5. Professional personnel
- ** 6. State ^b
- ** 7. Institution

- ** 8. Organization unit °
- 9. Department
- **10. Subject Index (omitted from Survey cards to enable Physiology Problem Research Code to be punched)
 - 11. Summary of proposed work
 - *12. Period of operation: start—month/year
end —month/year
 - *13. Funds approved for payment
 - *14. Fiscal year
 - *15. Status

* Items punched.

** Items coded and punched.

a. Selected agency prefixes (2 above) include:

- a. Government: Office of the Surgeon General, AF; Army Medical Service; ONR; VA; AEC.
- b. Public Health Service: National Cancer Institute; National Institute of Dental Research; National Heart Institute; National Institute of Mental Health; Division of Research Grants and Fellowships.
- c. Public and Private: (20) American Cancer Society; Childs Memorial Fund; Commonwealth Fund; Fuller Fund; Life Insurance Medical Research Fund; Macy Foundation; National Foundation for Infantile Paralysis; National Multiple Sclerosis Society; Nutrition Foundation; Rockefeller Foundation; Runyon Memorial Fund; National Vitamin Foundation; Whitney Foundation; American Heart Association; National Tuberculosis Association; Hyde Foundation; American Cancer Society—NRC Committee on Growth; National Research Council of Canada; Association for the Aid of Crippled Children; Research Corporation, Williams-Waterman Fund.

b. States (6 above) include all 48, D.C., plus Canada, British Isles, and France.

c. Selected organizational units (8 above) refer to 14 kinds plus 75 specific hospitals.

Summary:

- 1. Information available on approximately 4500 private, industrial, government, and Public Health Service grants plus about 50 PHS fellowships.
- 2. The Survey has project sheets, IBM cards, and IBM runs both active grants (May 1952) and professional personnel all grants (November 1951).

Status:

- 1. All physiological research projects registered with BSIE (May 1952) have been classified (Physiology Research Problem Code) by Mrs. Mary Hall.
- 2. Nearly all codings have been transferred to IBM sheets (in BSIE columns labeled 'Subject Index') preparatory to card punching.

II. *Agricultural Research Administration—USDA*

Project Cards

- 1. Status
- 2. Date project approved in ARA
- 3. Number (by work project,** by line project)
- 4. Bureau (division)
- 5. Institution

6. Location
7. Title
8. Object
9. Plan of work
10. Cooperation
11. Estimated date of completion
12. Professional personnel *
13. Whether antibiotics, toxicology, pharmacology, animals, or microbiology for cross-referencing project cards.

* Recently added to cards.

** Work Project is 'parent' one under which several line projects may be listed.

Summary:

1. No fund information is available for individual or Line Projects, but it may be obtained for Work Projects.
2. Approximately 4000 Line Projects are listed for ARA, while 8000-9000 are listed with the Office of Experiment Stations.

Status:

1. This information has not yet been made available to the Survey.
 2. Dr. Reynolds discussed it with Mr. Neil Johnson last fall, but additional time will be required for Dr. Bach to visit the ARA offices before any commitments can be made by them.
-

III. *Office of Naval Research Contracts*

1. ONR number
2. Institution
3. Number of professionals —total salaries/year
4. Number of technicians —total salaries/year
5. Number of grad. students—total salaries/year
6. Number of other people —total salaries/year
7. Capital equipment —dollars/year
8. Expenditures —dollars/year
9. Miscellaneous items —dollars/year
10. Overhead —dollars/year

Summary and Status:

1. Analysis of projects for the first 3 years, total costs figured and then averaged on yearly basis.
 - a. 100 contracts from biology, dental, physiology, microbiology, and clinical branches already have been analyzed.
 - b. Yet to be done for biochemistry and physiological psychology branches.
 - c. All ONR contract projects will be coded on the basis of BSIE codings by Orr E. Reynolds.
-

IV. *DOD Research and Development Board Projects*

1. Names of investigators
2. Location by institution
3. Cost per year

4. Project progress report
5. Number of people involved for the year

Summary:

1. Above information is obtainable from annual Technical Progress Reports.
2. Information will be separately obtainable for DOD contracts and the Intramural Program, except for the Army where intra- and extra-mural programs are not distinguished.

Status:

DOD classification will be changed to coincide with that used by BSIE. Orr E. Reynolds will begin this in June.

V. *Michigan Survey Research Center*

For note on Codes, see Appendix T, page 368.

APPENDIX N

EXCERPTS FROM NOTES BY BETTY LOBDELL ON THE ORGANIZATIONAL HISTORY OF THE AMERICAN PHYSIOLOGICAL SOCIETY (SURVEY PROJECT 16)

Affiliations of the American Physiological Society

At the time of its organization the Founders of the Society were evidently impressed with the desirability of maintaining an affiliation with medicine on the one hand and with the general biological sciences on the other. The medical connection was made with the Congress of American Physicians and Surgeons. This latter organization had just been formed. It provided for a conjoint meeting every third year of the national societies of the various medical specialties in order to bring together "the more active teachers and writers and workers in the leading branches of medical science." It was at that time a superior organization to the American Medical Association in that it was a more select body. The American Physiological Society with its relatively high standard for membership fitted into this group and its older members were prominent in the organization of the Congress. The affiliation was in every way desirable. The President of the Society was ex officio one of the vice presidents of the Congress and the Society had a representative on the executive committee.

As has been stated the first meeting held by the newly formed Physiological Society was in September 1888 in connection with the first meeting of the Congress. Thereafter for six successive triennial meetings of the Congress the Physiological Society met with them in Washington, at first in September but later, owing to complaint of the hot weather, in May. Within the Congress itself the closest affiliations of the Society were with the Association of American Physicians. On several occasions they held joint discussions. At the first Congress, 1888, as previously noted, there was a joint meeting of this kind, the subject for discussion being "The Relation between Trophic Lesions and Diseases of the Nervous System." The Physiologists were represented by Dr. H. C. Wood and the Physicians by Dr. E. C. Seguin. At the fourth Congress, May 1897, there was a symposium on "Internal Secretions" participated in by the Physiologists,

the Physicians and the American Pediatric Society. The Physiologists were represented by Dr. R. H. Chittenden and Dr. W. H. Howell. At the Congress of May 1907, there was a conjoint discussion of Acidosis, the Physiologists being represented by Dr. Otto Folin and the Physicians by Dr. E. P. Joslin.

This was the last Congress in which the Physiological Society participated. At the annual meeting in Baltimore, 1908, on motion of Doctor Meltzer the Society formally voted not to meet with the Congress in 1910.

The reasons for this action are not stated in the minutes, but the older members will, perhaps, recall that there had been some dissatisfaction on the part of the physiologists with the arrangements made for their meetings. The Congress had grown greatly in size. The members of the clinical societies far outnumbered those of the Physiological Society with the result that the former obtained the best assignments of rooms and upon the program. As a substitute for this connection it was proposed that arrangements be made to meet with the Section on Physiology and Pathology of the American Medical Association, but the proposal did not prove to be feasible owing to the existence of certain regulations which necessitated, either that the members of the Society should take out membership in the Association, or else accept invitation to the meetings in the status of invited guests.

Meanwhile suggestions had been made of a definite affiliation with the medical section, then section K, of the American Association for the Advancement of Science. At the 15th annual meeting in Washington, 1902, the matter was discussed but definite action was postponed on account of lack of a quorum, and there is no record that the proposal was brought up at the next meeting. Joint sessions with the AAAS were, however, arranged. There was a meeting with section K at New York in 1906, at Chicago in 1907 and at Baltimore in 1908. At this last meeting the Council asked for an expression of opinion from the Society on the question whether or not it was desirable to continue to meet in association with the AAAS. A motion made to continue the arrangement was lost, but a subsequent motion was carried expressing the feeling of the Society that combined meetings with section K were desirable from time to time, and giving the Council authority to arrange for such meetings at their discretion. The Council availed itself of this permission. At the Boston meeting, 1909, there was a joint meeting with section K. After an address on "Chemical Regulation of the Body Processes by Means of Activators, Kinases and Hormones" by the retiring vice-president of section K, W. H. Howell, there followed a symposium on "Internal Secretions" in which papers were read by R. H. Chittenden, W. G. Macallum, S. P. Beebe, J. B. Cooke and Harvey Cushing. At the Washington meeting in 1911 a similar conjoint meeting was arranged with section K with a symposium on "Acapnia and Shock." Papers were read by Y. Henderson, W. H. Howell, G. W. Crile, J. Erlanger and S. J. Meltzer.

In the next year, 1912, the first definite steps were taken toward the formation of a Federation with the Biological Chemists, Pharmacologists and Pathologists. The organization of the Federation of American Societies for Experimental Biology (FASEB) in 1913 seems to have satisfied the desire of the Society to bring its activity into cooperative association with other fields of scientific work. It is rather remarkable how persistent this desire for affiliation was. Some evidence of it is found in the proceedings of nearly all of the early meetings. Attention has been called to the efforts made to find suitable medical affiliations. The desire to establish associations with societies representing the biological sciences was equally evident. At the time of the organization of the Society arrangements

were made for joint meetings at times with the American Society of Naturalists. This Society was founded in 1883 and contained in its membership all the leading biologists of the country. It bore to the AAAS somewhat the same relation that the Congress of American Physicians and Surgeons did to the American Medical Association. A number of the members of the Physiological Society were members of the Naturalists, and there was for a time a feeling among some of them that the Society should become an integral part of the larger association, and thus emphasize the status of physiology as a biological science.

At the 6th annual meeting, New Haven, 1893, a Conference Committee consisting of Doctors Curtis and Lombard recommended a permanent amalgamation of the Society with the Societies of the American Naturalists, the Morphologists and the Anatomists. In this proposal the Naturalists were to function as the holding society. Each of the constituent societies was to elect its own members, but election to any one of the affiliated societies carried with it membership in the Naturalists. The societies were to meet at the same time and place, and there was to be a common fund in the hands of the Treasurer of the Naturalists to provide for general expenses and official publications.

The motion to approve this recommendation was defeated by a vote of 7 to 3, but at the next annual meeting, Baltimore, 1894, it was again brought up on a motion to reconsider. A motion was offered by Doctor Minot and seconded by Dr. Lee "that the society agrees to affiliate with the other societies on the terms already proposed." An amendment to this motion by Doctor Porter to the effect that "affiliation is desirable, meaning thereby an organic union of this Society with the other societies" came to vote and was defeated. Presumably the original motion by Doctor Minot was also lost, although this is not specifically stated in the minutes. A final echo of this relationship to the Naturalists occurs in the minutes of the 25th annual meeting at Cleveland, 1912. When a conference committee was appointed to arrange for the Federation with the Biological Chemists and Pharmacologists it was also directed "to confer with the committee of the American Society of Naturalists with regard to the question of forming a closer affiliation." If such a conference was held it was without result since no report was made subsequently to the Society.

APPENDIX O

EXCERPTS FROM THE PRESIDENT'S NEWS LETTER, AMERICAN PHYSIOLOGICAL SOCIETY, SPRING 1957

TOUR OF THE PRESIDENT-ELECT

The most important purpose of the President-Elect tour is to test the current thinking of Council and of those members of the Society who attend, speak up and vote at the business meetings, against a random sampling of the Society at large, its potential future members, and its friends. This sampling, it is hoped, is a true aliquot of the multiple interests of the Society, which includes the outspoken and the shy, the old and the young, those of firm convictions and those more uncertain, etc. It is an important aim of the visits to bring into proper balance the 'grass root' thinking of the membership with that of the governing bodies which, for the moment, determine policies.

It was my particular aim to deal with broad philosophical questions rather than with specifics. I wondered what physiology is, where the discipline is going and where the American Physiological Society fitted in. Other purposes of my inquiry were to determine:

1. Whether or not teachers and graduate students should be admitted to membership.
2. The role of the APS in teaching physiology, training physiologists, in recruitment and in public relations.
3. The need of glorifying teaching as distinct, but not separate, from research in physiology.

The answers were revealing to me in showing the diversification of viewpoints on these matters; however, it was pleasantly surprising that in some areas the views were strikingly consistent. Particularly was this pleasing to me in areas in which I had similar strong personal convictions which I did not hesitate to express.

Physiology, Physiologists and the American Physiological Society

In my opinion, physiology is dynamic biology. Physiologists are those who operate in the field of physiology as administrators, teachers, preceptors or investigators (or combinations thereof). I decry the splintering of physiology now going on and hope that the breadth and excitement of dynamic biology will unite all physiologists. There is need for broad concepts sweeping across all subdivisions to stimulate interest in biology. We are encumbered by the difficulties of semantics and of complicated technology, and by the overwhelming occupation with detail. All those factors tend to keep us down to earth so that it is sometimes difficult to see the beautiful vistas over the mountains.

There is too much dominance of medicine in physiology. Many of the sweeping discoveries of the future will come from other basic areas of physiology. We need a meeting of the minds of all types of physiologists since surely we are in a golden era of physiology.

We need to deemphasize system and organ physiology in the American Physiological Society. Splintering, in short, should be slowed down, stopped and reversed.

As to where the science of physiology and the American Physiological Society is going is anyone's guess. My own is that the study of regulation by hormones and the nervous system will become more and more dominant in physiology. This implies the study of the animal as a unit, rather than of its parts. It, of necessity, leads to concern with genetics, ecology and psychosomatics. Broad principles along these lines will develop which will be as exciting as those now occurring in the physical sciences.

At the same time, I would predict a greater concern will develop in relation to cellular and molecular physiology which will give more insight into the basis of the now fashionable area of system and organ physiology.

The era of radiations, aviation and extraterrestrial flight will force a more balanced distribution between the biological and physical sciences. I am given to understand that biology is, or may become, the bottleneck in future developments in those areas.

Admission of Teachers and Graduates to Membership in the American Physiological Society

This problem was thoroughly explored and many views expressed. We should concern ourselves with the problem of creating an 'umbrella' for teachers, graduate students and others who can be considered as professional or apprentice physiologists. This may mean the creation of an overall Biological Group encompassing all 'non-medical', pre-clinical and clinical biologists. This overall group might be created as a counterpart of the overall groups now in existence for physics, for chemistry and for psychology. These are far reaching actions and should be entered into slowly, cautiously and with due deliberation. The need is obvious, the manner of fulfilling the goal difficult.

Role of the American Physiological Society in Teaching Physiology, in Recruiting and Training Physiologists, and in Public Relations

There was surprisingly little opposition to the proposition that the American Physiological Society become actively involved in this broad area, although the tactics and strategy to be employed was a subject receiving wide divergence of views. This acceptance pleased me greatly since I, myself, believe this is an important role of the American Physiological Society. The recent action of Council in these areas is thus widely supported.

I do want to say a few things about public relations. Physiology (dynamic biology) is not getting its message across to the public, whose servant it is. Physiological endeavor and discoveries are labelled medicine, chemistry, physics, agriculture, etc. because these latter areas are familiar to the public, while physiology is less widely known. The problem of recognition of physiology as such determines recruitment, salary, and the attention received by physiologists in all areas of government, industry, research and university life. There is today a shortage of graduate students in physiology. Conditions of work in colleges and universities for physiologists are far from ideal. All these things are true both in the absolute and relative sense; relative, I mean, to other areas of science.

It is my considered judgment that the ultimate responsibility for all of this rests with the public. To act, the public must know. To know, it must be informed. Public relations is a dignified profession which serves to inform the public. I am impressed with the good that can be accomplished by good public relations.

Bringing Better Balance Between Research and Teaching

In the present era of rich allocating agencies both in and out of government, there has grown up a fetish, a worthwhile one by the way, about research. One undesirable by-product has been, in my opinion, the relegation of teaching to a somewhat secondary position among the less thoughtful. It is self-evident that all problems will not be solved in our lifetime. It follows, therefore, that new investigators need to be trained to succeed us. Teaching on this basis is as vital as investigation.

My suggested solution is that there be established two categories of distinguished teachers equivalent to the existing two special ranks of investigators, namely 'Established Teachers' and 'Career Teachers'. These titles should be conferred upon a limited number of persons who in the judgment of a selection

committee are considered pre-eminent in their group. The 'Established Teacher' should be on a five-year appointment, the 'Career Teacher' on a lifetime tenure. Emphasis should be on teaching ability and potentiality. While research is necessary for every teacher, the emphasis should not be on research, but on teaching. The support should come from an outside agency and remuneration should be greater than that received by others in the institution of similar teaching responsibility. This sketchy outline is far from complete. I recognize fully the difficulties of selection of qualities and persons, the procuring of funds for this program, and some of the problems the program will create. Nevertheless, the idea seemed to receive sufficient support on the tour to justify having a committee look into the matter.

—LOUIS N. KATZ

PROBLEMS IN BIOLOGY TEACHING IN AMERICAN COLLEGES

Summary of Report to the Committee on Education, American Physiological Society

In the fall of 1956 I made the first 'teaching tour' for our Society, as part of the program of our Committee on Education. I visited 20 colleges and 4 medical schools mainly in Ohio and North Carolina. I conferred with faculty groups numbering about 160 teachers of biology of whom about one-third are engaged at least part time in physiology instruction. The purpose of the tour was to make a reconnaissance of the present teaching situation in biology, with particular reference to physiology.

It is a rare event to discover a college teacher of physiology who is willing to call himself a physiologist. In most cases he has had at least one course in the subject, in graduate school. But his degree is almost never in physiology. He holds the Ph.D. degree in zoology, botany or biology, and his major interest usually is in one of the biological specialties other than physiology. If I attempted to urge the claims of physiology many of my auditors became uneasy. I made better headway if I talked about 'dynamic biology'. I devoted some time to pointing out that a functional emphasis has now developed in almost all biological specialties, both in teaching and research. This trend is widely recognized, but the college teachers often think of it as something other than physiology.

This psychological difficulty is related to the admission policies and professional attitudes of our Society. Of our 1500 members only about 100 teach at the college level. It has been our custom, for many years, to admit to membership only those who have made a substantial contribution to our science, in research and publication. Few college teachers can satisfy our requirements.

College teachers of biology, in common with their colleagues in other disciplines, often have to carry on their work under very discouraging circumstances. Regular salaries are low, and summer salaries, needed to supplement income, are often even lower. Teaching loads are heavy. In most of the colleges which I visited research activity is impossible. If present conditions in the smaller institutions are to continue the teachers might just as well be trained in graduate course work leading to the M.S. degree, and not attempt the more arduous preparation for the doctorate. They might thereby avoid some of the sense of frustration and defeat from which many of them suffer.

The college teacher of physiology is usually relatively isolated. He is rarely a member of our Society, has not attended our meetings, knows few other physiol-

ogy teachers, and has little or no contact with the faculties in the universities and medical schools of his region. These faculties have made little effort to keep in touch with him. The colleges which I visited have rather meager library facilities in our field. Even if more abundant materials were available the physiology teacher would have little time to read. Textbooks must remain his major source. Our committee should prepare a list of the recent monograph, symposium and review literature. A small library of this type should be exhibited at our workshops.

I want to express my admiration for the devoted service to our science given by many of the teachers whom I have met. They arouse the initial interest in physiology and point the way to the graduate schools. The smaller colleges are still a very important training ground for the recruitment of scientific personnel. In spite of all difficulties and deficiencies in these schools the close relationships between staff and students engender enthusiasms which many larger institutions fail to produce. The future development of our science depends very much upon the college teacher of physiology.

It appears that American medical schools exercise a very considerable influence upon the organization of biology teaching at the college level. In particular the teaching of physiology is being modified, or even, in extreme cases, suppressed. This influence is not an organized effort on the part of the Association of American Medical Colleges or any other official body. The pressure arises less directly, in advice given in the college catalogues, in conferences between medical deans or admission officers and prospective students, or in comments voiced at scientific meetings. The problem is therefore difficult to describe and assess. Nevertheless, it is a prominent factor in the thinking of many college teachers. While the special needs of pre-medical students should always be considered in planning the college biological curriculum, there is surely no justification for dictation or pressure by the medical schools which might influence instruction given to the large number of other students. The problem deserves further study by our Committee, to the end that our Society, after fuller consultation, may make recommendations.

The medical schools influence the teaching of physiology in the colleges in other ways. There has been a steady movement of Ph.D. physiologists trained in departments of zoology or biology into medical school teaching and research, or, to a lesser degree, into research in government or industrial laboratories. The result is the reduction in the number of trained physiologists available for service in the colleges. A study of 327 members of our Society shows that 55 per cent hold the Ph.D. degree only, 35 per cent hold the M.D. degree only, and 10 per cent hold both degrees. Forty per cent received their Ph.D. from college or university departments, but only 8 per cent now serve there. Seventy-two per cent serve in medical schools or hospitals, 20 per cent serve in government or industrial laboratories.

Medical schools have a certain advantage in recruiting graduate students who wish to specialize in physiology. Nevertheless, many such students are not aware of medical school possibilities when they make their choice, and tend to continue their study in the same departments of zoology or biology in which they took undergraduate work. Graduate programs in our field should be strengthened in such departments, and increased in number. A definite effort should be made to prepare college teachers of physiology at the Ph.D. level for schools able and willing to support them properly.

I have had opportunity to talk with a number of college students, majoring in

biology, who are considering graduate work. Most of them appear to be poorly prepared to make a choice of a graduate school. I made no effort to recommend any particular schools, but I did urge them to seek a faculty where they could take course work under at least three well trained physiologists, all active in research and able to teach at the graduate level. I took the position that a Ph.D. candidate in our field should obtain a wide range of course experience, from observations of protozoan life through invertebrate, cellular and comparative physiology to mammalian operative work. I stressed the need to acquire some familiarity with many experimental techniques, old and new. I warned them to avoid such graduate possibilities as are offered by some installations of the Armed Forces, in collaboration with a university, where only a few hours each week can be devoted to advance study and the permanence of the program cannot be guaranteed. I also warned them against the dangers implicit in part-time graduate work in which a stipend is paid from a research grant, held by a faculty member, which creates an obligation to help him with his own research. In some cases a species of exploitation develops, with degree work delayed and training narrowed. The graduate student should not be confused with the research technician. In lieu of such inferior programs I recommended the further development of national fellowships, such as those offered in increasing number by the National Science Foundation and the National Institutes of Health.

For the guidance of young people who are considering graduate work in our field the Society should prepare and distribute a pamphlet, describing graduate programs now offered in the universities and medical schools of the United States, Canada, and Mexico. In preparing such a pamphlet the Society should exercise discretion, publishing those graduate programs which are considered acceptable, after study of each by a responsible committee. Through its Placement Service the Federation publishes a list of Fellowships and Assistantships now available in our field. The proposed pamphlet should include the predoctoral positions offered by each school and by the NSF and NIH.

In the high schools biology instruction is greatly influenced by the schools of education. Their graduates staff the state, county and city departments of education and form a considerable percentage of the teaching faculties. The education schools stress the more formal aspects of instruction. They often emphasize methodology to the detriment of scientific content. A conflict arises between teachers so trained and another group, consisting of graduates of departments of zoology or biology, who wish to enrich the course content.

The conflict of opinion in the high school teaching field is somewhat reflected in the existence of two national societies of teachers. The older National Association of Biology Teachers, affiliated with the AAAS and the AIBS, includes both high school and college teachers and stresses course content. This association publishes "The American Biology Teacher" and organizes summer conferences. The newer and larger National Science Teachers Association, affiliated with the AAAS and the NEA, includes high school and college teachers in all sciences and mathematics and lays emphasis upon methodology. It publishes "The Science Teacher" and several bulletins. Our Committee should know more about the work of these two organizations.

Great variations exist in the choice of material for laboratory work in college biology. Except in physiology courses there is a strong tendency to use preserved material, even though, with little or no extra trouble, living specimens can often be obtained. Physiologists must regret this concentration of attention

upon the dead body. I recommend that our subcommittee which is collecting and studying laboratory manuals in physiology give some thought to this problem.

—WILLIAM R. AMBERSON

APPENDIX P

APPLICATIONS AND CONSEQUENCES

For each field of applied physiology (see list below) the following points are to be covered:

- A. Definition of the field and its relation to physiology
- B. Employment in the field
 1. Number of physiologists active in it
 2. Number of other kinds of people in this field of applied physiology
 3. Attributes of employment in the field
- C. Extent of physiology taught in the field
- D. Consequences of physiological contributions to the field
 1. From past contributions, including changes in physiology
 2. Effects of new instrumentation and techniques
 3. Case histories of utilitarian applications of basic physiological findings
 4. Money put into physiology by the field
 5. Money *from* physiological application in the field
 6. Future consequences of physiological contributions
- E. Needs of field
 1. Number of physiologists required
 2. Optimum amount of physiology to be taught
 3. Need to educate the scientist and industry on possibilities and advantages of physiologists in the field
 4. Need to erase cultural stigmata of industrial connections
 5. Is technical pyramid of field insufficient to support physiologists *per se*
 6. Are other scientists with secondary biologic skills utilized by the field for biological problems rather than special consultants
 7. Is (6) in part due to lack of familiarity with expert personnel outside the field
 8. Combinations of training needed for border areas between physiology and the field

FIELDS TO BE COVERED

Basic Sciences

Anatomy	Cytology	Microbiology
Anthropology	Ecology	Paleontology
Biochemistry	Embryology	Parasitology
Bioclimatology	Genetics	Psychology
Biophysics	Hematology	Radiobiology
Botany	Immunology	Zoology

Medical Sciences

Anesthesiology	Ophthalmology	Surgery
Dermatology	Otology	Tropical Medicine
Environmental Medicine	Orthopedics	Urology
Geriatrics	Pathology	Clinical Psychology
Gynecology	Pediatrics	Dentistry
Industrial Medicine	Pharmacology	Optometry
Internal Medicine	Physical Medicine	Osteopathy
Laryngology	Preventive Medicine & Hygiene	Pharmacy
Legal Medicine	Psychiatry	Physical Therapy
Military Medicine	Roentgenology	Public Health
Neurology		Veterinary Medicine
Obstetrics		

Agriculture and Natural Resources

Plant Production Animal Production Conservation Economic Entomology

Engineering and Industry

Industrial Physiology and Hygiene Human Engineering (Environmental Physics)
 Industrial Toxicology Health Physics

Application to Products of Industry

Food and kindred products	Printing & publishing	Electrical machinery
Tobacco	Chemical & allied industries	Machinery
Textiles & fibers	Petroleum & coal	Automobiles & equipment
Apparel, etc.	Rubber	Transportation equipment
Lumber & timber	Leather	Misc. industries
Furniture & finished lumber	Stone, clay, glass	
Paper & allied products	Iron & steel	
	Nonferrous metals	

Other Fields

Home Economics Health Education Nutrition

ESSAYS ON THE APPLICATION OF PHYSIOLOGY TO OTHER FIELDS
 (From Survey Project 4B)

Human Physiology	..... E. M. Landis	..... Harvard Univ.
Veterinary Physiology	..... H. H. Dukes	..... Cornell Univ.
Insect Physiology	..... K. D. Roeder	..... Tufts College
Plant Physiology	..... J. Bonner	..... California Inst. of Technology
Development of Plant Physiology	..... F. W. Wendt	..... California Inst. of Technology

History and Physiology	J. M. D. Olmsted	Univ. of California, Berkeley
Pharmacology	C. F. Schmitt	Univ. of Pennsylvania
Anesthesiology	R. D. Dripps	Univ. of Pennsylvania
Pediatrics	H. L. Barnett	New York Hospital
Otology	H. Davis	Central Inst. for the Deaf
Laryngology	H. G. Kobrak	Univ. of Chicago
Ophthalmology	F. H. Adler	Univ. of Pennsylvania
Optometry	G. L. Walls	Univ. of California, Berkeley
Hematology	E. Ponder	Nassau Hospital, Mine- ola, N.Y.
Dermatology	S. Rothman	Univ. of Chicago
Dentistry	L. L. Schwartz	Columbia Univ.
Physical Medicine	F. A. Hellebrandt	Univ. of Illinois
Therapy & Physical Medicine	F. J. Kottke	Univ. of Minnesota
Public Health	J. L. Whittenberger	Harvard Univ.
Preventive Medicine & Hygiene	A. Keys	Univ. of Minnesota
Health Education	H. F. Kilander	New York Univ.
Nutrition	H. H. Mitchell	Univ. of Illinois
Agriculture	M. Kleiber	Univ. of California, Davis
Physiological Embryology	S. R. M. Reynolds	Carnegie Inst., Baltimore
Human Development	L. W. Sontag	Antioch College
Gerontology	N. W. Shock	National Heart Inst.
Human Engineering	C. L. Taylor	Univ. of California at Los Angeles
Air Conditioning	L. P. Herrington	John B. Pierce Founda- tion
Bioclimatology	A. Henschel	Army Quartermaster Center
Psychophysiology & Military	R. G. Dags	Army Medical Research Lab.
Psychology	C. Landis	Columbia Univ.
Radiobiology	A. M. Brues	Argonne National Lab.
Genetics	J. W. Gowen	Iowa State Univ.
Zoology	C. L. Prosser	Univ. of Illinois
Paleontology	A. S. Romer	Harvard Univ.
Physical Anthropology	W. L. Straus	Johns Hopkins Univ.
Electroencephalography	M. A. B. Brazier	Massachusetts General Hospital
Microbial Physiology	R. Kallio	Iowa State Univ.
Health Physics	J. N. Stannard	Univ. of Rochester
Cytology	J. Gersh	Univ. of Chicago
Pharmaceutical Industry	K. K. Chen	Eli Lilly & Company
Industrial Toxicology	J. A. Zapp	Haskell Labs.
Animal Production	M. Kleiber	Univ. of California, Davis
Tuberculosis	G. W. Wright	St. Luke's Hospital, Cleveland

Summary by R. W. GERARD

APPENDIX Q

ACTIVITIES OF COMMITTEE ON EDUCATIONAL MATTERS

The Committee, consisting of W. R. Amberson, J. H. Comroe, Jr., C. L. Prosser and E. F. Adolph, was established in 1953. (A. W. Martin was appointed as an additional member in 1957.) Its aims are to provide communication among teachers, and to aid teachers to enlarge their experience in physiology. It is committed to the notion that teaching may share with research the high esteem of Society members. The following projects are currently active.

1. *Teaching Session.* This special session is held annually in connection with the spring meeting of the Society. This year a discussion was scheduled and held on the topic "Graduate Students in Physiology". The chairman (E. F. Adolph) proposed some twenty questions serially to a panel of eleven participants as listed on the Society's program. The participants were volunteers in advance of the discussion. The questions dealt with the aims of students, the qualities, the education and the needs of students. Diverse viewpoints were represented. In addition, two separate papers were given at the teaching session.

2. *Refresher Course.* The annual course was initiated in 1954 by J. H. Comroe. The course at the fall meeting of 1957 will be given on Tuesday, September 3rd, at Iowa City. Subject: "The Teaching of the Neurophysiology of the Central Nervous System." It is being organized by J. M. Brookhart with the assistance of V. Mountcastle and W. Nastuk. As usual, it is designed for non-specialists, and will illustrate general problems of instruction as well as deal with specific subject matter.

3. *Workshops.* Two workshops on college teaching of physiology will be held in 1957, with the financial support of the National Science Foundation. One, in the northwest sector, organized by B. T. Scheer, will be held at the University of Oregon in Eugene, August 12th to 23rd. The other, in the southeast region, organized by P. R. Morrison, will be held at Guilford College, North Carolina, from September 2nd to 13th. For each workshop about 30 participants have been selected from applicants. They will discuss common problems of attitudes, methods, and materials. The Committee on Education has been largely guided in its undertakings by the discussions at previous workshops. A subcommittee for guidance of the workshop project consists of C. L. Prosser and R. R. Ronkin.

4. *Teaching Monographs.* A small collection of monographs, suitable for use of college teachers and students, is being gathered by W. R. Amberson and C. Tum Suden. These will be available at each of the workshops, and workshop participants will attempt to evaluate the usefulness of the books represented. An annotated list of the titles can then be made for distribution.

5. *Summer Traineeships.* Temporary placement of college teachers of physiology in research laboratories is being accomplished with financial aid of National Heart Institute and National Science Foundation, and gifts from individuals. For 1957, some 47 applicants have been chosen by the Committee on Education. Among them several trainees of 1956 were reappointed. Each trainee spends 8 to 12 weeks in a laboratory of his choice, usually selected from a list

of laboratories belonging to Society members who volunteered to act as hosts. The trainee receives informal instruction in current laboratory procedures, and initiates some research activity of his choice. The interest, experience and motivations in research are expected to influence the teacher's instruction and guidance to students. The liaison with the host physiologist and institution will usually continue. The administration of this trainee project requires many weeks of time; it is being conducted in the Society's office by R. G. Dagg, with the advice of W. R. Amberson and W. J. Bowen.

6. *Research Grants to Trainees.* Applications for research grants are submitted to the National Institutes of Health from those who have been summer trainees. The purpose of these small grants is to aid those teachers who wish to undertake some form of laboratory research in establishing this activity in their own colleges. Grants are used for the purchase of equipment and supplies, and for compensation of student helpers.

7. *Roster of College Teachers.* For purposes of the Workshops and the Traineeships, a working list of those who teach courses in physiology in Arts colleges has been formed by Dr. Amberson and Dr. Dagg. By means of this list, workshops in particular territories are announced, and traineeship opportunities are broadcast.

8. *Teaching Tour.* The first tour by a member of the Society specifically in the interests of educational matters was made in November 1956 by W. R. Amberson. The cost of the tour was underwritten by the Council of the Society. Dr. Amberson visited a cross-section of Arts colleges, conferring with teachers and with student groups where requested. He brought back much information (see summary of report) showing the complex factors that determine the kinds of instruction done by teachers of biology and the future of students who may be considering a choice of careers in biology. Subsequent comments from some of the teachers indicated that both teachers and students appreciated the opportunity to converse with a visiting physiologist. A second teaching tour is planned for November, 1957, not limited to any particular kind of institution; invitations from those who may wish to receive a visit free of obligation should be sent to E. F. Adolph.

9. *Other Meeting Programs.* Members of the Education Committee and certain other Society members participated in special activities of other organizations. Our Society sponsored a session in the American Association for the Advancement of Science in December, 1956, organized by F. A. Hitchcock, on "The Training of Biological Scientists." The Committee participated in a special session of the American Institute of Biological Sciences in August 1956 on "Education and the Future of Biology." The Committee is also represented in other educational activities of AIBS, and of the Biology Council in the National Research Council.

10. *Policy.* The Committee on Education has thus undertaken a limited number of projects that appeal most directly to the interests and capabilities of Committee members. No evaluation of results from these projects can yet be obtained, except in terms of the immediate increase in morale among those who participated in them. The Committee wishes to point out that organized projects constitute a limited portion of the things that need to be done in education. The encouragement of effort and thought in teaching lies in the hands of every person engaged in intellectual work. Most of it needs to be done daily in unobtrusive ways. Friendliness and helpfulness to colleagues and students can easily outrank all the above projects in ultimate effectiveness in education

—E. F. ADOLPH, *Chairman*

APPENDIX R

DETAILS ON MEN AND MONEY

In 1953 the U. S. population was edging 160 million and the total labor force, including 3.5 in the military, was almost 67. In civilian employment were 62 million men and women (83). Total specialized talent was estimated at 1.3 million, about 0.5 in some areas of biology (122). Living college graduates (or holders of a professional degree not involving a bachelor's degree) numbered 5.8 million, 92% of all who had received degrees, and included 640,000 in natural science, 91% of all who had received degrees in natural science. Biological majors numbered 235,000 (92% of all degree recipients); those in applied biology, 300,000 (95% of all recipients), half each in agriculture and home economics; and health practitioners 480,000 (83% of recipients), including 205,000 (81% of recipients) physicians and 95,000 (81% of recipients) dentists (122).

The workers in natural science in 1953 numbered 200,000 according to the NSF (93), 237,000 on Wolfe's analysis (122); and biologists accounted for 50,000 (25%) or 52,000 (22%) of these. Workers in applied biology, 245,000 (205,000 of these in agriculture) and health fields, 735,000 (185,000 in medicine) are not included in these estimates, except for some high-level agriculture workers in the NSF figure. The most recent estimate (Meyerhoff, 56) yields 64,000 biologists: one-half in education (24,000 in colleges and universities and 7500 in secondary schools); this latter figure is still only a third of the 20,000 teachers giving high school biology (38); one-fourth in government (11,000 in federal and 5500 in state employ); 18% (11,500) in industry; and 7% (4000) in miscellaneous occupations. Of the 24,000 in higher education—38% of all biologists—5500 teach in biological science, 6000 in agriculture, and 13,500 in medical science. Wolfe's figures are: 10,000 teaching in biological science, 8000 in agriculture, 4000 in home economics, and 16,000 in medical science (including dentistry and other groups)—19% of the 200,000 college and university teachers (full-time equivalents).

The NSF (93) figure for 1951 gives about one-third each of biologists (including some in agriculture) in teaching, research and development, and other; more comparable categories are: 21,000 men in biology (and agriculture) divided: one-half (47%) in education, one-third (33%) in government, and the remaining one-fifth (20%) in various occupations, mainly (12%) manufacturing. By contrast, all scientists, in 1950, were distributed: 25% in education, 17% in government, and 58% in industry; and in 1956, 20%, 20%, and 60% (89). A preliminary statement for 1956 (89, 97) gives 250,000 scientists, three-fifths in industry and one-fifth each in academia and government; with biologists (presumably only 60,000) mostly (44%) in government, a third (34%) in teaching, and fewest (22%) in industry—surprising shifts. Other NSF figures (98) are 25,500 biologists (50%) in academia, 14,000 (28%) in government, and 10,500 (23%) in industry. Of the various workers (1953), three-fourths (74%) of all

in natural science are college graduates, with the biological scientists highest, 88%. In applied biology 62%, and in health fields 59%, are college graduates, the actual numbers now alive being: biological scientists, 235,000; applied biologists, 150,000; and health practitioners, 435,000 (122). For 1954, one estimate is 15,000 college and university teachers in biology and agriculture, in a total of 42,000 teaching science and engineering; other figures, for 1953 (108), are: 18,000 teaching life science and 6000 teaching agriculture—of the 63,000 scientists and engineers on the faculties of 1800 colleges and universities.

Since 90% of all physiologists are at the Ph.D. level, this level is of primary concern. Living Ph.D.'s in 1953, according to Wolfe (122), numbered 96,600 (91% of all who had received Ph.D.'s) and included 40,800 in natural science, of which 14,100 (90% of recipients) were in biological science. Another 3500 in agriculture and home economics and 600 in health fields, gives a total of biological Ph.D.'s of 18,200 (122). An estimate of NSF (93) gives 40,000 science Ph.D.'s in 1953, of which 13,500 (35%) were in biology and agriculture; and still another estimate (98) gives 23,000 Ph.D.'s in biology. NSF (93) figures for 1951 also give 40% Ph.D.'s and 5% M.D.'s among 21,100 (18,500 employed) men in biology and agriculture (only 60% of these were in biology—35% in animal, 11% plant, and 13% in bacterial areas), yielding at most 8500 doctorates. The present study identifies 5750 physiological scientists, of whom 80% have Ph.D.'s (and 9% have the M.D. alone), and one-third are core physiologists.

This population of workers in science is, of course, a cross section of the steady stream of additions and losses. The latter have averaged about 10% by death for biology Ph.D.'s and, since only about 10% of those now living are over 60 years old, this figure should not rapidly increase. Of living masters in biology, 9% are not in the labor force, and in the health field, 15% are lost; of bachelors (or those with the first professional degree) the loss in biology is 17%, in medicine 4% (122). It would seem a reasonably conservative guess that, with an average service life of forty years, losses of biology Ph.D.'s in the next decade should not exceed 1% per year.

In 1953, one-fifth of all high school students, 1.3 of 6.5 million, were taking biology courses, 73% of those in the grade where biology was offered (9). In 1957, 8 million pupils were in high school and 1.5 million of them were taking biology, half again as many are estimated for 1967 (63). Other figures for high school enrollment (87) are: 1955, 7.4; 1960, 9; 1965, 11.9. The number in college in 1957 was 3.2 million (63)—of whom 0.5 million took biology—with 6.3 million estimated for 1967. In 1953, 75,000 college students took a physiology course; a drop of 6000 from 1949 (Chapter X). More conservative total enrollment figures (83) are: 1953, 2.3 million (2.1; 82); 1955, 2.5; 1960, 3.0 (2.9; 122); and 1965, 3.8 (122); and still others (87) are: 1955, 2.8; 1960, 3.8; 1965, 4.9. College graduates in 1953 were 300,000 (83); and in 1955, 287,000 (275,000; 122); estimates (122) for 1960 and 1965 are 326,000 and 454,000.

In 1950, 25% of biological scientists (in comparison with 15% of all natural scientists) were women; and a year after graduation (1951) male majors in biological science were 23% in professional work (including teaching)—only 7% in biology—and 47% in advanced study (15% in the armed forces), while female majors were 55% in professional work—18% in biology—and 21% in advanced study. Of all graduating in biological science, one-fourth enter that field professionally; and only one-fifth of those taking physiology courses have

the background to continue in this field (Chapter X). Masters in biology living in 1953 were: 11% students, 11% teaching, and 60% in professional work—45% in biological science (122). Of all the 49,000 recipients of degrees (B.S. to Ph.D.) in natural science in 1951, only 42% (20,500) were then entering professional employment. With 36,000 degrees a year, estimated between 1953 and 1957, 15,000 would enter science (122).

Students in life science in 1953 constituted 8% of the graduate body (99), 17,000 of 210,000; and of these 9500 were in biology (108a) and 6300 were taking courses in physiological science. Majors in physiological science numbered 1600, with half in departments of physiology. Ph.D. candidates included 980 in physiological science, with 475 in physiology (Chapter X).

Ph.D.'s given in 1953 totaled 8310 of which 4720 were in science, 900 in biology plus 600 in other life sciences (93), 210 in physiological science, and 95 in physiology (Chapter X). For 1955 the figures are 8840 total (83), with 4900 (97) or 4800 (93) in science, including 1000 in biology, 500 in agriculture, and 300 in health fields. For 1960, science degrees are estimated at 5800 by one source (97), at 6700 by another (88). Total Ph.D.'s are placed by still another estimate (122) at 7000 for 1955, 6600 for 1960, 8500 for 1965. Specialized personnel in physiological science, as in all else, is now near neap tide; the new flood will roll in during the coming decade.

Industry in 1953 employed some 10,000 life scientists, including those in agriculture and health, and of these 3500 were in research and development, R&D (103). The life scientists constitute about 2% of the total industrial science and engineering force (89) and between 3% and 20% of research personnel in various industries (104, 105); and these fractions seem to be increasing. Figures for 1951 (93) suggest about 2500 R&D life scientists then; and for 1956 (89), some 12,000 life scientists in industry probably include over 4000 in R&D. Most industrial biologists are employed in the chemical industry (45%), with food (22%), manufacturing (19%), and paper (6%) next common. The life scientists in R&D (1953) included 1600 in biology, 800 in agriculture, and 1000 in health; an educated guess from the available data (103) would place them as follows:

R&D Life Scientists (1953)	Chemistry	Food	Manufacturing	Paper
Biology	1000	400	200	50
Agriculture	100	300	200	200
Health	700	100	200	50
All (1951)	1100	500	600	300

Since chemicals (and drugs) are growing especially rapidly, almost doubling in five years, it would seem a moderate expectation that by 1960 industry would need 3000 to 3500 additional life scientists in R&D (over 2500 in the chemical areas) and 8000 to 9000 altogether. The annual increase would be, say, 400 and 1000. This 400 compares reasonably with the estimate below (from Ewell's data) of 2000 more R&D biologists by 1960.

In the five years 1956 to 1960, new college teachers required are estimated at 60,000 (97) or 90,000 (23), almost 5000 of them in biology. If comparable increases (50% to 80% of the present number, depending on the estimate used) applied to the agriculture and medical fields, 20,000 new life scientists would be required for higher education. Put the figures at 1000 and 4000 a year, respectively.

In 1951, 7000 life scientists were in government, on one estimate (93), 35% of the 20,000 identified in rosters; another figure is 15,000 (25% of 60,000; 56); and an estimate for 1956 (89, 97) has increased this to 45%, almost 30,000 men, which may include a wider group. These figures suggest an annual increment of over 4000 a year, probably too high; but certainly government is increasing its share of life scientists. Say the average increment to 1960 is 2000 a year.

The roughly 60,000 biologists in 1953 included some 15,000 Ph.D.'s. Those in colleges and universities doing teaching and research numbered over 20,000 and included perhaps 10,000 of the Ph.D.'s; the federal government employed about 10,000 (and states another 5000), of whom maybe 2500 to 3000 were Ph.D.'s; industry employed under 10,000, including perhaps 1500 to 2000 Ph.D.'s (all in the 2500 non-medical R&D group); and another 4000 biologists, say 500 Ph.D.'s, remained in other categories. These estimates, and it must be emphasized that only general magnitudes enter here, show an annual need of 7000 life scientists at all levels, 4000 in higher education, 2000 in government, and 1000 in industry; and of these some 2000 must be at the Ph.D. level, up to 1300 in academia, 400 in government, and 300 in industry.

To meet these needs, there are presumably available some 20,000 bachelors a year in biology and another 50,000 in applied biology and health fields, but only 1000 Ph.D.'s in biology and 800 in agriculture and medical fields (estimates for 1955, above). A more stringent view is that little more than two-fifths of all degree recipients continue professionally and that only 15,000 recruits will enter natural science in each of the years now upon us (122). This would mean about 5000 biology bachelors a year and perhaps 3000 in agriculture. Through 1960, Ph.D.'s in science will not rise above 6500 a year, from the 1953-55 levels of about 4800, and the fraction in biology is falling, so that 1000 a year is perhaps a ceiling for the present; and an absolute increase in employed biology Ph.D.'s of not over 900 a year, plus 800 in agriculture and health, may be a reasonable figure. Clearly, the supply may meet the demand at the lower levels—7000 life scientists needed, 8000 produced—but will fall short at the professional level at which physiologists operate—2000 needed, 1700 available.

For physiological science, calculated as one-third of biological science, 700 Ph.D.'s would be needed a year; and for core physiology, about 2000. As seen, the anticipated supply is 200 in physiological science, 100 in physiology (animal) and surely not as many more in the plant and bacterial areas. The present distribution of physiologists, neglecting 'other', is 72% in academia, 16% in government, and 12% in industry; as compared with Ph.D. needs for biologists of 65%, 20%, at 15% estimated above. Again, the supply is tight for the needs, with the academic group under special pressure.

Turning now from men to money, the Gross National Product (GNP) was 360 billion dollars in 1953, having risen on the average 3% a year since 1910 (19). One or more percentage of this—3.8 billion on one estimate (19), 3.5 to over 5.4 on others (89, 107)—was spent for research and development (about two-thirds by industry, one-third by government) and about ten times as much (41 billion) was spent on the capital outlay (broadly interpreted to include, e.g. education) needed to convert the R&D gains into economic output. R&D expenditure has increased an average of 10% a year, three times the rate for GNP, and seems to be accelerating. Comparison of different industries shows a striking relation, which might well be causal, between percentage of sales income invested in R&D and percentage increase in total production. From 1939 to 1953: R&D's of 0 to 1% were associated with increases of 40% to 180% (e.g. food,

lumber, metals, paper, petroleum); of 1% to 3%, with 100% to 300% increase (rubber, glass, some machinery); and of 3% to 5%, with 400% increase (chemicals). Drug companies, of especial interest because of the rising employment of life scientists, invested over 5% in R&D and increased over 500% (19). The over-all R&D in industry in 1953 was 1.7% of sales, with high values in areas heavily subsidized by government, as aircraft, 9%, or electronic equipment, 6% (103). Like evidence comes from comparing countries; the greater the fraction of GNP spent on R&D, the greater the per capita GNP (44). Rough values are: Japan, 0.1% and \$250; France, 0.5% and \$1000; U.S. 1.1% and \$2000. Russia, with a late start, now invests 1.2% but still has reached only \$700.

Ewell, to whom many of these points are due, estimates that the U.S. rise in GNP, 3% a year, depends about one-third on population increase (or better, labor force increase, 1% a year) and two-thirds on rise in productivity—the product (in dollars) per hour per employed worker. Productivity has risen 2.4% a year for over forty years, but is accelerating (the average annual rise from 1946 to 1953 was 3%); and over half can be attributed directly to R&D. The return on R&D is cumulative over some quarter century, increasing along a sigmoid curve for each R&D addition, so that about one-fifth (say 60 billion) of the GNP of 1953 can be credited to R&D expenditures of 1.5 billion—a pay-off rate of over 100% a year for 25 years! And basic research (5% to 8% of the total R&D, 0.4 billion in 1953; ref. 107) has a still higher pay off; with the life science fraction (30% of basic research; ref. 107) still more rewarding. Projecting to 1960, and GNP should reach \$435 billion, with \$5.3 spent for R&D (or \$6.1; ref. 89); and by 1965 the figures would be \$500 billion and \$6.6 (or \$8.1; ref. 89). This would demand the addition, respectively, of 75,000 and 150,000 new scientists and engineers. With a minimal figure of 3% biologists in industrial research personnel, at least 300 a year from 1953, this means over 2000 more at the R&D level by 1960.

In 1953, funds for basic research were 435 million, 8% of the total R&D budget (107). Federal agencies supplied 36% of these (\$158 million) and used 11% (\$47); industry supplied 41% (\$179) and used 39% (\$168); colleges and universities supplied 14% (\$60) and used 47% (\$205); and other agencies, as foundations and societies, supplied 9% (\$38) and used 3% (\$14). Questionnaire responses, totaling 160% because of multiple checks, showed that physiologists received 55% from government, 24% from industry, and 21% from foundations; and NSF data for the same year (106) are in reasonable agreement—55%, 29%, and 11%, respectively, leaving 5% for 'other'. Intramural funds accounted for one-third of the total for animal physiologists; one-half, for plant physiologists. Other data showed a drop from 1941 to 1952 in the percentage of funds from industry, from 45% to 33% (Table XII-4).

Money was used mostly (71%) in physical science, the remainder (29%, \$125) in life science. Half (51%) of the physical science funds were spent in industry, only 8% (\$10) of those for life science; just 6% of the expenditures in industry were in the life science area. In academia, the two fields were more equally supported, 56% for physical and 44% for life science; but these constituted 71% (\$90) of all expenditures for life, 38% of all for physical science. In academia, also, 5500 men (full-time equivalents) did research in physical science, 5700 in life science, and 3400 in agriculture (108). Government spent 10% of the physical and 14% (\$18) of the life science funds, the latter constituting 37% of its expenditures; and the figures for 'other' groups were: 2% of physical, 7% (\$9) of life—life constituting 62% of expenditures (107).

Funds for research in biology in 1953 were thus spent: \$90 million in academia, \$20 in government, \$10 in industry, and \$10 in other ways. These figures agree reasonably with the distribution of biologists (and physiologists)—academia 72% of men, 76% (adjusted) of money; government, 16% and 15%; and industry, 12% and 9%. The lower money to man ratio in industry may reflect the greater proportion of sub-doctoral employees. Agreement is also fair with the estimates made above of the distribution of biology Ph.D.'s—10,000 in academia, 3000 in government, 1500 in industry, and 1000 in special activities.

Questionnaire responses indicate that 4000 physiological scientists used \$57 million in outside funds. Some undoubtedly reported for a group, but this may be the rule; the individual average was \$10,000. A study of 74 medical schools (106) indicated \$66 million used by 4600 men, an average of \$14,500 per man. The physiologists averaged \$14,300 per respondent, as compared with \$14,000 (\$11,000 on another basis) for Public Health grants (17) and \$9000 for BSIE projects—2300 of 4000 in the medical area, and 2800 supported by government (Survey Project 14). Incidentally since a published article costs on the average \$13,000 (Chapter VIII), one paper per year per grant is the norm. Further, since extramural funds constitute only 60% of all, 1.7 articles per man per year (Chapter IX) seems a proper value.

The figures in Table VIII-9 (from 100 and 102) show \$41 million from government and foundations for basic research in life science and a total for R&D of \$207 million. Values (in millions) of \$27 and \$183 (83) are probably less appropriate; and the ones used above, \$125 for basic research in life science (107), must be on a broader interpretation of basic research, as well as including \$10 from industry. Using the questionnaire figures, attributing one-fourth of physiologists' extramural funds to industry, the R&D figure of \$207 might become \$280 and that for basic research, \$55. Agriculture would then receive \$55 and \$6; biological science \$85 and \$17; and medical science, \$140 and \$30. Physiologists are oriented 70% toward basic research (Table VII-4), but this is also broadly interpreted. In any event, the \$57 million reported in the questionnaire is 45% of the larger figure (\$125 million) for basic research and about one-fourth of the total R&D for life science. This proportion is of the right order, with physiological scientists constituting a third of the biological group and certainly handling a larger share of the research funds; for, aside from differences in level of support, over half the effort of physiologists goes to research, as compared with one-third that of all biologists (Chapter V).

While on finances, it cost about \$20,000 a year to support a research scientist in industry in 1953 (19, 104; one estimate, 103, is \$27,000 for large companies), plus some \$12,000 in fixed equipment and \$16,000 in buildings (104). (At an average of 200 sq. ft. per person, at \$25 per sq. ft., and two supporting persons per scientist, this building figure would fit; but it seems high.) In various industries, supporting personnel ran from one to three times professional (divided about 3:2 between semi-professional and technical help, 93); and the Survey found that physiology departments (like clinical rather than preclinical ones) invested heavily in technicians. For each investigator (\$7000), then, is needed two supporting persons (say \$8000), interest on outlay (\$1500), and supplies (\$7500). An industrial rule of thumb is that total research cost runs 1.5 times salaries; and this can be split further, to equal amounts for professional salaries, non-professional salaries, and supplies, etc. One medical research institute was analyzed, per senior scientist (1956), as: professional salaries,

\$54,000; technicians' salaries, \$50,000; fixed equipment, \$15,000; supplies, \$25,000; miscellaneous, \$5000; building, \$90,000 (17×200 sq. ft. at \$25 sq. ft.). Averages from ONR contracts (Survey Project 14B) were: salaries of professionals (including graduate students, 14%), 52%; salaries of technicians, 48%; with another 35% (of salaries) for capital equipment (10%) and supplies. Finally, a study of PHS projects in 1950 (Reed) showed 68% of the total for salaries, 18% for supplies, 4% for permanent equipment, 2% for travel, and 5% overhead; and in NSF grants, salaries averaged 73% of direct costs, 66% of total cost, and were divided about equally between upper and lower level personnel (89).

Education is supported overwhelmingly by government. In 1953, federal agencies spent \$1.4 billion, of which \$75 million went to colleges and universities and \$70 million for advanced student support (41). The census figures (83), of \$450 million from the federal government, \$680 million from state and local governments, \$150 in gifts, and other sources to total \$2.6 billion, cover plant, research, and other expenditures. About \$1 billion of this goes to education, \$800 million for salaries of 200,000 faculty. The full-time equivalent science faculty of 62,000 (108), at a mean salary of \$6500 in 1953 (43, 98 and estimate), would have received \$400 million, which seems high. To restore the relative purchasing power enjoyed in 1908, better professorial salaries today should be about \$25,000 before taxes (74). A minimal effort to restore salaries to early century parity (an increase from \$7000 to \$12,000 for professors, 92) would require some \$200 million more a year; and to match the general 50% increase in real purchasing power—of physicians, say, and industrial workers,—another \$200 million would be needed. From 1939 to 1953, consumers' prices rose 90% and the average U. S. salary rose 285%; academic salaries rose only some 55%, from \$4000 to \$6200 (43 and estimate). It has been calculated (see 38) that the institutions of higher learning in this country now require an added \$4 billion of capital funds (for buildings, equipment, maintenance) and a like amount added to endowment (for salaries, scholarships, current operations).

Costs per student year for courses in physiology, partly as calculated by Dr. Adolph, should be: fifty square feet of space, initial outlay say \$1000, annual cost (interest, amortization, upkeep) \$200; equipment, initial cost, \$200; annual expense, \$40; supplies, including living materials, \$100; faculty salary, \$130—1500 full-time-equivalent men at a mean salary of \$6500 teaching 75,000 students. Total annual cost per student is almost \$500, or about \$35 million for all. With a 20% increase by 1960, not only would another \$7 million be needed for running expenses (without salary increases or rising costs) but \$20 million would be required for capital outlay. Actual expenditures in 1953, as estimated from the biased sampling of Survey Project 18H, were about \$400 per student; and new funds desired for 1954 were \$4 million for running expenses and \$10 million for building.

R. W. GERARD

APPENDIX S

EXCERPT FROM A LETTER (NOV. 15, 1951) FROM R.W.G. TO THE
EXECUTIVE SECRETARY OF THE AAAS

I suggest that the AAAS should establish a relationship to industry and the public, as the operating and liaison agency for American science, in much the same way that the NRC now functions as between science and government. In such a manner, industry could obtain expert scientific guidance and would gladly pay for this by support of the necessary AAAS committee and related activities and even of AAAS efforts to bring an understanding of science to the American people. Many industries or businesses which do not depend on science sufficiently to employ their own research and developmental scientific staffs, nevertheless could frequently use disinterested and expert scientific advice. This might range all the way from employment advice regarding competent scientists through extensive research studies affecting an entire industrial group. The AAAS should be prepared to supply advisory committees of any type needed by civilian users of such services. Each committee would, of course, be supported by the beneficiaries of its efforts, and with sufficient overhead and the like to maintain the necessary institutional organs.

I am aware that some activities of this sort outside of the governmental area are already undertaken by the NRC; and some joint exploration by the two organizations would undoubtedly become desirable before the AAAS undertakes a project of this sort. Unless, however, the position is taken that a single quasi-official agency should alone be responsible for all areas of science representation—in which case the AAAS has little possibility of effective functioning—this would seem an area that could well be allotted to the Association.

In giving service to the business and industrial world, the AAAS would not merely be giving particular aid and obtaining financial support; but also it would be contributing to its over-riding obligation of improving the genuine understanding of science by the layman. For the contacts established will be with leaders of public opinion; men who, once they themselves understand the great power of basic investigation, would help greatly in further expanding such understanding. Such 'popular education' concerning science might prove more effective than that which has been attempted, wholly inadequately, by direct appeal through the mass media. I take it as needing no argument that the importance of science to the national welfare, and the consequent imperative need for the people and their elected representatives to understand something of how science operates, makes such public education the prime duty of the AAAS. I see no other way to achieve this objective on a scale that will have any significance other than by enlisting the cooperation and support of industry—both in personal effort and in financial aid.

That industry is more than willing to join with American scientists for their mutually recognized obligations to each other and to the country is indicated by many straws. The response of the representatives of the mass media to the

AAAS Symposium on "Science and the Public" in 1946 was most heartening. They were enthusiastic about setting up and supporting a committee to achieve the objectives outlined in the Symposium (unfortunately, the only public record of which I know is in my note in *Science*, 106: 23-25, July 11, 1947,—but I believe some recordings were made at the time); but there was no official follow-up by the AAAS and nothing happened. The eager response of industrial leaders to recent invitations to participate in AAAS activities is a further earnest of the reaction to be expected. I am profoundly convinced that industrial leaders and organizations will contribute with the utmost generosity and active enthusiasm to any respectable programs that the AAAS may initiate and in which they are invited to participate.

As one concrete example, I would suggest the moving picture industry, and perhaps along with it that of television. On the one hand, the moving picture producers are constantly needing scientific advice—as they need historical and artistic advice—in the actual planning of their productions; and I presume they could use a good deal on strictly technological matters as well. On the other hand, they could be extraordinarily effective in general science education, not only with special 'shorts', but also in feature pictures in which the actual advance of science supplies both the plot and the dramatization.

Investments made by the Association in such efforts will soon and abundantly repay themselves.

APPENDIX T

SURVEY RESEARCH CENTER CODES

- I. Code Book for Survey of Physiological Sciences (ADI Document No. 5527)
The following special codes were developed for the Survey:

Major Classification	(p. 2)
Field	(pp. 3-4, 78-80)
Specialty	(pp. 6-8)
Society	(p. 10)
Comments About Scientific Sessions	(pp. 11-14)
Problems in Keeping Up with Advances	(pp. 16-17)
State and County	(pp. 20-21, 77-78, 82-83)
Positive Job Factor	(pp. 23-25, 36-38)
Negative Job Factor	(pp. 27-30, 39-42, 52-55, 61-64)
Department	(pp. 57-58, 68-69)
Degree	(p. 73)
University	(pp. 75-76)

- II. Code Book for International Questionnaire (ADI Document No. 5528)

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