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NIH-SUPPORTED BIOMEDICAL COMPUTER CENTERS

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The National Institutes of Health, as part of its Biotechnology Resources Program, provides grants to academic and other nonprofit institutions for the support of computer centers serving life science research. These computer resources generally have three component activities: service, technological innovation, and training. As foci of multidisciplinary endeavor, they facilitate the application of computer science, mathematics, and engineering to health problems. The resource mode of support has proved to be a near ideal administrative form for continually interjecting the latest computer technologies into the biomedical area and, even more important, for making the resource's own computer research activities responsive to the unfulfilled needs of the surrounding user community.

The accompanying paper (The Life Sciences Computer Resources Program of the National Institutes of Health, Comput Biol Med Pergamon Press 1972, Vol. 2, pp. 211-220), describes how NIH-supported computer resources relate, both organizationally and operationally, to life science research programs. Aggregate funding levels and trends involving the various types of computer centers over the past several years are reviewed. A number of specific resources are highlighted and examples of their scientific and technological accomplishments are given. Finally, the strengths and weaknesses of this NIH program, as derived through reflection on almost a decade of activity, are presented.

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The Life Sciences Computer Resources Program of the National Institutes of Health

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Abstract—This paper describes how NIH-supported computer resources relate, both organizationally and operationally, to life science research programs. Aggregate funding levels and trends involving the various types of computer centers over the past several years are reviewed. A number of specific resources are highlighted and examples of their scientific and technological accomplishments are given. Finally, the strengths and weaknesses of this NIH program, as derived through reflection on almost a decade of activity, are presented.

INTRODUCTION

This paper describes the computer resources program of the Division of Research Resources of the National Institutes of Health (NIH).* For ten years now this program has sponsored the development and operation of computer centers in medical schools, universities and colleges, and other non-profit institutions. At the beginning of the 1960's the computer was practically unknown in the biomedical world; today the computer finds application in almost every facet of life science research and in many areas of health care. Computer centers sponsored by the NIH have done much to bring about this decade of progress.

The purpose of this paper is to review the history of our computer resources program and to illustrate some of its accomplishments. I also will recount some reflections on successes and failures and some current opinions on what to do and what not to do.

GENERAL CHARACTERIZATION OF A LIFE SCIENCE COMPUTER RESOURCE

We at the NIH define as "life science computer resources" those computer centers which are dedicated to serving a community of biomedical scientists within a given geographical region. These resources almost invariably are focal points for computer science and technology within their scientific communities, and their efforts fall into four major categories: service, research collaboration, technological innovation, and training. Grant funds are used to support essentially the full costs of these centers, i.e. personnel, equipment, supplies, and other operating expenses. At several points later in this discussion I will highlight specific characteristics of the resource mode of support.

*An earlier version of this paper appeared in the Proceedings of the Association for Computing Machinery, August 1971.

ORGANIZATIONAL SETTING WITHIN THE NATIONAL INSTITUTES OF HEALTH

A few comments about our relationships with other NIH programs may serve to put the following material in proper context. The NIH is the primary, though not the exclusive, means through which the Federal Government sponsors health research and training. The vast majority of its support arrangements take the form of individual research project grants and are classified according to their relevance to specific categorical areas such as cancer, cardiovascular disease, and developmental disorders. For the most part, the agency itself is organized along these categorical lines. Our computer resources program, on the other hand, is one of several components within the agency that are concerned almost exclusively with the strengthening of biomedical research institutions *per se* rather than with the direct support of individual categorical research projects. The several different programs for direct institutional support can be viewed as means to upgrade and maintain the quality and the vitality of the health research *environment*. In the specific case of computer resources, our mission is to provide the biomedical research community with the most sophisticated technology pertinent to its needs.

HISTORY OF THE COMPUTER RESOURCES PROGRAM

The NIH initiated its sponsorship of life science computer resources in Fiscal Year 1963; the funds available for expenditure that first year were \$6 million. By 1966, 48 centers were in full operation and the total annual support provided was over \$8 million. Today, there are 36 sponsored resources at an aggregate annual funding level of just over \$8 million. Figure 1 shows the pattern of expenditures over the ten-year period.

Three characteristics of Fig. 1 are immediately obvious. These are (1) the exceptionally rapid growth rate in the first few years, (2) the dramatic diversification in the types of computer resources throughout the life of the program, and (3) the abrupt plateauing of growth rate in recent years. I will speak to each of these topics in turn.

The almost explosive growth of the program in the early years reflects more than anything else the fact that the U.S. biomedical community was *ready* for computers—ready at least psychologically if not technically. Life scientists had been watching their physical science brethren employ these machines to perform large-scale computations. Many organizations such as banks, industrial concerns, and government agencies then were turning in earnest to computers and computer-related methods for dealing with their information-processing needs. Even laymen had some conception—albeit mostly fantasy—of the power and potentiality of "electronic brains". And life scientists, then as now, were becoming increasingly aware that computers and other techniques derived from the physical sciences, mathematics, and engineering *must* become part of their own repertoire if the world's health problems are to be solved. In short, the stage was set to give computers an enthusiastic welcome in the health area.

The second characteristic of Fig. 1, i.e. the diversification in the types of computer resources, should come as no surprise to anyone who has followed the brisk evolution of computer technology and who also understands that the life sciences are an especially rich problem space for the application of automated information-handling methods. In the early 1960's, there was an almost exclusive emphasis upon batch-processing installations; by the early 1970's the life science community's range of interests had expanded to include analog signal processing installations, general-purpose multiple-access systems, and specialized computer

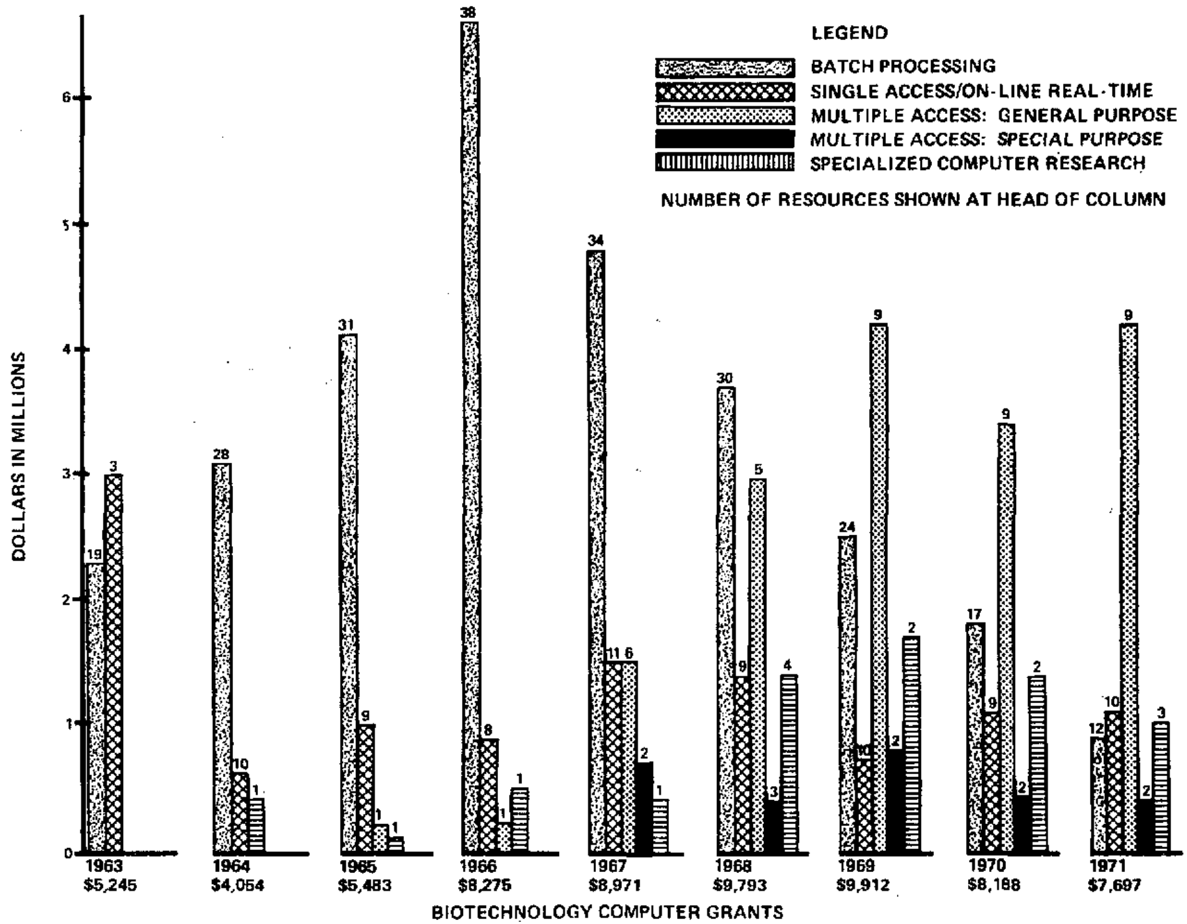

FIG. 1.

research centers focusing on the life science applications of biostatistics, image processing, artificial intelligence, and the like. This shift reflects the increasing sophistication of the technology, of course, and it parallels to some extent the pattern of computer usage in other application areas. But is also illustrates that at least some life scientists are not timid in exploiting the latest computer concepts and that the research resource mechanism can do much to help the user community stay abreast of new research tools and to influence the course that further technological innovation takes.

The third characteristic of Fig. 1, i.e. the abrupt curtailment of growth of the computer resources program in recent years, is, in all candor, a major disappointment. The plateau reflects the interaction of two basic forces: (1) the overall slowdown in Government research spending and (2) the rather cautious attitude on the part of the mainstream of the biomedical research community as to just how far the computer can (and should) penetrate their discipline. The net result, of course, is fewer opportunities for scientists in the biomedical computing field and more complicated program management, for whereas we once were so fortunate as to be able to follow almost every promising lead to its logical conclusion, today we and our advisors must determine *which* good ideas to encourage at the expense of which other good ideas.

These expressions of disappointment are not offered as a litany of gloom. On the contrary, biomedical computing is alive and well and growing stronger. Let me explain why the growth curve for our life science computer resources tells only part of the story.

First of all, one must take into account the organizational dichotomy in the DHEW with regard to the major health programs. Whereas the NIH focuses on health research and training, our sister agency, the Health Services and Mental Health Administration (HSMHA), is primarily responsible for facilitating the delivery of health services, the improvement of hospital facilities, the institution of public health measures, and the like. As a consequence, our program naturally tends to emphasize computer applications in basic research, clinical research, and medical education, whereas other programs sponsor computer applications in, say, hospital automation and routine monitoring of the critically ill. To be sure, much of the research ongoing in and around our resources is motivated directly or indirectly by such health services delivery problems. However, once a given activity moves from a research phase into a routine health service mode, it usually (and appropriately) moves to a computer facility more directly tailored technically and administratively to the task at hand. Essentially none of these latter facilities are reflected in Fig. 1.

A second factor not reflected in Fig. 1 is the rapidly plummeting price of mini-computers—the small laboratory instrument computers so valuable for on-line data acquisition and process control. Whereas such instruments were once sufficiently esoteric, scarce, and expensive to require support on some sort of an institutional basis (and, hence, by our program), today their production rate is high enough and their cost low enough for them to appear as line items in the budgets of individual research projects. Today the bulk of support for mini-computers in health research comes from the various categorical disease programs, and the computers are treated in much the same way as are spectrophotometers, centrifuges, or multichannel strip-chart recorders. Once again, the data for our life science computer centers show only a small fraction of such expenditures.

Figure 1 also is influenced very much by our own program policies. Generally, we do not sponsor a given computer resource indefinitely. As I will discuss in more detail later, we have found it prudent from both a scientific and a management viewpoint to withdraw our support systematically once a center is operating stably and to transfer the burden of support by some appropriate means to the user community. One consequence of this policy of "create, nurture, and withdraw" is that the currently sponsored centers are not the only ones now operating that are attributable to this program. In fact, at one time or another we have sponsored, in whole or in part, 59 life science computer resources, and I am proud to say that all but a handful of these are still in operation providing almost indispensable services to their communities.

As a fourth and final qualification of Fig. 1, we must not overlook the fact that many life scientists have access to computer centers established and operated independently of our computer resources program. Some exist within academic and other non-profit institutions and are supported by various combinations of public and private funds; still others are owned by commercial organizations and run on a profit-making basis. While our grant program still is unquestionably the most systematic way to initiate and maintain a viable and sophisticated life science computer resource, centers sponsored by *ad hoc* (and, sometimes opportunistic) concatenations of funds from other sources are an invaluable complement to our own efforts. Their very existence evinces a healthy heterogeneity in the sources and modes of support for health research in this country.

SOME ACCOMPLISHMENTS OF LIFE SCIENCE COMPUTER RESOURCES

I will now describe what I believe to be some of the most significant advances attributable to our program. While it will not be possible for me to discuss every activity worthy of

mention, I have selected a group which illustrate reasonably well the full range of our efforts. Specifically, I have included examples of batch-processing facilities, analog signal processing installations, and multiple-access systems. Moreover, the range of health research applications to be cited extends from molecular biology and biochemistry to clinical medicine and public health.

My first example is the Health Sciences Computer Facility at the University of California at Los Angeles (UCLA). This center was one of the earliest ventures under our program and today is the largest single recipient of our support. The center currently operates an IBM 360/91 computer in a time-sharing mode and serves not only its host institution but also several others in the far western United States.

The professional staff at UCLA over the years have given primary emphasis to the development and application of statistical methods for biomedical research. This center has become truly a national resource insofar as biomathematics is concerned and is probably best known for its BIOMED Series, a tastefully designed collection of statistical and numerical analysis routines for general use by life scientists. This collection of programs has been prepared to operate on several different brands of computei and is in active use in many parts of the world. By making the digital computer reasonably "friendly," even for use in some very sophisticated statistical analyses, the BIOMED Series has been a major contributor to the broad and relatively rapid assimilation of computers into the health community.

In addition to its continuing efforts on biostatistical techniques, the UCLA resource most recently has been pioneering in another area—the biomedical application of interactive computer graphics. Taking advantage of the time-sharing capabilities of their instrument and a powerful computer-driven cathode ray tube display system, the resource personnel have unequivocally demonstrated the value of man/computer interaction in the pursuit of biomedical problems. They have also demonstrated, along with others, that graphics technology is almost invariably the means of choice for such man/machine communication.

The utility of the interactive graphics system is well illustrated by its application in the field of public health. UCLA scientists have used this capability of the resource in conjunction with their mathematical models of epidemic mechanisms. Briefly, the computer is programmed to simulate the spread of a given disease through a given community for various combinations of user-defined parameters such as length of the incubation period, length of the immune period after infection, and frequency of interpersonal contacts. The user can monitor the time course of the simulated epidemic's progress on the display; in this particular case, the data is presented using a map of the census tracts of the City of Los Angeles. The user can also provide guidance to the model at any time. The emerging new understanding of epidemic mechanisms almost inevitably will improve the quality and effectiveness of our preventive measures.

Time-shared computer capability also has contributed directly to advances in health care delivery systems as will be seen with my second example—the life science computer resource at the University of Utah in Salt Lake City. This center is practically without peer in the breadth and quality of its programs in the health care field. The resource staff and collaborating scientists in the host institution have used the computer in automated cardiac catheterization, management of patient records, monitoring of the critically ill, automatic interpretation of electrocardiograms, automatic diagnosis of coronary disease, modelling of cardiovascular system functions, control of clinical laboratory instruments, and data acquisition from basic physiology experiments. The special time-sharing monitor

(MEDLAB) developed by the resource personnel for their CDC 3200 computer has been a crucial element in the smooth and steady progress of these activities.

Like the BIOMED Series, the MEDLAB System has been and continues to be exported to other research institutions. However, one of the most exciting "exports" is in its home environment, i.e. at the University of Utah itself. Using funds provided by the Regional Medical Programs Service, the Utah scientists have been able to establish a second computer installation almost completely compatible with the one sponsored by our program. With one machine dedicated to research and the other dedicated to health care delivery, it has been possible to bring the results of research into practical application with exceptional ease and speed. Moreover, the presence of two dedicated systems with distinct roles has done much to enhance the reliability of computer-based health service activities without unduly constraining the research activities. I will return to this point below.

My third example, the Washington University Computer Laboratories in St. Louis, Missouri, represents a change of pace in this discussion so far as computer technology is concerned; its emphasis on health care applications, however, parallels to a significant degree that seen at Salt Lake City. The Washington University resource is indisputably the most advanced center concerned with the design and application of mini-computers in the health area. In fact, the senior professional staff of this resource, when at the Massachusetts Institute of Technology in Cambridge, Massachusetts, designed and developed the LINC computer with financial support from our program. This computer was the forerunner of the multitude of laboratory instrument computers now being produced, and its rapid acceptance and productivity in neurophysiology, experimental psychology, etc., is impressive testimony to the skill and insights of its designers.

The Washington University resource has addressed its efforts to many health problems; examples are automated radiation treatment planning, real-time detection of cardiac arhythmias, and computer-assisted nuclear medicine. All three of these applications employ the programmable console, a mini-computer developed at the resource as a variation on the basic LINC computer design. This new machine is equipped with special electronics to allow easy interfacing via telephone lines to large-scale computers and, hence, facile operation in a "collaborative" as well as "autonomous" mode. In addition to the continuing research program involving them, a number of the programmable consoles are in routine use at Washington University and elsewhere throughout the United States for determining isodose curves prior to radiation therapy and for continuous monitoring of critically ill cardiac patients, most notably for beat-by-beat detection of extrasystoles.

In the foregoing three examples I stressed the immediate applicability of computers to health problems and the contributions of some of our grantees. I hasten to add that our life science computer resources have been equally prominent in advancing basic medical and biological science. The NIH has been noted for its commitment to basic research within the broad framework of its mission orientation, and much of the success of its programs stems from its deliberate emphasis on the acquisition of fundamental knowledge. I offer two examples of the many instances in which our computer resources have abetted these efforts.

The first case involves the areas of biochemistry and biophysics, specifically the mechanisms and controls for cellular metabolic pathways. For several years now the life science computer resource at the University of Pennsylvania in Philadelphia has been a leading center in the development and application of techniques for the simulation of metabolic systems such as the Krebs cycle. Resource staff have provided the user community with a specifically designed set of programs to construct and run mathematical models of these metabolic systems.

The simulation experiments made possible through this computer center are a vital complement to laboratory investigations and have afforded considerable insight into the detailed workings of fundamental life processes. The computer allows the pursuit of hypotheses that would be difficult, if not impossible, to test in the laboratory alone.

In a related field, the computer resource at the Stanford University Medical Center in Palo Alto, California, has proved to be of crucial importance. A unique time-sharing system called ACME has been designed and implemented by resource personnel there, and it is now in routine service operation to the entire biomedical community. One of its many features is a capability to acquire and process data from and control the operation of several types of laboratory instruments simultaneously. Among other applications, scientists at Stanford have used this system to control by entirely automatic means the complete operating cycle of a low resolution mass spectrometer. The computer guides the entire process, beginning with the insertion of the chemical sample to be analyzed and ending with a tabulation and graph of the results. There is no doubt that the future will see an ever-increasing number of laboratory instruments and processes placed under full computer control; our life science resources have done and will continue to do much to show the way.

WHAT HAVE WE LEARNED FROM ALL THIS?

I will conclude by systematically reflecting on the major features of the NIH computer resources program—its strengths and weaknesses, its successes and failures, its virtues and liabilities. The opinions expressed here are my own and may not necessarily concur in every respect with those of men who have observed the program at different times or from different vantage points. Nevertheless, I believe some basic principles can be discerned.

Let's begin with the good parts. Above everything else, I believe the success of our computer resources program stems from two of its fundamental characteristics—the *dedication* of the computers to life science activities and the creation of proper environments for biomedical computer applications. Freed from the necessity of compromising at almost every turn with the needs of, say, the physics department or the business office, biomedical computer specialists have been able to select equipment configurations, operating policies, and the like which seem best suited to them. Functioning directly within and for communities of health scientists, these resources rarely fail to have an influence on and to be influenced in turn by those whom they serve.

The notion and implications of dedicating computers to specific purposes are quite straightforward. Generally, in our experience at least, the more nearly homogeneous the user requirements, the easier it is to implement and maintain a viable capability. On the other hand, there often occur instances where an aggregation of users with radically different needs can justify a significantly larger machine than any one of them can alone and where the expanded technical capabilities and economics of scale outweigh the disadvantages of compromise. Obviously, for any given situation, it is imperative to select the most cost/effective alternative, where the cost computation includes an estimate for system implementation as well as for hardware acquisition. On the whole, institutional and regional centers staffed with experts and dedicated to health research and training have proved to be about the right balance between generality and specificity.

The notion of a proper environment for biomedical computing is a bit more subtle. In addition to being physically and philosophically close to the users, our resources exhibit an admixture of research and service activities and an emphasis on mathematics, the physical

sciences, and engineering that have proved enriching. Given leadership by experts in the technology who are committed to advancing health science, the resource setting is almost ideally suited for getting the results of technological innovation into routine use and, conversely, for having the needs of the surrounding community determine to a significant degree what computer research the resource personnel undertake. The day-to-day exposure of biomedical scientists to expertise in mathematics, the physical sciences, and engineering has spawned the kinds of multidisciplinary endeavors that so many of our health problems require. The specific provision of funds for programmers, statistical consultants, and other forms of "hand-holding" has had much to do with reducing the energy barriers to computer use.

One final entry in the virtue column is the policy of having users eventually assume at least some of the support of the resources through service charges. It has been our experience that direct sponsorship by our program and a minimal, if any, requirement for contributions by users is an effective way to bring a life science resource into being. The guaranteed support tends to let the resource director follow his instincts and insights relatively unfettered by the necessity of recovering his total costs; the associated absence of charges to users makes them more inclined to explore the many ramifications of this powerful technology. But once a resource has been in operation for several years and is providing relatively routine service, the ground rules change. Since it is almost impossible over the long term to control the quality of the science for which the computer is employed or to allocate services judiciously without some sort of pricing structure, service charge policies are routinely put into effect. These user support mechanisms not only allow an orderly reduction in our contribution but, by lessening the dependency of the center on one specific source of funds, also make it managerially stronger.

In the case of the NIH, the systematic introduction of service charges at the centers has served to place the burden of reviewing the need for *routine* computer services where it belongs—on the individual categorical research and training program. In the process, it has markedly diversified the sources of funds for computer use and, all in all, has had a stabilizing influence. As the costs of routine services are assumed by others, a portion of our program funds becomes free for the further pursuit of health-related computer research at existing centers or for the initiation of new ones. This policy has caused the costs of computing, like the technology itself, to become inextricably intertwined throughout the health area. To be sure, this strategy occasionally forces us to justify the need for computers to those who are somewhat less disposed to have them than we. But a careful look in a mirror from time to time usually is beneficial!

Turning to some self-criticism, I must say that our greatest shortcoming has been an educational one. We administrators, our advisors, and the scientists our funds sponsor routinely have failed, if not actually neglected, to demonstrate the full relevance of computer technology to human health. Our tendencies to selectively emphasize instrumentation and methodologies have often made us appear to have answers in search of questions; our all too frequently manifested propensities to promise more than can be delivered or to deliver what we promised later than we said we would has hardly instilled belief. To use Pogo's famous line, "We have met the enemy and they are us".

The therapy for this malady is simple but imposing. If computer science and technology are to continue receiving substantial support for applications in the health area, we must seize every opportunity to make the potentialities known. We must accept that the burden of proof rests on those of us who advocate the use of these machines and that it will continue

to do so for some time; we must be prepared to be judged more on our deeds and less on our fantasies, no matter how deep our convictions about the latter. We will have to make it clear that computer technology alone will not suffice to solve most health problems while at the same time convincing others that these same health problems won't be solved without it.

A second shortcoming of our computer resources program involves a combination of technical and administrative considerations. All too often we have *underfunded* our resources —both in hardware and in personnel. In the name of economy, we and our advisors have frequently held computer resources to less than the critical mass of capability and expertise needed to make their full impact felt. We have not always recognized that too much hardware is considerably better than too little and that one person too many is much more desirable than one too few. In the future we all would be well advised to remember that if a resource cannot be funded adequately, it should not be funded at all.

In the case of the transition to the so-called third generation computers, our tendency toward underfunding was compounded in many cases by shortcomings on the part of our grantee institutions. Most notable were their relatively meager efforts to secure adequate performance guarantees on the new equipment and its advertised software systems. In a distressing number of settings, the vendor delivered and was paid for a system which required extensive modification and embellishment by resource personnel before effective use could be made. In the light of these experiences we are working actively with our grantees to strengthen computer procurement practices and are reasonably optimistic about the progress that is being made. However, so far as computer systems are concerned, *caveat emptor* still is very much a word to the wise.

The third and final item in this confession concerns human beings. No matter how elaborate the administrative forms and no matter how sophisticated the instrumentation, in the last analysis the success of our program turns on the abilities and motivations of the people involved. Inadequate facilities can often be tolerated; absence of enthusiasm on the part of colleagues or sponsors can often be ignored. But unless a program like ours captures the minds and spirits of gifted individuals, mediocrity will be its only harvest.

We have not been blind, of course, to the virtues of having our resource directors be experts in computers and their biomedical applications. On the contrary, we have given this point so much attention on occasion as to make it an Achilles' heel. What I mean to say is that there have been cases where an institutional grant request has passed review largely on the merits of one man and where the viability of the resulting resource has been maintained almost solely through his efforts. When such a resource loses for any reason its predominant figure, the consequences are often catastrophic for all concerned. We and our advisors have learned to look at the *quantity* as well as the quality of the participating scientists in appraising a resource grant application.

Our dedication to finding highly qualified resource directors has rarely been matched, unfortunately, by our efforts to train individuals in the biomedical computing art. In retrospect, we have erred seriously in not providing *systematic* means within the health community for the education of applications programmers, systems programmers, digital engineers, and other computer-related specialists. Moreover, in only a few institutions have mathematics and computer methodologies been made truly part of the fabric of medical education, and our computer resources have been able to play scarcely more than an indirect role. A few moments reflection on the past decade leave little doubt that funds for such formalized training within our resources would have been well spent. In the future we hope to ameliorate this situation.

The absence from our computer resources program of a *formal* training component should not be interpreted to imply that training does not take place. On the contrary, understanding and appreciation of computer science and technology is conveyed in many forms. In some cases, it is on-the-job training of individuals employed by the resources; in other cases, it is through day-to-day collaboration by resource personnel with life scientists in the full context of a biomedical problem; in still other cases, it is through short courses and seminars dealing with FORTRAN and other computer languages and with the latest computer applications. Our grantee community, to some degree at least, has recognized and responded to the need to train a new generation of computer-knowledgeable individuals at both professional and non-professional levels, even in the absence of administrative mechanisms specifically designed for this purpose.

But we cannot let even this seemingly positive aspect of the training picture escape our critical glance. In teaching biomedical scientists about computers, whatever the means, our resources usually have not gone far enough. Too many life scientists associated with our resources hold to the outmoded concept of the computer as a giant calculating device; not enough of them are led to appreciate that it is a powerful *symbol manipulator* and that arithmetic operations are only one of the many manifestations of this. Moreover, life scientists who are taught to do their own programming rarely are made to see the full importance of copious documentation or the ultimately deleterious consequences when the biomedical knowledge encoded within a program is not kept clearly and discretely separate from the procedures which use it or operate upon it. Ironically, good computer science concepts are frequently jettisoned in the quest for new applications.

In concluding, I stress one particular point. Ten years ago life scientists wondered *if* the computer had utility in their discipline; today the only uncertainty involves just how far the utility extends. These machines are very much with us, their use is rapidly spreading throughout all areas, and their potentialities stagger the imagination. But the limiting factor in the health field, at least, is how skillfully—and responsibly—life scientists can apply these tools in combatting disease and human suffering.

SUMMARY

The National Institutes of Health, as part of its Biotechnology Resources Program, provides grants to academic and other non-profit institutions for the support of computer centers serving life science research. These computer resources generally have three component activities: service, technological innovation, and training. As foci of multidisciplinary endeavor, they facilitate the application of computer science, mathematics, and engineering to health problems. The resource mode of support has proved to be a near ideal administrative form for continually interjecting the latest computer technologies into the biomedical area and, even more important, for making the resource's own computer research activities responsive to the unfulfilled needs of the surrounding user community.