THE IMPLEMENTATION OF COMPUTING SERVICES IN A MEDICAL RESEARCH ENVIRONMENT

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ABSTRACT

The process of implementing computing services into any medical research environment is a complex assortment of definitions, staffing, equipment, funding and political factors. The importance of defining one's needs is uppermost. Without clearly stated terms of reference, the foundations of any computing facility vacillate, the consequences of which can be calamitous.

With firmly established objectives, a Director initiates procurement of the equipment required to satisfy the specific needs of investigator-users. The choice of equipment is almost solely dependent on the type of services to be provided. A simple batch terminal to an existing computer does not require the same expertise as a real-time, on-line computer system. The latter demands a staff of intelligent, well qualified individuals, versed in operations, education, statistics and systems software.

Although each type of staff specialist is vital to the success of a facility, the educational group can produce the greatest results. The dirth of health professionals knowledgable in computing techniques is one of the greatest barriers to the successful implementation of computers in the health care system. The problems of the health care system are many and cannot be solved by computer scientists or data processing experts. These disciplines can be of valuable assistance, however the impetus must come from those who control the medical process.

Significant amounts of funds are needed to staff and equip any computing facility. With the decreasing emphasis on basic research, subtle encouragements to study the problems of the health care system are being generated by numerous funding agencies. This thinking cannot be ignored if a viable, permanent biomedical research computing facility is envisaged.

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I N T R O D U C T I O N

"Computers suffer from the same difficulty as electron microscopes, recording spectrophotometers and multichannel pulse height analyzers, i.e. everyone wants one."

Saenger, E.L., Sterling, T.D.
Annals N.Y. Academy of Sciences
Vol. 115 - 591-599, April 1964

A. THESIS STRUCTURE

Establishing the guidelines as to how biomedical computing facilities can service this desire is the primary goal of this dissertation. That computers have arrived, are currently being used in many basic and clinical research applications and will become integrated into the health care system is taken for granted. Not taken for granted, however, is their role in direct patient care; the areas in which they can be most efficiently applied; and the related costs involved.

Many investigators have had access to or have made use of a computer over the past fifteen years and the results of their work is well documented. The 1969 issue of cumulated Index Medicus contained over 900 citations related to computers and data processing. The fact that a significant portion of these papers are highly research oriented attributes to the arrival of the computer as a tool in medical research. However, much controversy is centered about the lack of progress in applying computers to the care of the sick. A well known authority (W9) has written that the purpose of any research in medicine is to find new relationships and refine knowledge of already known relationships among the elements which constitute living systems and to find better ways of using this knowledge for prediction and control of living systems. As medical research must, in the end, justify its existence by contributing to health care delivery, the tone of this work, though research oriented, is slanted to the implementation of computing services which will have an indirect if not direct benefit on the nation's health.

To paraphrase Hamming (H4), it would be more satisfactory and certainly much easier to discuss one small technical application of computers in medicine. However, there exists a danger of getting lost in the details of a singular problem expecially in the veritable blizzard of papers appearing each month. Narrower and narrower specialization is not the answer. A good part of our difficulties is in the rapid growth of the interrelationships between medical research, clinical medicine and computing science. There is a pregnant analogy in the words of a FORTUNE editor (W8) who wrote "....the root cause of our abuse of the environment: in modern society, the principle of fragmentation, out-running the principle of unity, is producing a higher and higher degree of disorder and disutility."

The material for this work has been gathered from four years of experience in the field, as well as an extensive review of the literature on the subject. A MEDLARS search of 1968 - 1970 publications related to medical use of computers extracted 729 citations, less than 3% of which were directly relevant to the thesis topic. Information received from over 60% of the medical schools in the United States has provided unpublished statistics in the form of annual reports, grant proposals and task force recommendations. Personal visits to over a dozen medical computing centres as well as personal communication with some seventy individuals complete the sources of information.

In order that the reader understand the scope of the thesis, the next section outlines the assumptions under which it was written. The limitations imposed by time and academic considerations are also presented. A comprehensive analysis of computer applications in medicine is not intended. Rather, the pertinent factors to be considered in establishing a biomedical computing facility are outlined and discussed. The findings will be of most benefit to those individuals responsible for or involved in the implementation of computing services in a medical research environment.

Chapter 1 unfolds as a brief history of early biomedical computing and reveals that, clinically speaking, little has changed over the past fifteen years. Chapter 2 suggests the foundations and principles upon which a medical computing facility should be laid. It stresses the importance of clearly specifying and defining what type of research the facility is to service. It further concerns itself with the variety of equipment available to meet the variety of research applications present in most medical schools. Arguments that no one computer can service this variety of needs are presented and the suggestion of a hierarchy of computers is outlined.

The staffing requirements, based on the findings outlined in Chapter 2, are the contents of the third chapter. The inter-disciplinary role of any computing facility and the need for capable management is discussed in depth. The political and non-political aspects of financing a computing facility are covered in Chapter 4, including the need to continually assess what investment in dollars would be needed to achieve stated goals and to predict the ultimate value of the investment in advancing medical research and the delivery of health care.

An introduction to a few of the problems of computing in the wider "Health Sciences or Medical Centre" complex concludes the work.

B. ASSUMPTIONS

Avoidance of some technical computer terminology is not possible although it has been kept to a minimum bearing in mind that the text was prepared for an audience of senior medical administrators.

The first assumption made is that the facility being discussed is organizationally within a university medical school. This premise can be extended to include a facility in a medical centre affiliated to a number of hospitals and research institutes.

A "central computing facility" concept has been adopted and is clarified in subsequent chapters. It is assumed that there exists a need to provide some integrated or co-ordinated approach to the computing services of a medical institution. Hence, all discussions pertain to a multi-departmental computing facility - not a smaller laboratory machine, although the centralized facility may encourage installation of other computers in laboratories or departments.

In order to clear up semantic differences, the term "small computer" refers to that class of machine which have 16 - 18 bit word lengths, has a maximum of 65 thousand words of core and cycle time in the order of 1 microsecond. Sometimes called, "process control" computers they differ from other similar computers by virtue of their memory protection and direct storage-access features which enable them to multi-program and time-share.

For compactness the text contains statements referring to the Dean of a medical school. These can easily be related to the Executive Director of a medical centre or any other similarly placed official. Dollar figures within the text are Canadian although the built-in error of such predictions negates any great difference. All references to the male pronoun "he" can be freely translated to "she" if so desired. Finally, it is expected that not all readers will agree with the findings and that discussions will arise therefrom.

C. LIMITATIONS

Although one should not isolate biomedical research computing from the total health field, certain limitations have been imposed on this work. The many varied and intertwined aspects of hospital accounting and administration are not covered. Many existing biomedical computing facilities process both research and administrative matters and some controversy exists as to the effectiveness of such an organization (L3, P2). One hears a similar debate in industry that accounting jobs are more important than scientific development ones. Although the issue is brought up, no in-depth analysis of the problems is given.

The computer oriented clinical service aspects of a hospital such as the generation and retrieval of automated medical records, capturing of patient histories, laboratory systems, multi-phasic screening and electrocardiogram analysis are also mentioned but not covered in depth. Although analog computers are being used in medical research, their numbers are few and their applications limited, hence, they are not included in this work.

No one specific application is pursued in great detail nor are the sometimes unique problems related to the general practitioner focused upon.

The philosophical arguments that "doctors are not properly trained to use computers", the lack of standardized terminology; existing emphasis on the memorization of numerous facts and the lack of unique identification of all individuals are considered but only in the general context of education as opposed to the live problems encountered in implementing hospital oriented clinical systems.

Detailed information as to the physical dimension of computers; their heat, space and electrical requirements; arguments for and against the leasing/renting, importance of accessibility; the planning of proper working conditions, and the many day to day aspects of operating a computing facility is not given. These topics are well documented in the general computing and management literature and the points to be considered are no different in medicine than in any other field.

Although the need for capable management is stressed, proven management and administrative techniques are not discussed. Matters concerning the medico-legal aspects of confidentiality of the patient record are not brought up nor are the related security systems needed to assure the legibility of both the originator and extractor of medical data.

CHAPTER I

HISTORY

"The United States boasts of having the best medical care in the world. Yet this care is inadequate. A young house physician from one of our large metropolitan hospitals recently complained that he and two other doctors were forced to see and treat 180 patients in the course of a 3 hour clinic. The expanding demand for medical services that has resulted from Blue Cross and similar prepaid medical care plans, cannot be met by our present facilities with present methods. To establish a diagnosis, takes too long. Co-ordination of the efforts of those responsible for various care is too haphazard. All our work is piecework and it is all done by hand."

Duncan A. Holaday
Science, Vol. 134: 1172
October, 1961

To cite at length, the pioneering efforts of biomedical computing would reveal what areas of medical research were first to explore the use of a computer as a new scientific tool. Such an account would be of minimal practical value, other than providing an interesting exercise in learning the reasons why the military consequences of World War 11 started it all. However, to sample the thinking and philosophies which were prevalent in the late fifties and early sixties might be of some benefit. Their content is enlightening to say the least.

A. PRE-FIFTIES

Prior to 1950, digital computers were relatively unknown to medical research. Gibbs and Grass (G3) had developed in 1947, mechanical devices to integrate and frequency analyze electroencephalogram samples. Others such as Hessburg and Burch (B4) used analog computers to conduct similar studies. The famous Cornell Medical Index questionaire to collect self-administered, medical and psychiatric data without physician participation had its initial beginnings in the late forties (B6, B7).

By the mid-fifties, an expanding interest (L7, M5), in the use of electronic devices to study the low signal amplitudes of the human body was apparent, stimulated in part by the work of Schmitt and his colleagues who used computers to suggest biological servomechanisms for certain features of vector electrocardiograms (S10).

The punched card system of data processing was invented in 1889 and by 1936, Atanasoff (A3) was using cards to assist in the study of complex optical spectra. In 1943, Black-Schaffer (B5) designed an elaborate (and surprisingly modern) Hollerith punched coding scheme for syphilis studies. This technique was used by others (H5, R7) although in some cases, the cards were "marginal punched cards" which were separated by rods and could be only loosely defined as being automated (L6). By the late fifties, more computer-assisted work was underway and one could find 15 citations under automated data processing in the 1960 issue of Cumulated Index Medicus. By 1965, there were more than 35 biomedical computer facilities in the United States, dedicated to research studies (A4), and over 450 citations in Cumulated Index Medicus were related to the subject.

This exponential growth in published material is most encouraging if one looks upon the computer as a powerful tool which has helped in the advancement of medical research and medical cures of human illnesses (AN5). One the other hand,

"During the last decade, there has been increasing awareness of the need for improved techniques in handling clinical research data."

This rather general statement appears quite often in today's literature and could be construed as prophetizing the role of computers in clinical medicine for the seventies. Yet, the quote is taken from the May 7th issue of J.A.M.A., 1960 (S11).

B. LATE FIFTIES AND EARLY SIXTIES

In July of 1959, Ledley and Lusted reported (L8) that before computers could be used as an aid to the medical diagnostic processes, much more needed to be known about how the physician makes a medical diagnosis. No one was arguing that complex reasoning processes were involved. It was widely believed that errors in differential diagnosis resulted more frequently from errors of omission than from other sources. A few months later, Ledley (L9) discussed the great advances in medical knowledge which had not been matched with a parallel advance in making this knowledge available to the practicing physician. He pointed out that the media for exchange of ideas had not yet been adequately developed and that most communication amongst researchers took place at conferences and symposia. The inability of the overworked practising physician to attend such meetings was not mentioned but no doubt was implied.

A 1961 editorial (AN6) pointed out that the thorough system review required to capture, analyze, and act upon patient data may too often be eliminated because of impatience on the doctor's part or because evaluation of the diagnostic implication of many seemingly unrelated symptoms detected is a difficult exercise in logic. It was suggested that a computer might be used to evaluate the information collected through a careful system review by a physician whose only concern would be the accurate determination of the presence or absence of a discrete list of symptoms and signs. Diagnosis might then be improved.

Considering the $19 billion spent on biomedical research in the past 10 years (Figure 1), the suggestions of the early sixties do not appear to have been heartily endorsed. A cursory scan of almost any given journal, reveals suggestions of an amazingly similar nature.

The reasons for this are not straightforward and are in part due to the highly conservative motives of medicine and to the oversell of the early sixties. The advocates of "hospital information systems", "clinical management information system", "total general information medical processing systems" were listened to, funded and trusted. Unfortunately, these individuals for the most part had succumbed to pressures of modern advertising and to the subtle marketing tactics of computer manufacturers. They were not those concerned with the problems just cited. They refused to accept the principle that medical objectives were not clearly formulated and hence, unacceptable to automated proceedures. Their "information systems" were more "patchwork quilts" which functioned, in many cases, only on the knowledge and inherent idiosyncrosies of several key clerical employees (J5).

Commercial and accounting-oriented computer specialists, as well trained as they might be, do not have the necessary background to successfully apply computing technology in the health sciences (S17, L18). As will be discussed in subsequent chapters, most successful applications of computers to date are in those limited areas the project leader has the highest level of medical competence.

The incidental, pedestrian programs which automate the inventory in pharmacy or prepare payrolls do not "turn on" the medical community (G2). It is of course quite natural, and useful, to use computers to perform existing tasks more quickly and comprehensively. But they will begin to improve things really dramatically only when existing processes are reconstructed to take full advantage of the capabilities of computers (N6).

Some comfort may be had in the knowledge that in the past, any new technological advance has been initially rejected and feared: rejected because of the belief that it could not work as well as existing devices; feared because of the suspicion that it might (F8).

	60	61	62	63	64	65	66	67	68	69	70
Health Services	27	(29)	(31)	(33)	(35)	36.8	4.1	46.7	52.4	(56)	60
Biomedical Research	0.8	(1.0)	(1.2)	(1.5)	(1.7)	1.8	2.1	2.3	2.4	(2.5)	2.7

Notes: 1.( ): indicate estimate

2. Source: B1

Figure 1.

Aggregate U.S. National Health Expenditures by Type of Expenditure for Calendar Years 1960 - 1970 in Billions of Dollars.

C. SEVENTIES

One would expect, nevertheless, that much has been learnt during the relatively static growth period of the sixties. That the advice of the intellectual and experienced leaders of today will be acted upon, can only be hoped for. Alarm about applying computers in medicine, fully justified by the facts and long overdue, is a required precondition of reform. But alarm, by itself, puts out no fires (W8). The suggestions being currently made, are not easily digested for they imply significant changes in medical education, the role of the physician in the cure of the sick and the funding of health delivery agencies. Yet computers are involved in the evolutionary process of social change and improvement. As they come to play a prominent part in the study of social and health care problems, it must be insured that they are used for the actual implementation of change, not as one more destracting influence. (F7).

The perfect analogy to the history of biomedical computing during the past fifteen years, is difficult to find. In some ways, one can consider the growth to that experienced by the teenager who from his/her thirteenth birthday, goes through a period of unknown adjustment, constant questioning and moral confusion. Upon becoming an adult, he/she then matures, prepared, trained, capable and wanting to make a contribution to society. The teenager's growth to adulthood spans a total of nine years. Biomedical computing has gone through fifteen years to date and has as yet to reach adolescence. Nevertheless he/she is becoming more mature.

C H A P T E R 2

F O U N D A T I O N S

"Biomedical computing is a coherent body of knowledge which is difficult to characterize independently, but which interacts with each health function".

R. D. Yoder, 1968

Ref: Y2

Establishing the foundations of a biomedical computing facility is almost always more difficult than the originator(s) had conceived. Problems unique to the computing field, to the inter-disciplinary nature of the service and to the newness of the approach are often not realized, ignored or passed over (A8). Reports of facilities which for one reason or another did not flourish beyond the initial stages are not uncommon (E2, G1, S8). Nevertheless, most computing facilities play a significant part in the future of a medical installation. Successful systems attract advanced researchers, weak ones generate discontent.

Abetting political, conflicting priority, and usage problems before they occur is best managed by clearly defining the biomedical computing facility's terms of reference (M11). Although easily said and often quickly done, unless the facility's objectives, goals and purposes are understood by all concerned, conflicting opinions arise (R12, B9). In establishing goals care must be taken to see that aggregate goals are not achieved through unintended individual costs. The terms of references must properly identify existing needs and anticipate future ones for just as in social matters, one man's benefits are often another man's costs (B8). They must clearly define the facility's freedom to make major configuration changes, modify programming policy and provide terminal equipment with or without committee approval. Awareness that a computing facility draws departments together as never before is one which reaps benefits a hundredfold.

A. DEFINITION OF NEEDS

In most instances, the need for computing services is initiated by one or more individuals who, through the course of their work, have already made use of a computer. They usually approach the Dean with a request for funds to either purchase an isolated, independent computer or to establish a facility capable of providing improved services. At the point, a committee is established to discuss the merits of the request and make appropriate recommendations. Herein lies one of the Dean's most important decisions for the committee's initial role is a most vital one.

Assuming that the committee,

a. represents all those in the environment who are interested - including the clinicians,

b. has on it members capable of judging the technical feasibility of the request

c. contains those who are blessed with "common sense"

the first recommendation to be made is the reasons why the existing services (which are often very capably provided by the main university computer centre or a commercial organization) are inadequate (C3). This is an important consideration for a few singular individuals may aspire to obtain services which they alone cannot economically justify. They may then attempt to convince others (whose needs are being adequately met) that improved capabilities are needed. Once a computer has been installed, those convinced to join in the support may not be firm enough in their thinking to make actual use of the new services. It has been reported (Y3, S7), that with the advent of multi-programmed time-shared utilities the need for a computer centre is often completely eliminated. The current state of these utilities can in some cases alleviate the capital outlays, operating costs, space requirements and administrative problems common to all computer facilities.

Nevertheless, due to geographical separation, unreliability, improper type of computing (e.g. batch instead of on-line), privacy of data and other factors, many medical schools aspire to satisfy their own computing needs. In studying the need for improved services, the committee describes the major research projects the facility will attempt to serve which reveals the breadth of interest that has been created and the nature and extent of the preparation of the prospective users of the facility (G6). As pointed out by Sterling and Pollack (S7), a definition of the overall scope of effort must be made to determine what equipment is needed and/or desirable, how much it will cost, and what can be deleted with minimum loss, since the initially determined cost will be excessive, regardless of the amount.

Upon realistically and objectively assessing the existing deficiencies, the committee next determines the nature and scope of in-house computing services needed. These fall into basically three categories, each of which may have several variations:

1. Batch
2. On-Line
3. Real-Time

It is assumed that, at this point, the committee is aware of available funding and that it is felt worthwhile to pursue studying the types of service needed. Matters pertaining to the financing of a computing facility are discussed in Chapter 4.

B. BATCH SERVICE

This type of service is the easiest to provide and, in its initial stages requires the least amount of funds. It is most often met by installing a remote batch terminal which communicates either directly or over telephone lines to a larger facility (usually the main university computer). Most input is via punched cards and after a delay of some 1 - 24 hours the results are returned to a printer. This type of facility handles a wide range of applications (Y4, H5, H6, N3), ranging from exotic, free-format file management needs (Y5, D1) and optical processing (L12, Y7) to simple-calculating programs. It is by far the most common service provided and especially satisfies those whose projects require extensive computational capability and random access to large data bases. It is a service which is sometimes "played down" by the on-line advocates, nevertheless, many useful and practical problems can be solved, especially if turnaround time is low.

As batch usage increases it may be thought advantageous to install a system which is capable of handling some of the work locally. Carried a step further, a large batch-oriented system, installed within the medical school might be deemed the only answer. Certain of the larger medical schools (e.g. Stanford, Baylor, Minnesota, UCLA) have large batch-processing machines within their confines (D6, L23). These are primarily dedicated to medical research, education and clinical needs as opposed to a university computer which services all faculties and schools in addition to medicine.

In these times of fiscal uncertainty, to duplicate already existing facilities is economically difficult to justify. Providing that an acceptable batch service is being maintained by a university or commercial machine, that confidentiality of medical data is not a vital issue, that a fair share of the prime-time computing is provided and that the large system is technically capable of handling the load, installation of a pure batch machine in a medical research environment is not encouraged. Far greater benefit can be obtained expending funds on additional teaching staff to educate investigators and on providing on-line and/or real-time services.

C. ON-LINE SERVICE

Access to a computer system from multiple terminal sites via direct cable or telephone links is highly desireable and offers many advantages (Y3). Work performed on a teletype or typewriter terminal directly connected to a computer usually imposes little or no burden on the user at data gathering time. The ability to develop, debug and process programs in one sitting has proven, under certain circumstances, to be more productive than batch-oriented programming (M10). Being able to type one's own data into a typewriter and receive an immediate factorial or multi-linear regression analysis saves hours of desk calculation (R10). The promising areas of computer assisted patient histories (S5, S9, M8, G7) and medical decision making (B16, B15, A10, C12, L23) are greatly enhanced. The delays and difficulties inherent in batch processing are overcome (R9) and the increasing demands to process narrative medical data are facilitated by on-line processing (Y6, S16).

Once again the computer used can be a central-university one although, in this case, only the larger well funded medical facilities are usually able to provide this service in-house (F3, L11, R8). Smaller "process control" computers with on-line, interactive capabilities are now being installed within the medical institution (P4, G12, A6). These offer the advantages of modularity and lower costs in addition to the capabilities of handling some batch work and communications to larger systems, as well as on-line work. Installing such systems is not without difficulties however, especially where large masses of data are involved. Medical researchers doing their own on-line file manipulation programming are often inexperienced in computer techniques. They do not usually wish to be concerned with the intricacies of an operating system, hence a flexible and self-checking filing capability must be designed. Also, a high degree of reliability becomes critical once a service has been implemented. Travellers expect that once a paved road has been built, it will be kept in condition so that speeds of 70 mph can always be maintained.

D. REAL-TIME SERVICE

Real-time service is by definition similar to on-line, with the added factor that analog or digital input and output is involved. Here, the computer is an integral component in an experiment and at least part if not all of the input facilities are transferred from point of origin to the computer in an electrical signal mode (S21). Often the computer-generated output is used to determine subsequent steps in an experiment or to produce computer-controlled stimuli. The complexity of this work is ten fold more difficult than batch and requires a level of personnel competent in a number of different fields. Often, this type of service is the only one which is able to solve particular problems such as laboratory data acquisition (M9, H9, F4, E3, S22).

More often than not, this type of need cannot be serviced by a large, batch oriented centralized facility (R3) and requirements of immediate, closed loop response encourages the use of in-house small or mini computers. A real-time system is much closer to the biological orientated thinking of most investigators. It enables him to alter the course of an experiment or to explore in greater depth some unexpected finding and to correct invalid data at the time the problem occurred (P9). It is also conducive to graphic displays of data as opposed to typewritten alphabetic or numerical information (V1). The advantages provided are many though the difficulties encountered are usually subtle and intricate in nature (S23, AN11).

The decision as to which services to provide is a complex one involving factors such as financing, staffing requirements, research areas being pursued and the existing political structure. No black and white solution exists. After considerable deliberation and thought, one is led to believe that a system of computer(s) serving <u>all three</u> types of needs is perhaps both economic and practical. As pointed out, the research environment generates a wide variety of applications requiring a wide assortment of computer sophistication (A2). No one single computer on the market today can adequately and economically satisfy all three types of computing. A combination of computers, arranged in a predefined hierarchy, can furnish the service, reliability and flexibility which most medical environments demand. If a natural evolutionary process is envisaged with initial batch services being provided and later upgraded, then the above concept deserves consideration.

E. HIERARCHY OF COMPUTERS

It has been alluded to by many (S21, M9, P5, W11, L17, AN10, AN11, W12, A7, C3, S27, B17) that the hierarchy being discussed should comprise of inter-linked small computers with some accessibility to a larger(s) machine. As depicted in Figure 2, it is further suggested that the key elements are the computers within the nucleus, namely the co-ordinating computers (P6). Their functions, and initially only one computer is necessary, is to co-ordinate computing by

a. communicating to one or more large systems

b. providing on-line capabilities to remote terminals

c. providing real-time service to those experiments which cannot justify or do not require dedicated mini-computers.

d. interfacing other small and mini systems to make available the increased computing capabilities of larger machines.

The vital link between

1. the co-ordinating computers themselves
2. the co-ordinators and other small computers
3. the co-ordinators and larger systems

can be effected by direct digital cable hook-up, by telephone communication transmission, by manual transfer of tapes and discs or by specially built hardware. Each technique, except perhaps the latter, is both proven and technically feasible. An installation's specific requirements and financial support

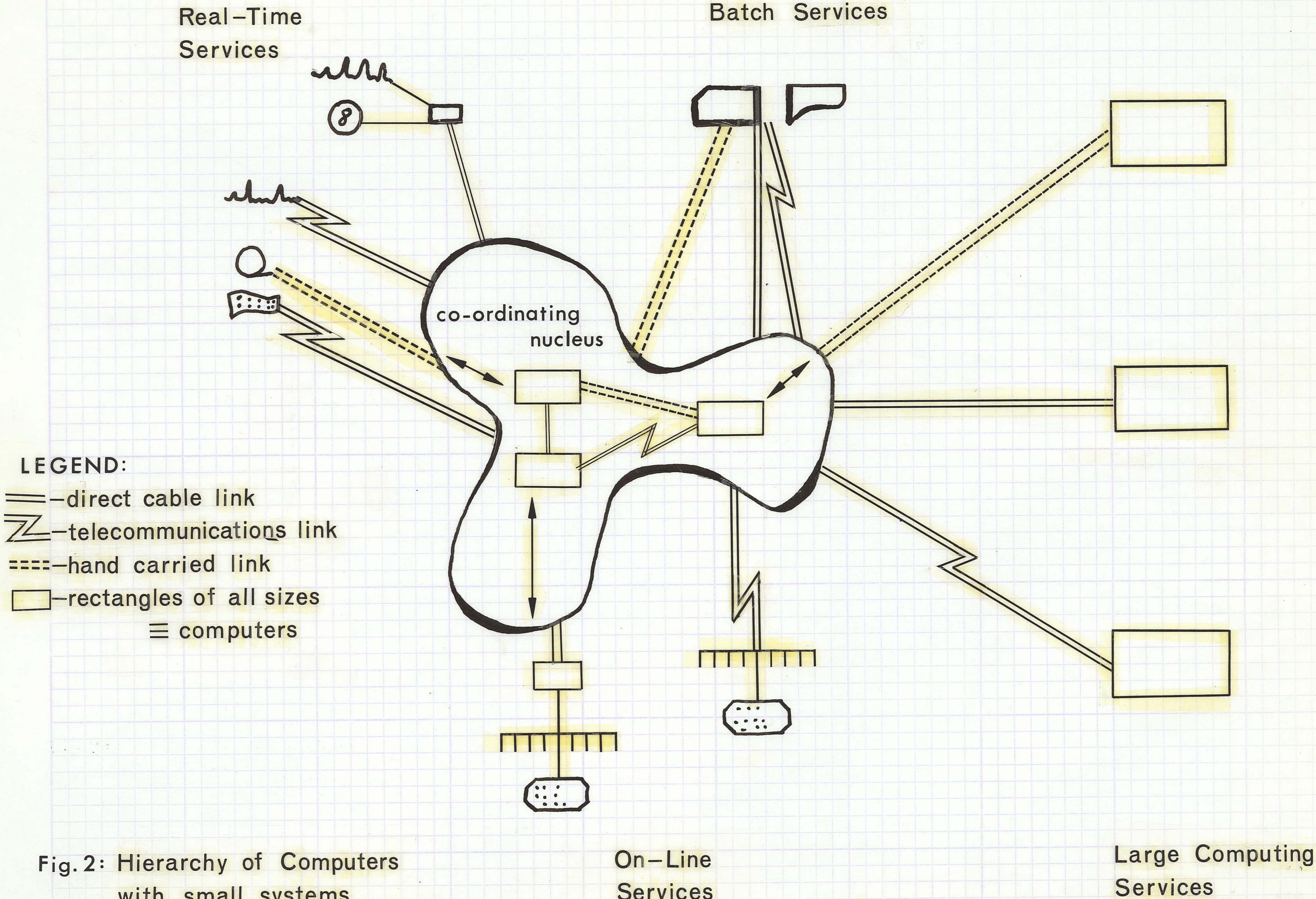

Fig. 2: Hierarchy of Computers with small systems acting as co-ordinators within the nucleus.

dictate which combination to use.

The advantages of such a hierarchy of computers are many and are discussed to some extent in the references indicated. In particular, the approach is modular, economic and modern. Because the nucleus and the periphery can be incrementally added to or modified with relative ease, a hierarchy is modular. At the onset, batch requirements are satisfied by a university or commercial computer and the nucleus contains a batch terminal. As on-line and real-time services are needed, the nucleus expands with the addition of one or more small systems. The periphery also grows with the installation of mini computers designed and implemented to serve specific, well defined needs.

Growth can proceed in small incremental steps, controlled by the health services resources available (P7). Abundant capital outlays are minimized as the larger more powerful machines are only used when needed and not purchased. Centralization is encouraged, within the bounds imposed by the need for dedicated systems. Common peripherals such as card readers, printers, discs and tapes are shared, minimizing operating costs. Finally, the concept is economic in that, price performance improves by accessing various large computer systems which have been designed to handle specific tasks.

A hierarchy of computers is modern because it accepts the fact that hundreds of computers are already installed, many of them providing reasonably adequate service. In many cases, the periphery is present and nucleus is all that is wanting. Investigators, stifled by the limitations of their existing systems can be satified while those who could not justify stand-alone system can now be serviced. Although economically practical one does not assume that amalgamation of computing power is politically possible in all environments.

Finally, a hierarchy of computers satisfies Fontana's (F9) specifications for a multi-discipline, multi-laboratory system. He reported that is should:

a. Collect both analog and digital inputs from many sources within and among laboratories.

b. Process on-line, physiological information in an integrated and interactive manner.

c. Provide on-line program development and software maintenance at the same time that the computer system is in use for research support.

d. Rapidly present results in both electronic display and permanent form.

e. Transmit and receive information from other computer systems.

F. FACILITY'S ROLE

After the committee has decided the type of service(s) to be provided, the next recommendation concerns the facility's administrative structure within the institution. If it is placed at a departmental level reporting to the Dean (T1, G8, S6), one is assuming that the facility will provide services for more than one department. That it should be responsible for all matters pertaining to computers is somewhat controversial, although common sense and sound economic theory support such a consideration. The importance of establishing a separate, self-governed department of the institute, free from the bounds of any one department, cannot be overstressed (B13). Computers, by way of their cost and information-transferring capabilities, are multi-disciplinary (Y2).

A number of individuals (H3, L4, K2, P3, S2, S14, C6, R11, S6), have over the years, stated that the basic difficulties facing computing in medicine are primarily due to inter-disciplinary and inter-departmental problems. This is most unfortunate, however, the situation does exist. Communications, even within medicine, is becoming increasingly difficult (N4). To delegate to an existing department the task of servicing the computing needs of other departments is not only fraught with danger but is also conducive to installation of computers in each individual department. Although this concept of a computer per laboratory is supported by some (L1, H11, M4, P2) and certain definite advantages are evident, the approach must be considered under economic cost benefit analysis (C4). In those environments where large batch computing and small real-time needs exist, n small computers will likely perform more efficiently and productively than n^2 mini computers. Sharing should be encouraged to the maximum extent possible (S4, B13). Partial availability is usually much less an impediment than partial capacity (F2).

Investigators requiring special capabilities such as interactive modelling in APL should be encouraged to patronize those facilities which have the software and hardware to meet their needs. Herein lies a usually overlooked aspect of a biomedical computing facility, namely that of knowing what is available for what price. Rather than assuming that all computing must be done within the confines of an institution it is wiser to direct specific application to those computers which can best service their needs. Acquiring this degree of knowledge and expertise usually entails a significant level of internal research within the facility which is sometimes neglected or perhaps even not allowed (S6). An unfortunate state has arisen if users look upon a central computing facility as a gas station providing fast and friendly service but giving no thoughts as to how one might better fill an automobile's gas tank. Advancements in computer technology do not take place at the same rate as advancements in medicine. To stifle internal research in favor of pure service, degrades the level of service to the point of becoming archaic (J2). Unless the relation between the computer facility and the research laboratory is a collaborative one, innovative development of computer applications simply fail to occur; the computer facility becomes just another machine shop and its personnel just technical service functionaries (G6). By the core research conducted by the facility staff, an indication of technical capabilities of the staff and the quality of their understanding of biomedical research computing needs and problems is readily given.

G. SELECTION OF A DIRECTOR

Upon completing the above duties, the committee should be charged with the appointment of a Director. This may require the assistance of those individuals already involved in directing a biomedical computing facility. These scientists are aware of the inherent difficulties of their posts. To find a capable Director, requires not only good searching, but also good fortune. Few individuals today are equipped with the talents required. The foundation of a co-operative computer facility must contain the proper leadership of an individual who is able to promote, communicate, motivate and otherwise facilitate co-operation among participating investigators (L16). Different people consider certain assets as being most important. Schwartz (S15), is of the opinion that a new breed of professional is required. A "health information scientist" trained in medical sciences, computing science, decision theory, operations research, industrial dynamics, systems analysis, and the application of behavioural sciences to large social systems. Leadership in the future may indeed come from such broadly trained individuals, however, the present environment suggests that the medical or biological scientist with computer expertise is more suited than the computer scientist with some biological knowledge (S7, R4, AN7).

This is not meant to imply that any physician with or without computer experience would be succesful. Nor on the other hand does it suggest that a computer expert (H3) with little medical knowledge would not prosper. Rather the individual with an extensive exposure to both is a definite asset. An indication of this need are the two comprehensive volumes "Computers in Biomedical Research" by Stacy and Waxman (S12) published in 1965. One of the reviewers (S13) of these tests noted that both volumes emphasize the use of the computer as a tool in the hands of the research worker and do not explore the computer as a technological device. The texts merely show how a computer is used to do something that could not readily be done before without it. Because of this the computer scientist may have great difficulty in reading much of the book unless he also has an extensive biological background.

No matter what his background is, the Director will have to outline detailed specifications of the services to be provided for tendering to computer manufacturers. A comparative analysis of the possible choices in hardware and software followed by a defense of the particular computer necessitates a certain degree of computer expertise. As pointed out in Chapter 3 this technical expertise may in some cases be provided by an assistant, who has experience in this area.

With the appointment of a Director the committee's role may change from a policy setting to an advisory capacity. In accordance with the Director and soon after his appointment, long range plans should be established in order to avoid the situation where demands outstrip the supply even before the factory smell has worn off the equipment. Further, the necessary lines of communications should be established. Caution should be exercised to make certain that all users have a forum in which their needs and dissatisfactions can be heard (G11). When communication ceases, the usefulness of the facility decreases. One way to insure this communication is for investigators to participate at every stage of planning and setting up of the computing facility (C8). Priorities will need to be continually re-evaluated, for different projects will require preferential treatment at certain times.

A means of allocating computer usage may be necessary and may be done on the basis of time or on the basis of dollars. Advocates of both exist (G10, N5). The President's Science Advisory Committee on computers in Higher Education (H10) chose to believe that measurement in dollars is more meaningful to users and is more useful in comparing the value of computing with the value of, say, laboratory apparatus or special-purpose computers than is measurement in terms of computer time. Regardless of whether the unit is time or money it is important that some allocation procedure be used which provides effective control.

That the Director be able to administrate is usually taken for granted and sometimes with disastrous consequences (G9, L19). Yamamoto (Y1) noted that institutions which propose to foster computing research facilities should not only assure themselves of the personal capabilities of their principal investigators but also should assure them of appropriate faculty or administrative power. One can only add that the Director will further be given the responsibility of resolving natural competition for space, funds, equipment, personnel and computer time. To alleviate these conflicts he should be empowered to foster collaborative contacts which, in many environments, are currently based on random chance, or at the researcher's instigation. The individualistic and isolationary thinking which permeates medicine in general is one of the barriers which has to be overcome.

C H A P T E R   3

S T A F F I N G

"....Large computers bear about the same relationship to....... smaller ones as a Boeing 707 bears to a Piper Cub. Like the 707 they are too costly to be sitting idle, but they also need more highly qualified - and more highly paid - personnel to operate effectively".

Alexander, T.
FORTUNE, p. 129

October 1969

The implementation of computing services presupposes that human beings are available to operate, program and maintain computing equipment. The amount and level of staff required is a function of the type of services to be provided and the sophistication of the investigators who will capitalize on the services. In most cases as the type of services improves so too must the quantity and quality of staff. If one assumes that only a terminal batch-type service is to be provided, Figure 3 depicts a suggested personnel structure with each enclosure representing an individual or a group of individuals.

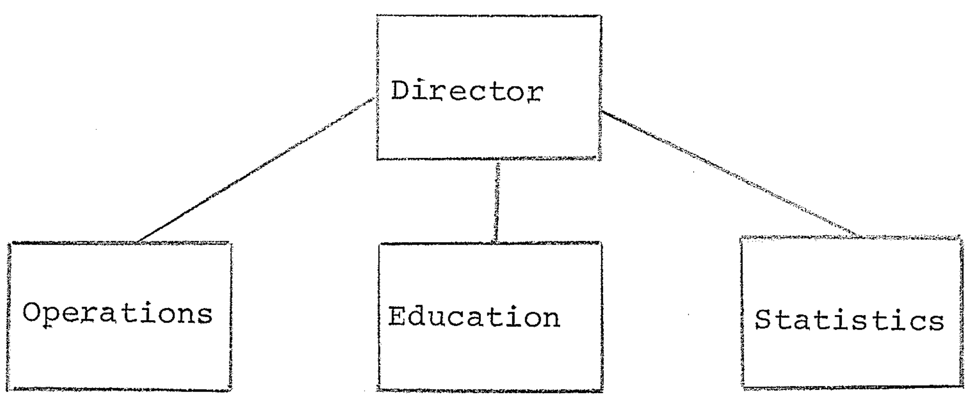

Figure 3

The importance of a proficient Director was alluded to in Chapter 2. The success or failure of a facility will often depend solely on this person. The internal programming, documentation and operations standards he establishes will greatly affect the outcome of the facility. That he preferably be a physician or scientist trained in the biological sciences with adequate training in computer science has been discussed. It is just as unreasonable to expect the computer expert to solve the problems of medicine as is it to expect the engineer and toolmaker to perform the surgical operation or the pharmacologist to treat the patient. In medicine, it is the physician who knows what information is needed and how it should be used and it is he who must lead the way into change, not the experts of other disciplines (S13).

The varying requests and requirements of biomedical computing necessitates above average managerial capabilities. In studying Figure 3 the Director could conceivably also function as the sole individual in Education and Statistics. Performing these lower level duties exhibits a management philosophy which is advisable throughout the staffing structure.

Although not supported in the literature searched, experience indicates that overqualified personnel should be hired at the onset. As an example, to hire a junior operator who in nine months would be unable to supervise a group of 2 - 3 operators burdens the facility with too many workers and too few leaders. The same logic holds true for most positions. In the formative stages of an organization one is more astute in hiring senior level staff to perform junior duties, rather than junior staff who are unable to later cope with senior level responsibilities. The argument that senior level personnel leave for greater opportunities is valid. Nevertheless, such a person will likely have made major contributions to the organization of his section such that at his departure, a more junior level person may indeed be able to function effectively.

Along with the Director in this structure are three groups which on the surface function independently but in the real world depend upon and communicate extensively with each other. That the senior members of these groups are able to assume supervisory responsibilities is oftentimes ignored in the academic world of which medicine is a part. The administrative and managerial functions of any facility must not rest solely with the Director. An atmosphere of functional independence should be created where decisions are made without the Director's consent. This type of structure is sound provided active two-way communications exist and the senior members of each group are able to function with minimal supervision.

A. OPERATIONAL

The first of these is the OPERATIONS group who's function is to operate the terminal equipment in such a manner as to assure a reliable and dependable service. As they are attending to individuals who believe that a sick person arriving at a hospital should not have to wait days or weeks for treatment, similar criterion for rapid computing service is put upon the operators. Low turnaround times are their primary goal although in many instances they have only a minimal control over the actual execution of a job once it is sent to the computer.

This group also usually provide keypunching services in order to speed up transcribing of data onto cards. An often overlooked responsibility is that of assisting in the design of input forms and data collection sheets. Medical researchers are noted for the diverse and sundry manner in which they capture raw data (S7). More often than not they have never been exposed to automation and their data is rarely conducive to keypunching or computer processing. Yet decisions are regularly made on the basis of processed data which may be used in matters of considerable consequence to a project or institution (L19). Much time and effort can be saved if researchers are taught as early as possible the fundamentals of good form design as well as the importance of accuracy of observation and careful data recording. As the operations group deals extensively with such forms, their advice on the design and formatting can be invaluable. It should be noted that this group is not usually expected to "advise" on the validity of the content of the form but rather on its physical and dimensional characteristics.

The important role of this group is often disregarded. That they, in some instances, must co-ordinate a heavy batch load, simultaneously with on-line activity and time critical real-time experiments is casually overlooked. If the services being provided are more than a simple batch terminal, then the efficiency and intelligence of these individuals has a surprising effect on the success of a computing facility.

B. STATISTICAL

Most individuals, concerned with the use of statistics in medical research agree that there exists a definite need to provide biostatistical services. The dangers of misuse and abuse are well known. The power of the overworked "t-test" to prove significance of any experiment, whether it be normally distributed or not is evident in the technical literature. As Dixon (D2) points out, the problems of how to use statistical programs and the pitfalls of inference that can easily result have not been resolved. Some controversy (R4, S4, A11) exists as to whether or not a computing facility should be charged with the design and interpretation of biostatistical analyses. In assessing the pros and cons it is suggested that, once again, a compromise appears in order.

It can be argued that the type of statistic capabilities within a computing facility should be highly "computing oriented". A group of individuals should be charged with implementing existing statistical packages (D7, S30), and developing new or special-case programs as needed. That they should educate users as to the packages' characteristics, usage and formats is also obvious. Notwithstanding these responsibilities the group could also be expected to assist in proper experimental design, provide instruction to undergraduate and graduate students, and orient the physician toward the importance of quantitative work.

This latter role may be a primary function of the statistics group although in some instances the responsibility lies in a separate disjoint department of biostatistics. These departments already exist in numerous medical schools and their usual objectives are to organize research efforts by assisting in formalizing hypotheses, experiment design, data capturing and analysis of results. The expansion of these objectives to instruction and orientation of medical personnel toward the importance of quantitative work would seem better suited in this milieu. Further, this group is usually already in the mainstream of research activities and intimately aware of the projects underway.

C. EDUCATIONAL

The final group in this structure is that of education and programming consultation. Many (R4, S7, G2, L5, W7, N1, Z1, AN12) have eloquently pleaded over the years that the medical student and the life scientist be exposed to information processing. Others (L19) have gone as far as saying that the success of a medical computer system depends more on the effectiveness of the education and training programs than on the degree of sophistication of the computer hardware. Unfortunately, too few (S3, J4) have heeded the recommendations. The majority of instruction in biomedical computing is on an informal, often casual,basis or is restricted to a few specific areas (W6, H8). Upon reviewing the progress of computers in medicine, one tends to agree with Caceres (C3) that a computer system becomes relevant in an environment only after the education and training of the prospective researchers, developers and users.

The basic objective of any research is to apply the findings of the laboratory into the real world. That good, provable laboratory results do not gain automatic universal acceptance is partly due to a lack of training and education. Implementation of results does not necessarily follow good initial results (C5). In the specific area of clinical service, systems designed and tested in a research environment are often unsuccessful when transformed to patient care. The reasons are not due to differences in facilities and professional competence but rather due to the research team's neglect of the acceptance problem. Those who are to use the information must be informed - otherwise they resist active implementation.

Looked at in another light, few application projects succeed if

a. the person seeking the answers is unfamiliar with the tools being used.

b. the person generating the answers is unfamiliar with the questions.

c. the person generating the answers is not the same as the one generating the questions.

As pointed out by Slack (S25), an increasing number of computer programs are being written for use by people other than the writers and sometimes these people have neither responsibility for, nor vested interest in the use of the programs. If people are to interact with computers the consequences of this behavior must be reinforcing.

For the same reason that a Director should preferably be a biological scientist with computing experience, so too should a researcher wishing to use the computer as a tool understand it. In the manipulation of drugs, the physician with appropriate knowledge can make up for shortcomings in reliability and quality (C3). As pointed out by Saunders (S26) in his review of Payne's (P10) article on the basic principles of computers, the concept that computers augment cerebral functions - not replace them, is too readily forgotten by many research workers looking for a device to substitute for their own inadequacies.

In biomedical computing, an experienced investigator who understands his equipment does not become disillusioned by its shortcomings. To paraphrase Sterling and Pollack (S10), "Developments in medicine brought about by the computer are most often stimulated, guided, originated and finished by the medical man himself". He need know nothing of programming, but as with any link in his instrumentation system, he must have means for checking the performance of the whole system by providing an input whose response can be predicted (F9, L19, W9).

Not all investigators need to understand computers in depth - although in real-time projects success is directly proportional to the principle investigator's involvement. No amount of machinery can compensate for inaccurate and incomplete scientific observation (N4). Yet, certain tools should be provided which can be used without verification. As an example, the user should expect the computing center to supply not only routines for finding the special functions such as sin, cos and log but also routines for matrix inversions. In most cases he is not interested in how these are programmed, provided that he can impose criteria relevant to his problem (H7).

Various levels of knowledge are needed to stimulate the efficient use of computers. Via courses, lectures, seminars, tutorials, workshops and informal coffee sessions a series of multi-level stimuli should be aimed at the gamut of the health professional field (A5). New teaching tools are becoming available to assist this process. One such tool is the PLATO system developed at Illinois which simulates results in models constructed by students (B10, B11). The computer-assisted instruction in Continuing Medical Education is another example of using computers to teach others about computers (H8).

By instructing researchers, their graduate students, their technicians and their secretaries, the programming load is diverted. The need for a centralized group of computer programmers is minimized. It is intuitively obvious that programmers (or technicians taught to program) working in the day to day environment of a laboratory are better suited to "understanding" a specific problem than their confrère in a centralized facility who at the same time is attempting to understand 2 -3 other non-related problems. It has been argued (S4, S19, S20) with due justification that a pool of centralized programmers is a more efficient use of manpower, that tighter programming standards ensue and that documentation procedures are better. In a research environment however, countless small - medium projects are initiated which require little or no documentation for they are seldom re-used (S18). To document them would take longer than it took to write the program. In the dynamic discipline of biomedical computing, it seems particularly important to avoid standard approaches which are destined to be outdated before they can be widely implemented (G6). Larger projects, on the other hand, can be adequately documented in acceptable form by the teaching of

a. good coding technique which encourages internal documentation

b. formal documentation procedure

c. the advantages, merits and reasons for documentation

As to programming standards, one is more likely to instill the use of good techniques to a class of non-programmers who are eager to learn. If never shown poor programming techniques they are less likely to use them. Experienced programmers on the other hand - those who usually staff a centralized facility - often come with preconceived notions and programming habits and are reluctant to change. The teenager taught proper driving habits when 14 - 15 years old is less likely to need a defensive driving course at 20 than the one who taught himself or "picked it up" from various sources.

If one assumes that it is wiser to teach people to program for themselves then one must be prepared to devote many hours helping them learn a new language. Above adequate consulting facilities are needed (S7). Staff teaching various courses should also be adept at consulting on problems of all sizes, shapes and forms. To leave a student stranded after setting him on his way could be more damaging than never having spoken to him. To be unable to discuss an already experienced investigator's problem will not stimulate him to support the facility. Good follow-up techniques in the form of consultation and further material must complement the teaching element. As reported by Meyer (M6) continued utilization is not self-generating but requires constant promotion.

Upon reviewing the overall progress of computer applications in medicine, one intuitively feels that a centralized programming group defeats the purpose of encouraging the medical profession to use computers. As pointed out earlier until the investigator, physician and user is familiar with his tools he tends to be an unproductive workman. To coerce the medical scientist to use automated procedures by using a programmer who has difficulty understanding the medical terminology and thinking can be deemed inefficient. Rather, to encourage the scientist or one of his well-trained technical staff to learn the language seems wiser. To repeat what was stated a few pages earlier computer systems only become relevant when the investigator, developer and user has been duly educated and trained (C3).

D. SYSTEMS ORIENTED

To staff on-line computing services, introduces a new breed of computer scientist - namely the software programmer or analyst. This individual assumes responsibility for the internal workings of the computer system (K1). As pointed out in the previous chapter, most on-line and real-time systems are such that the equipment required is installed within the institution's confines. If such is not the case, and a remote computer's on-line capabilities are being used, the need for the systems person is greatly minimized.

Most computer manufacturers with on-line systems provide time-sharing or executive monitors (AN8, AN9). To assume that these are all that the salesman drums them up to be can be fatal. Almost always, modifications, customization and additions are needed in order that it function in the manner most beneficial to the institution's needs (W9). For economic reasons, computer companies usually design systems with business, scientific or large industrial applications in mind. Medical establishments using such packages are frequently victimized by the inefficiencies of using a prepackaged software program in a way other than that for which it was originally intended (S7). As a general rule of thumb, one does not expect support from the computer manufacturer - especially in software. To modify a "standard" operating system is usually against company policy for it implies that the software is no longer "standard" and hence cannot be universally supported.

In addition to tailoring the operating system, software staff concern themselves with developing utilities which increase the efficiency of specific application programs (B12, W13). On-line interactive language capabilities (B13, G12, B14), which are proving to be increasingly useful in both the clinical service and the research environment, help make computers more accessible to the biologically trained scientist or physician (G6). Further, if the system installed is expected to handle some batch work as well as on-line, another degree of complexity in the operating system increases the demands upon this group.

If this level of computing services has been reached, an assistant director is oftentimes advisable to maintain the day-to-day operations of the facility. This individual should be technically capable of supervising either all or specific groups within the facility. Bearing this need in mind when choosing nucleus personnel simplifies the transition. The assistant should also be sufficiently versed in managerial expertise to assure smooth operation and effective utilization (D4). He can and should complement the Director as a catalyst in the symbiotic process of bringing together physicians and computer scientists (S14).

E. REAL-TIME ORIENTED

With the provision of batch and on-line services satisfied, the focus turns to satisfying the needs of real-time oriented investigators. This requires a group of individuals who work in close conjunction with the systems people. It is their responsibility to design and implement interfaces between the experimental apparatus and the computing system. Their work is primarily with those investigators who require the processing of continuous biological signals. These signals, produced during a live experiment, are converted into a form acceptable to the computer all the while maintaining the active information content (S21). The response to these signals may be either immediate (i.e. on-line and real-time) or delayed (i.e. on-line capturing with later batch processing). Special drivers which control the analog-to-digital and digital-to-analog conversions are usually written by this group.

This group accepts responsibility for the conversion process by determining the format problems that may require a separate solution for each application. In more complex systems, timing of simultaneous input, processing and output functions become critical. With the processing of analog signals, decisions on sampling speed cannot be taken without a thorough investigation of the waveform concerned, the data required from it and how the program will achieve the required output data. Special attention is given to multi-channel analog input for the analog to digital conversion must be sufficiently fast, not only to be sure of obtaining the peak height but also to ensure that this highest reading is a true reading (S21). Since all information from biological sensors is not representative of functional change, the electrical characteristics of the instruments and the signal being received must be thoroughly understood if noise, artifacts caused by disturbances in sensor devices,malfunctioning amplifiers and unrecognized physiological variations are to be recognized and the final output of the instrument depended upon (W4, W5).

F. EPILOGUE

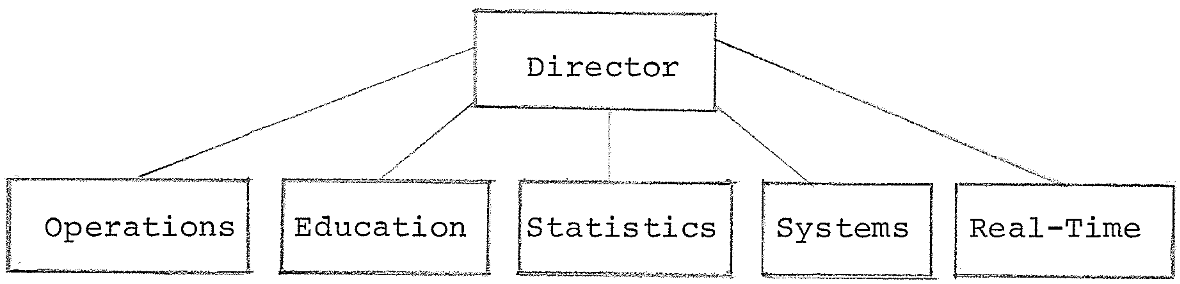

Figure 4

Staffing a facility with all five types of personnel as depicted in Figure 4 requires a Director and staff who can accept an increased demand upon their administrative talents in addition to their scientific capabilities. Concentrating on "people problems" will consume much more time than technical problems (L19). As in any activity, an increase in the scale of operations is accompanied by increased requirements in managerial skill and intra-institutional authority (R4). When one takes on a facility which provides batch, on-line and real-time computing, the ability to service larger projects and to investigate certain unique aspects of computation in the medical environment comes to the fore. The diversity of goals blunts the value of scientific merit as a sole criterion for support (Y1). No longer can a facility be questioned only on the scientific merit of its work for not all projects can be successfully implemented on a computer. Management type decisions must be made to assure maximum use of the services provided.

When requesting monies to fund a computing facility, designed to serve the needs of many investigators, the skeleton of the application is essentially the same as for any research grant, but the overall design must be much more broadly conceived. More than just technical and scientific competence in the mere operation of computers must be reflected. The proposal also must reflect adequacy in the assessment of the quality of the research of the prospective users, perspicuity in the matter of administrative structure and relationships, knowledge of local and natural resources, and awareness of possible alternative approaches that might exist for finding solutions to the problems presented (G6).

In conclusion, the Director's role as an inter-disciplinary and inter-departmental co-ordinator takes on a human relations orientation. He will become involved in the politics of assessing the relative merits of small laboratory computers. In view of the large dollar value associated with computer devices and staffs, it is reasonable that all of the institution's computational facilities be co-ordinated through one person. If this co-ordination is not provided, it is possible that computational facilities will spring up in several areas and attempt to provide overlapping services. The costs of computing are high enough at best without further increases due to inefficient fiscal management (H10).

Finally, the Director's colleagues will expect him to contribute to the concurrent processes of data processing in hospitals, the improvement of health services to the community and the clinical service aspects of automated patient care. His role as a social scientist carries with it a need for extreme tact, compromise and effort, the exercise of which almost succeeds in exhausting the individuals who pledge to work in such areas (S6).

C H A P T E R 4

F I N A N C I N G

One of the first considerations given to funding a multi-departmental biomedical computing facility is that it usually entails a permanent commitment (J1). Although some medical institutions (G1, E2) have removed their systems, for the most part, when a computing service is implemented it remains as an integral part of the institution. An informal survey (R1) revealed that financing is the most common problem being faced by both investigators and the computer facility themselves. The impending fiscal crisis being experienced by most universities (AN1, AN2, H1) will undoubtedly have an affect on the future outcome of biomedical computing. Caution should be exercised to assure that adequate long-term funding is reasonably secure. The difficulties arising from the uncertainty of the availability of research support can frustrate even the most conscientious and competent of computing facility directors (H2, L2, J3).

A. COSTS INVOLVED

The amount of money needed to support a computing facility is directly proportional to the type of services to be provided. A reliable estimate for funds can only be generated after the facility's objectives and terms of reference have been firmly established. Beyond the standard components such as the number of support staff required and the equipment to be installed additional factors need to be considered.

Providing the minimal service, that of a batch terminal to an existing university or commercial machine, typically entails installing a medium speed card reader and line printer. Two types of expenditure are involved:

1. Initial Capital Outlay.
2. Yearly Support Expenses.

The first may range between $5,000 and $25,000, which includes the clearing or restructuring of an existing room, the installation of additional electrical power and the addition of extra air-conditioning capabilities. The latter may not be necessary if the existing building facilities are capable of handling the equipment's heating load. The requirements for acoustic tiling and raised flooring, common to most computing centres, are not usually needed at this stage of development.

The second expenditure is usually in the order of $20,000 per year comprising of some $14,000 to rent the terminal, $5,000 for the salary of an operator and $1,000 to cover supplies such as tabulating cards, computer paper and miscellaneous items. If the terminal is to be linked over telephone lines to a larger computer, additional expenses for datasets and line costs in the order of $3,000 - $8,000 per annum are not uncommon. The actual computing charges encountered with each job run are assumed debited to individual departments' or investigator's budgets and are not usually part of the funds required by the central facility.

As in any general service of this nature, exact costs can be obtained from any institution which is currently providing similar services. The point to consider is that the initial capital investment and the recurring $20,000/year provides a minimal service for only those satisfied by a "batch type" environment. Further, no programming support of any kind is included. If serious consideration is being given to providing funds for an in-house computer to do the batchwork, the order of funding increases 5 - 10 fold. This approach was previously discussed and found to be unnecessary for all but a few of the larger institutions.

To provide more sophisticated types of computing services introduces additional requirements in staffing, planning and management expertise. The same holds true for funding. To provide in-house on-line computing services is an order of magnitude different for it introduces not only a need for more sophisticated staff but also additional equipment. On-line capabilities to remotely-located larger machines may be less expensive though the higher CPU rates, line costs, inaccessibility, privacy of data and priorities are factors which indirectly increase the price to be paid. In comparison to the estimates for batch type facilities, additional expenses in capital outlay come in the form of acoustic tiling to reduce noise in the computer room, additional air conditioning to meet heavy heating loads, and raised flooring to support air conditioning plenum and hide the myriad of electrical cables involved. Additional capital funds in the order of $20,000 - $50,000 could be required. Office space for staff may have to be built further increasing the initial capital outlay.

The yearly support expenses of providing in-house on-line services vary depending on the amount of equipment installed, the degree to which new or improved software is needed and to what extent time-sharing capabilities are required. Equipment rentals could range from $25,000 - $125,000 per year with the lower figure reflecting the most basic and often restrictive of on-line systems. The staffing requirements in addition to operators (more than one is usually needed as on-line services tend to be used in the evening as well as during the day) are those of software systems programmers. At least one is usually needed to maintain the computer's operating system and implement updates. To rely on the manufacturer for this support is both unwise and uneconomical. Often the quality of staff provided are of questionable value and rotation of personnel is a common trait of the industry. Recent "unbundling" changes has introduced exorbitant rates in the order of $35.00 - $50.00/ hour for the use of a manufacturer's programmers. A competent systems programmer is usually in the $9,000 - $14,000 bracket and can be an invaluable asset to any computer facility (K1). Thus when some $5,000 for supplies is added in, the yearly expenses for an on-line system are in the order of $40,000 - $200,000. As the system increases in size, the requirements for additional software staff also increases, hence the disproportionate rise in the upper limit. Once again applications programming capabilities are not included.

The third level of services which can be provided is a real-time system which occasionally comprises of both on-line and real-time capabilities. Additional expenses are encountered in acquiring new "analog-oriented" interfacing equipment and additional electronics-oriented staff. To predict the costs of a real-time system is most difficult as they are closely tailored to the number of investigators involved, the degree to which interfaces need to be built or purchased, the geographical distance of the laboratories from the computer, the amount of programing required, whether multiple experiments are to be handled concurrently and the requirements for immediate access.

Each installation varies so much from others that it is difficult to make objective assessments of the costs involved. Yearly budgets may range from $100,000 - $500,000 per year.

From this broad range of figures, it becomes apparent that computing services may require monetary provisions in the order of those of regular departments - especially if all three types of service are required. A 1969 survey (P1) reported that for 90 medical schools, the average rental in computer hardware was $18,700 per month. This represents a yearly outlay of some $225,000. As noted by the author, the accuracy of the data is in doubt, however, even a 50% error would indicate a significant operating investment.

Finally, in addition to operations, systems and electronics staff, funds are required for the educational and statistical elements of the facility. Depending on both quantity and quality these may vary from $15,000 - $100,000.

B. TYPES OF FUNDING AVAILABLE

Non-trivial sums of money are involved in providing computing services. No attempt to be rigorous was made in the previous section as each situation is so often unique to itself. Rather, an overview of the factors involved, was oriented to revealing the variety of services that can be provided and the order of costs associated with each. There is ample documentation in the literature of each type of service; however, few reveal the costs involved, especially the often forgotten or hidden development costs.

Given that a certain type of service has been agreed upon, the types of funding available most often come from four sectors of the economy:

1. the university
2. funding agencies
3. hospital commissions
4. private sources

Initially, university funding would seem the wisest to seek. This source is moderately stable and if reasonably small sums ($10,000 -$30,000 per year) are requested, the chances of success are quite high. The impatience of other funding sources which often leads to poorly conceived work whose value is not commensurate with the expense and labor involved is not usually prevalent in universities (S7). Further, if the institution puts up some of the funds, proof of its commitment is made to other sources (G5). As reported by Gee (G6), through NIH's grant re-evaluation process, it was found quite early that unless the university medical school or hospital complex itself contributes substantially to support of a biomedical computing facility an unhealthy state of isolation is likely to occur and result in a mundane, uninspired technical service operation.

The prime advantage of academic funding is the freedom normally left to the investigators as to the kinds of computer research to be pursued while the prime disadvantage is that it does have a limit. A certain level is attained and additional support becomes difficult to justify. Conflicts with the University's administrative and computing science sectors may arise as to priorities of the university computing dollar (R5).

Monies available from funding agencies are usually obtained on a block grant or fee-for-service basis. The block grant to the biomedical computing facility has the advantage of allowing the facility's director the choice of putting the funds into those areas which he feels are most worthwhile. Implicit in the commitment of support for a designated period is the freedom to diverge from stated plans if early results indicate the necessity. Fee-for-service, on the other hand, puts the facility on a service bases, dependent on its income by the use of its facilities by other investigators.

It is a mechanism to free Federal funds for the establishment of new facilities and for the continued support of the innovative development of new kinds of computer applications in those facilities where such capability exists. Further, as a computing facility expands and the number and variety of research programs being serviced increases, it becomes virtually impossible for a single review group to maintain its standards of evaluation of the quality of the investigative efforts for which computer-services are needed and requested. The fee-for-service system shifts an appropriate share of the responsibility over to other review groups which specialize in the substantive disciplines of the individual or investigator-users of the facilities (G6).

It is felt by some (J1,R4) that a combination of the two is most satisfactory. Fee-for-service insures that the computational impact of each research project is recognized, while block grant or independent financing allows and encourages the facility to research and develop basic computer methodology relevant to the health sciences. The latter approach is favoured though the former is most common, due in part to the decrease in the amount of total funds being allocated to biomedical research in general (C1, AN3).

Funding from hospital commissions may be in the form of direct payment by hospitals for patient-oriented services performed or direct payment by the state or provincial government for services provided on a community basis. On the surface, neither of these would appear related to the computing services of a research facility; however, it is suggested that herein lies the future of the computers' role in medicine.

Other sources such as individuals, small indirectly related organizations and benevolent funds are usually minor in relation to the other three although in some instances they provide the primary support of private medical schools.

Brief mention should also be made of a funding source which, up until recently, has been considered by many as being out of bounds. That is industry. It has been reported (C3) that the health-service delivery cannot be improved unless industrial technology is fully brought into its appropriate position in medical system development. The suggestion that hospitals need business management (M3) to solve their problems and the success of the prepaid group practice Kaiser Permanente health care program (W3, V2, C7) deserves serious thought. The implications of soliciting industrial support may be controversial. Nevertheless, industries could conceivably be a major source of the future.

C. REQUIREMENTS FOR CONTINUED SUPPORT

It was previously mentioned that both universities and the biomedical research community are experiencing a shortage of funds. The reasons are economical, sociological, ecological and outside the scope of this work. They are also political. The cities, the poor, the environment, law and order, etc. are the new priority items (C1). Also, on this new list is "health services". That the health care system is coming under vicious attack (E1, S1, W1, A1, F1, R2, W2) is a significant point which indirectly, though subtly, affects biomedical research. Universities and hospital commissions are primarily funded from state or provincial governments while funding agencies are most often federal government agencies. Due to political pressures from various sources, many governments are asking, is it relevant, is the money being infused into various segments of the economy producing any noticeable results?

The Canadian Senate's Special Committee on Science Policy headed by Maurice Lamontagne feels that research and development efforts should be directed towards fulfillment of broad social and economic goals, not motivated by disinterested scientific curiosity (M1). In much the same manner as in industry (C2), governments are de-emphasizing allocation of basic research funds for it is felt that these are not producing tangible results (M2). As pointed out by Norton (N4), major advances in medicine can, in the main, be made only in the scientific fields of measurement and experimental therapeutics. Animal experiments may not get very far for their results can be dangerously misleading.

As yet, few applications have been developed that are part of the routine delivery of care to the sick (L14). A significant amount of the $2.7 billion spent by the U.S. on biomedical research in 1970 (B1), went into the search of pure knowledge. Although there are advocates (T2) who cogently express that the quest for basic knowledge must continue at the levels of today, they appear outnumbered by the political voice of the "average man" who neither rises to nor understands such lofty goals. Those institutions whose computers primarily assist in researching the problems of the health care system are likely to be the ones who will have the least difficulty in acquiring funds.

The advantages of using computers to pursue research in "human oriented" projects (L10) is that its worth to society can never be criticized to the same extent as those projects which isolate themselves in the laboratory. Values and money are closely related to treating the ill and more clinical studies are needed (L13). These studies do not come easily. They are difficult because the study of sick people requires much more effort, time and intellectual versatility than the study of phenomena observable in a laboratory. A rat or test tube is always available and replaceable, keeps its appointments promptly, does not move out of town, makes no demands on the investigator, requires no informed consent, and can readily be destroyed to find out what has happened (F5).

Of interest is a government report (AN4) which revealed that of six categories, Physiological Monitoring, Diagnostic Laboratories, Medical Records, Business Office Transactions, Logistics, Hospital Information Systems, only the very patient-oriented Diagnostic Laboratories could expect funds from 1969 - 1973 comparable with those given in 1968. In this vein, the design and implementation of a computer system to monitor the vital signs of patients in an intensive or coronary care unit is a worthy though expensive task (G4). To redistribute such funds into research of screening methods with the immediate benefit of monitoring the signs of potential disease victims in the ghetto and urban areas is also a worthy, though more trying task. It involves assessing whether the abnormalities revealed by multiple screenings are significant, whether further treatment has any benefit or even whether the patient's knowledge of abnormal findings may not itself be harmful. Further, the public has to be educated to understand just what can and what cannot be discovered by these routine checks (N4).

Such projects are likely to receive receptive hearings when they reveal that computers in this realm can, to some extent, alleviate the urban to suburban physician sprawl (A1). They permit diagnostic and screening procedures to take place with a level of personnel well below the average practitioner. As Williams points out (W3), one of Kaiser's biggest problems is developing an appointment system that will screen members so that the sick can get in for service while the well and "worried well" can still be appropriately taken care of without swamping their doctors. In much the same way, to request funds to research the implementation of the now, well established EKG computer-assisted processing (M7, C9, L15,F6, D3) in the rural and remote areas of a state will stimulate a funding agency (AN11) - concerned with the lack of health care facilities in these areas - more than a request to design a system to automate the medical records of a large teaching hospital.

To paraphrase Rhind (R6), "real-doing" is what funding agencies demand of the computer and scientists who run it. They will not be disappointed if investigators are results-oriented, if biomedical computing facilities are kept up to date with the needs and wants of the health care system, and if applications are designed to help specific people do specific jobs better. They will be disappointed if the computing scientists promise to provide information that subsequently proves useless and misleading; or if they demonstrate lack of understanding of health problems; or if they become mesmerized by the elegance of their own solutions, the beauty of their own systems and machines.

As lucidly stated by Barnett (B2), one of the most important issues in implementing computers into any element of the medical system is the "characteristics of the power structure, priorities of the health care establishment and the mechanisms for deciding which costs are reimbursable by whom".

C O N C L U S I O N

When completing a work of this nature, one aspires to believe that he has been successful in revealing the complexity of the topic. Implementing computer services into a medical research environment is a multi-faceted, obstruse and heterogeneous undertaking. Yet medical research is only one element of the total health care system.

No mention was made of the man-machine communication problems which exist (S28) when implementing computers into a hospital. One must study the implications of these devices. Do they assist in automating the status quo or are they of benefit in restructing the entire diagnostic and therapeutic process? Their use as vehicles in transmitting and receiving medical data is becoming more widespread (AN13, C10), yet the manner in which medical data is captured has been questioned by Weed (W14) and others (F5, S17). If the raw data is incomplete, inaccurate and illegible, how is the transfer of such information within health centres to take place? The prospective compilation of cumulative health records is being continually urged, yet a single hospital has difficulty in integrating all patient-oriented records while simultaneously maintaining an effective information system required to carry out routine procedures dependent on patient data (D5, J6). Nevertheless, Flagle (F10) contends that an element of information should be gathered and acted upon only if the value resulting from the action taken exceeds the cost of gathering the information.

To be able to make such a judgment, accrual accounting systems which match revenue and expense over the same time period are needed. Costs of hospital operations cannot be evaluated unless related to the characteristics of the patient service load (L20, A9). Yet the patient service loads of a hospital are affected by those of other hospitals. The routes by which patients obtain health care are unknown. Some have suggested that a state or nationwide medical information system is needed to sort this information out. Yet many questions remain unanswered. Is the real purpose of a "medical information system" to provide a data base for research by health care practitioners, administrators and planners (L17, C11)? Who is held responsible for the accuracy and content of the data in these systems, the physician, the patient, the computer-facility director or the programmer? What will the cost to the taxpayer be? Files will have to be very large for medicine does not appear to know for certain exactly which data to capture (L17).

These are but a few of the questions which are being raised. There are many others. Some concern themselves with the rising cost of health care, the lack of standardization in medical terminology (L22), the role of multiphasic screening and the education of health related personnel. The interactions between the elements of the health care system namely, research, clinical (patient) service, education, hospital administration and community (public health) service are amorphous at best.

One cannot in the course of four years experience hope to manifest any firm conclusions on how to best go about solving the problems. It has been suggested (S29, T3, G13) by others that we must return to the basic concepts of curing the sick. The need to find some means of alleviating the burden on health care delivery is obvious. Whether this will come about by restructuring hospitals (S29) or by separating the sick from the well (G13) is open to discussion. Perhaps more fervent prayer is the answer? Perhaps by a world-wide moral, financial or sociological crises (L21)? Whatever the means, it seems evident that it will take the computer at least as long as it took the stethescope to be routinely used in medicine.

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