Instrumentation in Bio-Medical Research (1957)

Pages
26

Size
6 x 9

ISBN
0309361613

Klopsteg, Paul E.; Biology Council; Division of Biology and Agriculture; National Research Council

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Instrumentation in Bio-Medical Research

Report of a Survey

by

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Consultant to the Biology Council

DIVISION OF BIOLOGY AND AGRICULTURE

Publication 472

NATIONAL ACADEMY OF SCIENCES — NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, N.W.

Washington 25, D. C.

Library of Congress Catalog Card Number: 57-60017

PREFACE

As part of its assignment, the Biology Council holds "hearings" on matters of patent concern to the future of the biological sciences. Under this title it has sponsored and supervised the survey on "Bio-medical Instrumentation" which forms the substance of the following report. To Dr. Paul Klopsteg, who has conducted the survey essentially single-handed, the Biology Council is deeply grateful not only for lending it his broad perspective and experience but, above all, for the judiciousness, patience, wisdom and tolerance with which he braved the difficult task of sifting, correlating, reconciling and synthesizing the host of data and opinions, often conflicting, with which his respondents confronted him. Sincere thanks are also due the members of the *ad hoc* committees who participated in the discussion and articulation of the findings; as well as to all those whose informal advice was sought and who gave of it freely.

The Biology Council has adopted the report substantially as it was submitted in summary by Dr. Klopsteg with the endorsement of the Drafting Committee (Philip H. Abelson, Arnold O. Beckman, H. Stanley Bennett, Henry C. Meadow, Francis O. Schmitt, and Paul Weiss). For the convenience of the Biology Council and other organizations whom it is destined to serve, the text of the report has been somewhat rearranged and expanded so as to itemize, besides the final conclusions, some of the essential arguments in back of them. In this re-edited version by Dr. R. B. Stevens, Executive Secretary of the Biology Council, the report is now presented with the endorsement of the Biology Council. Its major purpose is to expose the many facets of this urgent problem, as they appear in a cross section of current thought. Their evolution has led to certain unified tenets and recommendations, which promise to be of lasting value. Other conclusions are but provisional, subject to further critical exploration and debate. But one thing has emerged beyond dispute: that some systematic thinking about the problem as guide to practical action is called for. If this report does nothing more than get this process under way and provide some guide posts for charting its course, it will have served its purpose.

PAUL WEISS, *Chairman*

December, 1956

Foreword

This paper summarizes work by the Biology Council of the Division of Biology and Agriculture, National Academy of Sciences — National Research Council extending over about two years. The problem of instrumentation in biological and medical research was identified as an area in urgent need of attention and was first specifically considered at a meeting of the Biology Council in March, 1955, when Dr. F. O. Schmitt submitted a memorandum entitled "Instrumentation and the Training of Professional and Technical Personnel in the Various Fields of the Life Sciences." His report was also addressed to the Biophysics and Biophysical Chemistry Study Section of the National Institutes of Health, of which he is chairman, and consisted of a three-page summary, a short paper by Kurt S. Lion, and certain correspondence with administrative officials of instrument companies. One month later an advisory group met to consider the merits of establishing institutes for bio-medical instrumentation and recommended that an extensive and critical study be initiated.

Funds adequate to conduct such a survey were obtained for the period August 1, 1955-February 28, 1957, from the National Institutes of Health (RG-4490) and Dr. Paul E. Klopsteg, formerly president of Central Scientific Company and Associate Director, National Science Foundation, was persuaded to act as principal consultant to the project. A careful sampling of fact and opinion, looking toward the formulation of reasonably specific plans for systematizing bio-medical instrumentation and instrumentation training, was undertaken.

In late June of 1956 Dr. Klopsteg laid before a special committee of sixteen persons, at Endicott House, Dedham, Massachusetts, his "Interim Report." This paper was considered at length and, as a final move, the conference group designated a subcommittee of seven persons to draft, under Dr. Klopsteg's chairmanship, a revised version of the interim report on the basis of their own collective experience and judgment, incorporating the information and opinion brought out during the day's discussion. For two months members of the subcommittee worked, largely by correspondence, to carry out the assignment; the effort culminated in a "First Draft" of the final report. On September 15 the group assembled in Washington, D. C., to give the manuscript a last scrutiny.

The third draft, based on the September discussions, was presented as

a finished report to the Biology Council at its regular meeting in October and was accepted by them as the basis for Council action. The present paper attempts to combine, in integrated form, pertinent elements of the several earlier draft reports, of conference and committee discussions, and of Biology Council deliberations. It should serve as a starting point for planning effective action programs and putting them into operation.

General financial support for the Biology Council during the period in which this study represented an important part of its program has been generously provided by the Directorate of Research and Development, Department of the Air Force; by the Office of Naval Research, Department of the Navy; and by the United States Atomic Energy Commission.

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INTRODUCTION

Research in biology and medicine, no less than in other areas of science, is critically dependent on experimental methods and devices providing for observation, measurement and control, and the processing and reduction of data. "Instrumentation," for the purposes of this report, may be used as a catchword for a very broad effort—essentially that of capitalizing on the methodology and conceptual approach of the more exact sciences (mathematics, physics and chemistry), including instrument production and distribution, and procedures for testing. The primary aim of this survey is to see how instrumentation, as thus defined, and "instrumentology," the study and application of physical principles and mathematical operations to designs for the experimental study of specific problems, might logically be expanded and adapted to the service of biological research. A secondary consideration is the enlistment into bio-medicine of those who are already trained in physics and engineering.

Biology is a fragmented science; its subdivisions are dependent on the diverse experimental techniques and devices of the physical sciences to varying degree. It is peopled by a group whose training is neither in engineering nor primary physical sciences. It seems therefore best to dissect the problem, sorting out its several aspects, and fixing eventually on a few basic tenets. Quite likely, in view of the complicated nature of the question, its solution will be approached not by a single route but by several, each adapted to specific, recognizable situations. There now exist units at universities, colleges and other research institutions where effective work in devising tools for biology has been, and is being, done. Their success lends incentive to the search for a larger answer to the question posed and strengthens the belief that substantial solutions to the problems will be found.

Four classes of biologists are involved: (1) the scientist who seizes upon a particular technique, developing first-rate competence in it, and utilizing it in a very primary sense; (2) the scientist who utilizes a given technique at a less sophisticated level, or but temporarily, and who might be considered to have only secondary competence in it; (3) the individual who turns the instrumentation segment of his research program over to another; and (4) the individual who foregoes the use of instruments altogether. Any survey, to be effective, must be comprehensive enough to include the more efficient use of the instruments we now have, the development of better instruments, the training of biologists in more skilled and resourceful use of instruments, and the establishment for the biological technician and technical specialist of a respected and adequately rewarded station in the scientific community.

THE NEED

As use and complexity of instruments in bio-medical research increase, and as research becomes increasingly a team operation, our present highly informal procedures become less and less appropriate. Such unsystematic practices are both ineffective and inefficient, resulting in serious losses of time and money, in distortion of research patterns, in use of instruments ill-adapted to a particular project, in failure to realize more than a fraction of the total potential of modern developments in instrument science. Despite the fact that there are a number of persons in the biological community preeminently fitted by temperament and aptitude to become expert specialists in the use of instruments in support of research, and despite the enormously increased demand for this type of individual, it remains a most difficult task to establish for these workers a recognized station of respectability, with the deserved professional status.

There is all too little evidence that biologists as a whole feel, with genuine urgency, that something needs to be done. Many are quite happy with very minimum standards, which leads them to attempt all sorts of short-cut solutions to their instrumentation needs. Others, dissatisfied in varying degree with matters as they are, still fear moves which they view as attempting to replace traditional university training and as emphasizing method over problem. One of the grave handicaps encountered by Dr. Klopsteg in his travels about the country collecting on-the-spot opinions was the wide difference in viewpoint, especially in relation to the status and role of biophysics. An attempt fully to reconcile these opposing views is very likely to fail—it is better strategy to state them as they are and leave any decision to the individual reader. But in reaching such a decision, he must keep in mind that among those interviewed must have been some who were too single-tracked to step outside their specialized channel of interest and, furthermore, that even though immediate needs and the demands of the future may differ, any practical measures must be designed to fit both.

Divergence in view among participants in the survey was largely on the question how best the desired ends might be obtained—majority opinion was decidedly convinced of the urgency of the situation and the desirability of doing something tangible to alleviate it. It was pretty well agreed that those who do recognize the need and who pioneer in planning for the future must risk being wrong and move ahead on something which will alert others to the realities of the problem.

Concerning Existing Facilities and Equipment

A most obvious specific need is to make available to maximum degree what equipment is now in existence, whether it be rare and expensive items or conventional instruments, perhaps through the establishment of rental pools and a clearing house through which items only temporarily needed at a given institution could be relocated. Such services might be extended to provide, also, specialized technical personnel for the operation of equipment on loan.

There is need for extensive, continuing outside assistance to the facilities now in being—those grassroots elements now doing a large part of the work in bio-medical instrumentation and destined in the future to act also as feeders to any more comprehensive center. Very substantial support could be given existing facilities, at all levels, before there is appreciable danger of going beyond the point of optimum returns.

Improvement of Techniques and Instruments

Basic to any consideration of bio-medical instrumentation is the need for general improvement in the machines and their use. This recognizes, among other things, need for types of instruments not now available and knowledge of how to design instruments to fill these needs; some way must be found for getting top skills concentrated on development of new instruments. An instrument, once developed by the physicist for his own purposes, must ordinarily be engineered to a more dependable design before it can readily be adopted by other physicists or non-physicists in their research.

It is inherent in the nature of biological research that needed skills and techniques cannot be transferred directly from physics and chemistry. A given instrument is useful only in the context of the particular problem, and most are not designed or conceived of with biological problems in view —perhaps there are impressive numbers of instruments around for which the techniques or applications to biology, however potentially important, are not obvious. Among the significant needs, then, are those *not* recognized —the realization that nature can be probed effectively by certain physical methods. It is this ability to divine a need in biology or medicine in terms of instruments that must be provided in the education of this new group we sometimes call biophysicists.

Training and Personnel Utilization

There are at least three aspects to the problem of efficient utilization of available and potential manpower as it relates to instrumentation in biology and medicine: (1) the need to inform or train senior scientists concerning particular instrumentation problems, with minimum expenditure of their time; (2) the desirability of reducing the interruptions now inflicted on research biologists by others seeking to "borrow" their skills and advice; and (3) the opportunity to replace expensive technicians at many points with less costly automation. There is a time element to consider—when a given machine is new and rare, one must be most concerned with the efficient use of equipment; when abundant, with the efficient use of manpower. In the latter case, solution may call for the establishment of technician pools and for groups equipped to do specific instrumentation jobs on a consultant and contract basis. Finally, there is need for the erection of formal courses and curricular sequences in educational institutions to train new personnel at various levels of competence and for various kinds of work in instrumentation.

It is not sufficient to supply biology and medicine with a given number

of qualified persons; the diversity of personnel needs must be recognized and dealt with. First there must be technicians, sufficiently skilled to keep standard equipment in running order, service it, and operate it. Second, there must be instrumentation specialists familiar with the more sophisticated instruments, their theory, construction and methodology, and capable of adapting their use to specific bio-medical problems, including improvements of design and operation. These would form a new class of "biological engineers." Finally, there must be the creative instrumentologists, thoroughly acquainted with the principles of the physical sciences and capable of inventing new and better tools for the study of organic systems.

Professional Status and Recruiting

To speak of the service to biology rendered by those skilled in the research methods of the physical sciences is not to imply for them a subordinate position in the scientific community. Quite the contrary, ways must be found to guarantee proper professional status for the instrument specialist, if the program is to succeed. A model for the relationship which should exist between bio-medical investigator and instrumentation specialist may be seen in that between writer and librarian. It should not be necessary, as it now is, by circuitous talk to make a case for those in responsible positions in instrumentation facilities or to employ devious stratagems to secure for them academic or staff appointments.

Biologists deplore the fact that they do not get what they feel is their share of competent persons coming into science. Despite this shortage, and despite the very considerable body of individuals potentially fitted for these very jobs, research organizations use highly unsystematic procedures in securing and selecting their technicians and instrument personnel. If there is one paramount need, therefore, it is to supply bio-medical laboratories with manpower having the requisite training and ability. To accomplish this, bio-medicine must keep its recruiting program as active as those of its competitors, so pattern its appeal as to reach all levels of capability, and enlist the aid of those who are primarily concerned with teaching and training—there must be emphasis on channeling promising students toward the methods of physical science.

Information Exchange

In the final area of need it is imperative: (1) that information on the present fund of ideas and experience be disseminated and that availability of instruments be made known; (2) that emerging needs and inadequacies be made known to those who develop and manufacture equipment; (3) that some device for informal exchange of opinion be set up; and (4) that some way of cataloguing all available equipment and skills be devised. Preparation of an authoritative handbook of principles and methods would be a desirable dividend from an active instrumentation center.

BASIC CONSIDERATIONS

In the foregoing paragraphs we have attempted to spell out, without extensive comment, recognizable needs in bio-medical instrumentation. In addition, there are a number of issues which have been subject to differing interpretations and, often, opposing points of view; these must be taken into account before a valid set of conclusions can be formulated. It was to such issues that the conferees devoted a large proportion of their time and effort; space limitations admit only of essentially undocumented summaries here. No special significance attaches to the order in which the following items are listed.

The Individual and the Team

Although it should always be possible, particularly at the conceptual level, for a scientist to pursue his research successfully as an individual, with such help or advice as he may seek, there seems little doubt but that, in most instances, the attack on a large and difficult problem by a cooperating group of scientists is likely to be more effective. In resolving the question of the proper relation between technician and investigator and between investigator and instrument, however, some argue that new techniques characteristically come from individual laboratories and that in a separation of research scientist and technician there lies the danger that the service worker will become sterile. Others feel that the obligation of the competent investigator to attend to every technical detail himself has been unduly stressed, though they at the same time disavow any intention of supplanting the human brain with machines.

Informal Assistance and Interference

The individual possessing an instrument is in some measure custodian of a resource, particularly at the university level, and in that measure obligated to make the machine accessible, to inform his colleagues of its value and limitations, and to educate others as broadly as his work will tolerate. But it seems evident that, if instrumentation is to expand, this kind of service must not be left indefinitely to the favors and good graces of willing colleagues—the demand for voluntary courtesies would before long reach such absurd volume that the system would break down completely. It is just because the established research laboratory and university department must train the next generation for the long haul that they cannot tolerate continual interruptions by outside visitors.

Dispersal versus Centralization; Diversity

One must attempt to balance the relative merits of large and small facilities, of dispersed and centralized patterns of installations, judging which is the more likely to survive and prosper—and recognizing that diversity may in the end be the wiser choice.

Wholly aside from financial considerations, treated elsewhere, the concept of a single large national center has been criticized by some as too ambitious, too risky, too difficult to assemble and staff, and by its nature

remote in space and spirit from the preponderant majority of biologists who might hope to profit from it. Those who doubt the wisdom of the comprehensive facility fail to see how all the many ramifications of bio-medical instrumentation could be encompassed in one establishment without at the same time forming an unworkably enormous organization.

Equally competent scientists, of the opposite persuasion, feel that the local university instrumentation unit already exists on virtually every campus that could support one, and that means simply do not exist at the remaining institutions to undertake such a venture at "threshold" size—that, in putting the facility in special reference to activities on the campus, unique problems arise as the program becomes parochial, ingrown, non-competitive, as it encounters established customs and seems threatening to upset existing organizational and fiscal patterns. In essence, they are convinced that if a center is to be large enough to be dramatically new and different it will be too large for university sponsorship; if it is small enough to be part of the university it will not achieve the comprehensiveness that many concerned with bio-medical instrumentation feel must be reached.

The answer, developed later in this report, seems to be a hierarchy of facilities from the individual to the regional (perhaps eventually national) center—with maximum emphasis on cooperation and coordination amongst them.

Educational Implications

From the outset, the educational aspect of instrumentation was recognized to include instruction of professional research personnel, of technicians, and of a new class of technical specialists or biological engineers. It will range all the way from formal courses in established methods to subtle changes in the general education of biologists, such that they are in tune with the increasing emphasis on instrumentation in research and fully able to capitalize on its contributions. Involved, somewhere, is the relation of research biologists to instrument operation, selection and development, and the balance between substituting technicians for scientists, on the one hand, and liberating scientists for creative activities, on the other.

The university must be urged to set up needed courses, to employ and recognize the personnel required to handle instruction, and to see that the teaching is as carefully organized as are the more orthodox items on the curriculum. There cannot be a course for everyone and for every need—some workable compromise is called for. And there will always be problems which cannot await university courses. Here the scientist must work out his own salvation—the more competent he is the less will he require outside help.

Grant Policies and Fellowships

The general trend in fund-granting policies is toward greater leniency, toward allowing costs of visits to other laboratories for instructional purposes, and toward permitting procurement of instruments to be included on the research grant application budget. It will probably continue to be

difficult for an unproven investigator to get the more expensive items in this way but, as appropriations become more liberal, inclusion of funds for equipment on grant applications will have less and less effect on their final disposition. The parent institution, normally the actual recipient of the funds, should be encouraged to assume responsibility for the adequate use of the instruments purchased therewith.

Each new crop of fellowship recipients, by their almost random migration to new posts, create a valuable cross-fertilization. There are perhaps two shortcomings in the fellowship programs as a means to acquire *ad hoc* instrumentation skills: (1) they do not, except in a few cases, provide for the mature investigator; and (2) tenure is ordinarily for one year, which is for the older scientist too long a time to spend in learning a new technique. Perhaps greater over-all flexibility would be desirable.

Continuity of Support and Staff

There can be no doubt that the success of any plan will hinge upon the enthusiasm of the devoted individuals comprising the staff, inspired to work not just as service personnel, who will see that the job gets done. It is this devotion that will permit adjustment to the host of intangible factors certain to plague the enterprise, and will insure continuity during the early, critical years. Whatever the source of funds, the granting agencies *must* assume responsibility for continuity. The new venture should be carried on for enough years to rid it of operational defects, after which it may be expected to continue on its own momentum, with support from a variety of sources.

Personnel Problems

Planning cannot be in a vacuum; it must deal with practicalities. The purely technical problems cannot be separated from those of human relations which, in the minds of many, constitute the one biggest difficulty confronting the instrumentation program.

Personnel relations involve not only the interplay between biologist and physical scientist, but among all of the diverse individuals—scientists, instrument makers, designers of equipment and techniques, students—who will be associated in an instrumentation facility. To be assured of success a plan must be suited equally to the conformist and to the individualist. As the venture depends for its successful outcome on cooperation, its organization and operation must be so skillfully drawn that points of friction are foreseen and avoided—that causes for grievance or complaint are minimized. Perhaps the greatest factor in the success of a center will be the adroit management of a director skilled in the appraisal of character as well as ability, and wise in the leadership of a diverse group.

Nothing so clearly points up the issues at stake as the controversy, to put it bluntly, over the status of biophysics. This group is trying to win recognition as a separate discipline and its members are understandably concerned about any move possibly reducing their role to one of subservience to bio-medicine. Psychologically, it would appear easier to develop

the requisite cooperation between a biologist and a man who regards himself as appointed to the instrument field than between the biologist and the man who is primarily a physicist or chemist. This points up the possible advantages of beginning with the formation of a new institution, or of attaching the center to an organization already sympathetic to this sort of thing—indeed the National Laboratories may be uniquely the place where the idea would be accepted. Finally, what of the students who attend? They will fairly begin to ask where they may go, without becoming second-class citizens, as they move out into a new job.

Communications and Publication

One deterrent to progress in bio-medical instrumentation has been lack of adequate intercommunication among those concerned. Instances may be cited where several laboratories, recognizing the same problem, have independently undertaken to develop the apparatus with which to handle it, each without knowledge of what the others were doing. In other cases research workers have set about devising an instrument which, in a well-developed design, has been already commercially available. Hence an information clearing house is indicated, which might well make available current technical information about commercial instruments, apparatus and other research aids. It might serve as the means for channeling, in both directions, information about needs and requirements and about ways of meeting them, between users and producers of scientific instruments.

Assuming efficient dissemination of information on established instruments and methods, and close cooperation on development of new techniques, it is still necessary to get those interested in instrumentation together for informal interchange of opinion on new techniques, data reduction, application of statistics, applications to biology, etc. Such informal gatherings must be supplemented by more systematized occupational guidance and instruction. It could be that the informal gathering is a device having special promise for instrumentation. If gathered about instruments and methods, irrespective of discipline, people might cooperate in a very productive way. The avowed theme ought always to be centered on problems in instrumentation, in preference to research results, *per se.*

Viewed in one light, there are now plenty of journals in which the results of research of biophysical nature can be published. Nevertheless, its dispersal through a multiplicity of journals renders retrieval of the information more difficult and tends to retard professional recognition. The literature of science is weak in critical reviews of instrumentation; journals are not happy to receive papers on method unless in conjunction with research results. Reviews by competent men on instruments, showing the lacunae of understanding, the limitations, range of use, etc., would be a positive step in which could be fairly easily instituted. There is no shortage of published material, but rather of organized information on methods and techniques, articles which tie history with the present and include unsolved problems.

Service Functions

It is doubtful if solutions worked out for the large universities and research centers can be translated directly to the innumerable small institutions, where good research could go on and which are a natural resource of manpower for the bio-medical field. To what extent can commercial laboratories be expected to satisfy the more humble needs of these institutions? It is no effort to find examples of such service laboratories, profit and non-profit, now in being, which provide for "outpatient" tests and measurements, equipment rental, or external contract operations.

At the moment rental is customary only on larger and more expensive items, or in cases where the manufacturer is trying to introduce a new machine. There could be a central service for routine instruments if the demand were great enough. What would be needed is not so much a physical pool as a pooling system or procedure. But just because equipment is thus made available by no means assures that people will know how to use it. Rental and training make a neat package, and one suspects that the technicians and the instrument will in the long run go together.

Many hold certain reservations about widespread adoption of rental—for the less expensive items it may only occasionally be a long-range economy, and both instrument dealer and manufacturer can be expected to worry about the effect on sales volume. Speed, in any case, and accessibility to the worker in the poorly financed laboratory, are two telling arguments in favor of a rental system. And in a situation where so very large a proportion of research is supported by grants in aid, the policies of granting agencies must be sympathetic to inclusion of rental items on the project budget estimates.

Rental would permit exploratory use of an instrument, the utility of which had not yet been ascertained. If successful, it would often then be purchased. At present, it mostly has to remain untried.

CONCLUSIONS AND RECOMMENDATIONS

Implicit in the results of the survey and in the several conference discussions of those results are the conclusions that: (1) there is need for action in the area of bio-medical instrumentation—that matters cannot be left to *laissez-faire* treatment; (2) even so, there is no royal road or master formula—one can but lay down general guiding principles; (3) it is probably best to start one, or perhaps a few, centers under a variety of formulae; and (4) the movement will lead to a new class of "biological engineers" at the professional level, requiring adaptations in the educational program and attention to their acceptance and status. As it now stands, the survey gives only limited support in the immediate future to the big national center envisioned at the outset.

In seeking a solution, one may take either the perfectionists' approach, waiting until everything is optimum, or that of the individual who starts with courage along a chosen line, subject to evolutionary improvement with the aid of the biological community. One can wait for an overwhelm-

ing demand, or anticipate the need and try to prepare for it. Whatever the eventual plan, its success will depend on the enthusiasm of the devoted individuals who see that it is carried out.

A possible series of moves to improve the situation might consist of: (1) recommendations on what can be done at the present time to make more effective use of existing facilities; (2) recognition of education as the only promising long-term solution; (3) identification of and encouragement for facilities and programs now in being; and (4) demonstration that perhaps the best catalyst for science as a whole is to bring into existence under optimal circumstances a center or centers where interested persons can make maximal contributions.

Where a number of institutions in one area engage in bio-medical research, a cooperative unit may best serve their interests; this unit may be comprehensive, or may restrict its activity to specified functions. What is done will depend on available facilities, ease of financing, and on competence and motivation of the participating scientists. Obviously, an initially modest facility may, by its contributions, merit expansion into a large, comprehensive center.

Six specific recommendations were formulated in an effort to crystallize opinion; these are presented here without any implications of priority in time or relative importance:

1. Information Clearing House

   That steps be taken to establish an information clearing house through which new developments in bio-medical instrumentation may be more effectively disseminated, needs may be expressed and needs met, and that this be done either independently or in association with a contemplated instrumentation center. The information center so established would undertake to collate published literature and government research reports as a library service function.

2. Instrument and Technician Pool

   That a study be made to determine the optimum scope and organization of a pool of instruments to serve biological research, a companion roster and pool of technicians, and a service facility available for performance of specific tasks on an external contract basis.

3. Instruction

   That provision be made for instruction in the use of standard instruments and for the formal training of technical specialists and technicians so urgently needed.

4. Professional Status

   That the deliberate design, development and use of instrumentation for research requires close personal association between the biologist and the "engineer"; this association is favored by day to day contact in academic surroundings. The senior positions require scholars with a high level of professional training and a primary interest in the work for its own sake, i.e., men eligible for academic or staff appointment.

5. Student Recruitment

   That students with special aptitudes in instrumentation and the laboratory arts or engineering be identified early and encouraged to seek training in bio-medical and biophysical research on the basis that it holds promise of a rewarding career.

6. Hierarchy of Facilities

   That instrumentation facilities may assume all degrees of complexity, from technical assistant to complete multi-institutional or national center, capable of further development, and that such a hierarchical structure should be fostered.

SAMPLE MODEL

It can be convincingly argued that the best and quickest way of working out the many troublesome details is actually to establish an institute of instrumentation and to solve each difficulty as it arises. In short, the important thing may be to get started, however modest the initial step. At what point in the hierarchy this venture should be undertaken is a matter for debate, but selection of a particular level should not be inferred as prejudicing the adoption of action programs at other levels. And it remains a possibility that all of the suggested solutions are desirable; that what is most needed is to provide cooperation and coordination. Consideration should be given to the wisdom of forming a group to facilitate this coordination, and to the returns which might be expected from a possible network of consultants. Or, such a coordinating agency, pulling together the new unconnected elements of bio-medical instrumentation, might be precursor to an eventual instrumentation center.

Action is needed. Needs, when recognized, are normally met. Full implementation might most easily be achieved by breaking the problem into segments; letting the manufacturers provide periodic training courses; setting about the immediate establishment of an information transfer center; helping individual facilities incorporate more and more of the features shown by the survey to be advisable; on a larger scale, establishing new units to be operated as conjoint enterprises of several institutions properly disposed; and, as the most inclusive solution, eventually forming one or more comprehensive national institutes.

Those who are engaged in planning instrumentation research facilities for bio-medicine, in expanding existing laboratories and soundly operating them, might profit substantially from reports of experiences in various universities about the country. Such reports have been presented in conferences sponsored by the Biophysics and Biophysical Chemistry Study Section of the NIH, and are available there. We are here particularly concerned with formulating a sample blueprint for that type of instrumentation facility judged most promising by the participants in the present survey—a *regional center* developing from the joint activities of a group of interested universities and research laboratories.

Cooperative Mechanisms

There is a new and healthy trend in U. S. academic circles toward cooperative enterprise—witness the parcelling out of special functions by the Southern Regional Education Board; cooperation such as that among medical schools of the Mountain states; the activities of Associated Universities, Inc., responsible for administration of the National Laboratory at Brookhaven; and the Midwestern Universities Research Association. In these instances, for the first time, universities have been willing to recognize their individual limitations and make compacts for integrative action.

Certain advantages of this machinery for an instrumentation effort were immediately apparent to the committee—it fits into the sought-after regional concept; it avoids the special difficulties inherent in the local campus scene; and it makes possible a breadth of coverage beyond that available to existing facilities without the risks involved in setting up a very large, independent center. Whenever a number of institutions pool their efforts the program acquires two distinct aspects: (1) a corporation of some sort, of which the individual universities are members; and (2) provision for actual use of the instrumentality by members of the corporation and/or others. It seems wisest to go slowly in any plan to concentrate a very large accumulation of physical equipment and buildings in a new center, and to rely as much as possible on a "paper" organization with coordinating machinery for encouraging the development of special facilities scattered judiciously throughout the cooperating group, each member providing an appropriate fragment toward the harmonious pattern of the whole.

Desiderata

Whether the regional center here advocated exists in the abstract as the effective combination of separate elements in cooperating institutions, or as a physically distinct facility, more or less self-sustaining, certain specific items must be taken into account:

1) Assurance that there are able, interested scientists involved who are strongly aware of need for physical and personal aids for the conduct of quantitative bio-medical research, and who would use them if they were made available.

2) The kind of physical and intellectual environment commonly associated with research in the physical sciences.

3) An atmosphere conducive to collaboration among scientists from various fields, for example, assistance to a biologist in acquiring a technique which he intends to employ; of teamwork among a group, each of whom brings his specialized knowledge to bear on a common problem; of free, informal discussion; of formal advisory aid from staff experts in the planning, design and construction of the experimental tools of research and assistance in their proper use.

4) Formal courses as well as informal training in the methodology

of the physical sciences, including both the philosophical and practical aspects, with emphasis on bio-medical problems.

5) Temporary in-residence association, with the center, of scientists from other institutions, as well as permanent faculty appointments to the scientific staff of qualified members of any of the science faculties of the cooperating institutions.

The desirable solid foundation for the establishment and operation of a center would include: (a) means for the procurement and handling of biological materials, to maintain their supply and suitability for research studies; (b) classrooms and laboratories designed and equipped for teaching and exploring the methodology of the physical sciences in bio-medicine; (c) associated shops to render the services essential to the research techniques and for the practical training of technicians; (d) a supply of standard commercial instruments and such special ones as will meet the requirements, with technicians for their maintenance and, where indicated, their operation; and (e) an adequate library to support the research and teaching program.

A model center, established to meet the desiderata just enumerated, would have, in the aggregate, a staff competent to handle, for example: mechanics, heat and acoustics; optics, with emission and absorption spectroscopy, microscopy and photography; electricity and magnetism, with electrical measurements, electronics and control devices; radiation, with x-rays, x-ray and electron diffraction, electron microscopy, radioactive sources and tracers; hydrogen ion and oxidation-reduction potentials; polarography, chromatography and molecular spectroscopy; etc. It would be equipped with commercially available instruments and apparatus; new devices would develop out of specialized research requirements. The shops would be staffed by technicians qualified to teach and train; and one or more competent reference librarians would be employed. Obviously, the "paper" phase, or counterpart, of the regional center would not assemble staff and equipment in a single spot, but would otherwise fit the pattern outlined.

Administration and Support

At this point it will be necessary to find someone to take charge of the action phase, for even if the particular solution offered in this summary is not accepted, the basic considerations will stand. A likely move, once the survey is completed, is to call an organizational meeting of persons invited from universities, industry, granting agencies, instrument societies, etc., to decide what may wisely be undertaken. It will be up to the individuals at each institution to assess their own place in the total scheme, what they can be expected to do, given a reasonable amount of guidance.

The method of choice in financing will depend on the particular idiom adopted, but cannot fairly be considered an insurmountable obstacle. Money is available in large amounts for the right kind of program, and individuals who are convinced of the need for action must somehow be made aware of this fact. Partial support, at most, can be expected from industry. There is no question, on the other hand, of strong Federal support

for central or regional centers and perhaps even for the construction of new space for smaller laboratories now inadequately housed. Certainly it seems a proper government function to establish and finance an information clearing house and library facility.

Within a wide limit of comprehensiveness, a meritorious plan, carefully worked out and presented by scientists of recognized competence, should encounter no special difficulties in obtaining funds from a number of government agencies. Later, possibly, funds from private sources may become increasingly available and there is always the likelihood of some support from the institutions comprising the managing corporation which administers the regional center.