Medical Informatics

Origins of Medical Informatics

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Medical informatics is a new knowledge domain of computer and information science, engineering and technology in all fields of health and medicine, including research, education and practice. Medical informatics has evolved over the past 30 years as medicine learned to exploit the extraordinary capabilities of the electronic digital computer to better meet its complex information needs. The first articles on this subject appeared in the 1950s, the number of publications rapidly increased in the 1960s and medical informatics was identified as a new specialty in the 1970s.

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Computers, automobiles and telephones are now among the day-to-day tools of physicians. Starr credited the telephone and the automobile with the greatest improvements in the productivity of medical practitioners.[1] According to Starr, physicians were among the first to use telephone exchanges, built in the late 1870s, to connect with local drugstores and to communicate with patients requesting house calls. Automobiles were reported in the *Journal of the American Medical Association* in the early 1900s as being capable of cutting in half the time required for house calls and enabling patients to more readily visit physicians in their offices. Although Hollerith was working on punched cards for the 1880 census at the time Bell was beginning to market the telephone, it is quite evident that physicians have been much slower to adopt the computer than they were either the telephone or the automobile. Norberg estimated that in 1955 there were 240 computers in use, in 1974 there were 165,000 and in 1984 there were millions.[2] It is hoped that the plethora of computers in the 1990s will find physicians exploiting the full potential of medical informatics.

Origins of a New Name

The earliest references to any applications of electronic digital computers in medicine appeared in the 1950s in biophysics, bioengineering and biomedical electronics publications. New names appeared such as medical computing, medical computer science, computer medicine, medical electronic data processing, medical automatic data processing, medical information processing, medical information science, medical software engineering and medical computer technology. These terms were often used interchangeably, such as medical computer science for medical information science, as if what was processed—that is, information—was the same as how it was processed—that is, by computer. Yet, not until the early 1970s did it become clear that there was a need to settle on a name for this new domain of medical knowledge. To agree upon "medicine" or "medical" was not very controversial as any standard dictionary defines these terms as relating to or concerned with the research, teaching and practice of preventing, diagnosing or treating disease.[3] Some health professionals, however, prefer that the term "health" be broadly interpreted to not only include good health—the freedom from illness or disease—but also poor health—that is, being ill, sick or with disease.

To find a single term to include science, engineering and technology was more difficult. Harrison attempted to clarify "the confusion within the public, and also within the scientific community, as to the nature of science, engineering, and technology" and defined these terms as follows:

> Science is the process of investigation of physical, chemical, biological, behavioral, social, economic, and political phenomena. Engineering is the process of investigation into how to solve problems and includes everything the investigator does from the acceptance of the problem to the proof of the validity of the solution. Technology is the process of production and delivery of goods and services. Science drives engineering and technological innovation, but it is equally true that both engineering and technology drive science.

Harrison concluded

> It is the combined body of knowledge derived from the processes of investigation that are science, engineering, and technological innovation that has

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ABBREVIATIONS USED IN TEXT

AAMSI = American Association for Medical Systems and Informatics
ACM = Association for Computing Machinery
AFIPS = American Federation for Information Processing Societies
AIEE = American Institute of Electrical Engineers
AMIA = American Medical Informatics Association
CT = computed tomography
IBM = International Business Machines, Inc
IFIP = International Federation for Information Processing
IRE = Institute of Radio Engineers
LINC = Laboratory Instrument Computer
MEDINFO 74, 77, 80 and 83 = First, Second, Third and Fourth World Conferences on Medical Informatics
MEDLARS = Medical Literature Analysis and Retrieval System
MUMPS = Massachusetts [General Hospital] Utility Multi-Programming System
MIT = Massachusetts Institute of Technology
NCHSRD = National Center for Health Services Research and Development
NIH = National Institutes of Health
NLM = National Library of Medicine
SAMS = Society for Advanced Medical Systems
SCAMC = Symposium for Computer Applications in Medical Care
SCM = Society for Computer Medicine

become a resource of unprecedented value . . . There is no term in the English language to encompass this conglomerate of knowledge.[4]

Anderson at Kings College of Medicine (London) has documented the origin of the name "medical informatics":

As you will see from the book on "Education in Informatics of Health Personnel,"[5] we had been searching for some time before 1974 in the IFIP [International Federation for Information Processing] Technical Committee No. 4 to find a suitable term for the subject area. Professors Pages and Gremy of Paris were interested in at least two aspects being represented in the final term, namely, the French terms "informatique" and "automatique" that were used in France for medical information science or data processing. It was certain we had to find a new term for the book, and after much discussion we incorporated the words to form the name "medical informatics." We intended it to cover both the information and data parts as well as the controlling and automatic nature of data processing itself (J. Anderson, MD, written communication, May 1986).

It is noteworthy to a reader of the historic publication, produced by a working group of nine leading European medical educators, that they used the term "medical informatics" throughout the book and even formulated guidelines for a curriculum to teach medical informatics[5]; yet, nowhere in this book was this new term defined. In their discussion of this subject and how to teach it, however, it was apparent that medical informatics was meant to embrace all of the following: medical computing, medical data processing, medical information processing, medical computer science, medical information science, medical information systems, health care information systems, computer hardware and software, computer and information technology, applications of computers and data processing to the health services and basic concepts of computer science fundamental to medicine. As Anderson pointed out, the French literature had for ten years or more used the terms *informatique de médecine* or *informatique médicale,* and departments with these titles had been established in the 1960s in France, Holland and Belgium. The 1979 edition of *Harrap's New Standard French and English Dictionary* defined these French terms as follows: "*informatique*—information processing, data processing"; and "*informatique médicale*—medical computing."[6]

Although Anderson attributed the origin of medical informatics to the French, the Supplement to the 1976 *Oxford English Dictionary* credits the origin of the English word "informatics" to a translation from the Russian *informatika* and attributes its first definition to the following:

1967 FID News Bull XVII.73/2. Informatics is the discipline of science which investigates the structure and properties (not specific context) of scientific information, as well as the regularities of scientific information activity, its theory, history, methodology and organization.[7]

A search in MEDLINE of the National Library of Medicine (NLM) back to 1966 showed that articles in the French literature used the word *informatique* in 1968.[8] Another article in the French literature written in 1970 was entitled in English, "Study of an Informatic System Applied to the Public Health Services."[9] The next article found using the English word was published in 1972 in the Polish literature and was entitled "Informatics in Health Service."[10] A 1975 article in the Polish literature referred to *informatyki medycznej.*[11]

A search through NLM's MEDLARS CITE book catalogue found that the English term "medical informatics" first appeared in 1974 in the historic book already mentioned, the *IFIP Medical Informatics Monograph Series,* Volume 1, *Education in Informatics of Health Personnel.*[5] A search through DIALOG's* Modern Language Association International Bibliography (MLA BIB) back to 1968 showed that the word informatics appeared in the title of a Russan book as *informatika* in 1975.[12] The German literature used the term *medizinische informatik*[13]; however, the first German article written in English that used this term was published in 1977 with the title "Education in Medical Informatics in the Federal Republic of Germany."[14]

It is clear that Anderson's proposed new name "informatics" solved Harrison's need for a term to encompass science, engineering and technology,[4] and it freed this new field from all previous more limited names and notions. In the United States, the earliest definition of medical informatics appeared in the preliminary announcements distributed in 1977 for the Third World Conference on Medical Informatics (MEDINFO 80) in Tokyo, wherein I, as the program chair, defined the term: "medical informatics as the application of computer technology to all fields of medicine—medical care, medical teaching and medical research." Shortliffe at Stanford, however, emphasized that medical informatics included more than the applications of computers to medicine because some investigators in the field study the basic science of medical computing as a subject rather than as a tool.[15] He gave examples of studies in artificial intelligence that advanced medical information science, yet without any obvious application. In support of this view, Blois at the University of California, San Francisco, School of Medicine used medical information science to study and advance the theory and concept of medical information itself.[16] Although Yamamoto at George Washington University (Washington, DC) suggested it might be advisable to discontinue this search for a new name,[17] a committee of the Association of American Medical Colleges stated,

*Literature searches in DIALOG—PsycINFO (Psychological Information), EMBASE (formerly EXCERPTA MEDICA), MLA BIB, SOVIET SCIENCE AND TECHNOLOGY and ACA AM ENCYC (Academic American Encyclopedia)—were provided by Margaret Amara, Librarian, Center for Advanced Study in the Behavioral Sciences, Stanford, Calif.

Medical informatics is a developing body of knowledge and a set of techniques concerning the organizational management of information in support of medical research, education, and patient care. . . . Medical informatics combines medical science with several technologies and disciplines in the information and computer sciences and provides methodologies by which these can contribute to better use of the medical knowledge base and ultimately to better medical care.[18]

Ten years after the historic conference in France that resulted in the name "medical informatics," many of the original European and American participants again met to reconsider the term. Medical informatics was now broadened to include not only the device—that is, computer—and what the device processes—information—but also all medical research and development, education and medical practice, including physician assistance functions such as clinical decision support and expert consultant models.[19]

Although the standardization of medical terminology is very basic to medical informatics, not until 1985 did the American Society for Testing and Materials, which has served as a catalyst in the United States for developing and publishing voluntary consensus-based standards for a variety of products and systems (including computerized systems), establish a subcommittee on medical informatics.[20] This subcommittee is expected to develop an "official" definition of medical informatics. Until then, it is proposed that medical informatics be defined as computer and information science, engineering and technology in all fields of health and medicine, including research, education and practice.

Origins of the New Field

The everlasting quest of humans for information has resulted in the development of increasingly complex technology for counting, recording, storing, retrieving and communicating data. A computer is the obvious tool for these data-processing functions.

Goldstine at Princeton University (Princeton, NJ) attributed the concept of the electronic digital computer to Billings (the first Director of the National Library of Medicine) and its invention to Hollerith.[21] Billings, while Assistant Surgeon General of the US Army, was asked to assist the Census Bureau and to take charge of the work on vital statistics for both the 1880 and 1890 censuses. Hollerith was an engineer who graduated from Columbia University (New York) and went to work for the US Census Bureau in 1879.[22] The census was handwritten on cards that were then manually sorted into various categories and hand counted. To obtain additional information then required manually resorting and recounting. According to Goldstine, Billings conceived the idea of using cards that had data represented by notches punched into the cards, which could then be mechanically processed.[21] Billings asked Hollerith to work out a solution to this problem. The result was that Hollerith invented in 1882 a paper card with 288 locations for holes that ran under a set of contact brushes, completing an electric circuit when a hole was present. The punch card was devised by Hollerith to be equal to the size of a dollar bill to avoid having to manufacture new equipment. He also built machines for electronically punching and sorting these cards. Billings was a member of the census committee that decided to use the Hollerith punch-card system for tabulating the 1890 census. The census data on 62 million people were processed in three years. Hollerith went on to set up the Tabulating Machine Company in 1896, which became the International Business Machines (IBM) Corporation in 1924.

The First Digital Computers

The first all-electronic digital computer was invented by Eckert, Mauchly and their co-workers at the University of Pennsylvania (Philadelphia) in 1946. The computer was called ENIAC for Electronic Numerical Integrator and Calculator; it used 18,000 vacuum tubes as its active logic elements and had wired program plug boards and programming switches for storage.[23] Von Neuman in 1945 devised a method for storing programs—that is, instructions as distinguished from data—in a computer by an electrically alterable memory capable of storing both the instructions and the data to be used in calculations. In 1951 Eckert and Mauchly used von Neuman's stored program technology and built UNIVAC (Universal Automatic Computer) for the US Census Bureau for use in the 1950 census. This was the first computer to handle both numeric and alphabetic data, and it used magnetic tape drives to replace punched cards as a storage medium.

The second-generation digital computers, in 1958, used transistors instead of vacuum tubes and added magnetic-core storage memory designed by Forrester at the Massachusetts Institute of Technology (MIT, Boston). The third-generation computers appeared in 1963 in the form of solid-state integrated circuits consisting of hundreds of transistors, diodes and resistors embedded on tiny silicon chips, a process called large-scale integration.[24] This permitted the construction of a hierarchy of computers of different sizes. The IBM 360 series, introduced in 1964, was one of the earliest third-generation mainframe computers. Minicomputers, smaller in size and designed to do generalized though more limited tasks, were successfully marketed in the 1960s, especially by Digital Equipment Corporation as their Programmed Data Processor (PDP) series.

The First Personal Computers

Clark and Molnar in the Lincoln Laboratory of MIT in 1962 built a special-purpose Laboratory Instrument Computer (LINC) to maximize the degree of control over a computer by an individual researcher.[25] This was essentially a prototype personal computer with transistor circuitry, ferrite-core random access memory and magnetic tape storage, and it was small enough so that one person could assume complete responsibility for programming and operation, fast enough for simple on-line data processing while an experiment was in progress, logically powerful enough to permit more complex calculations later, if required, and with limited user-friendly features to facilitate training of persons unfamiliar with digital computers. The first personal computers were built in 1971 by Blackenbaker (called Kenbak I), and by Hoff of Intel Corporation (W. M. Bulkeley, "Who Built the First PC?" *Wall Street Journal,* May 14, 1986, p 31).[24] The fourth generation of computers, in the 1980s, exploits very-large-scale integration containing thousands of components on very tiny silicon chips. They have a greatly increased performance despite the smaller size and lower cost.

Programming Languages

Just as there evolved different generations of computers, so there developed different generations of programming languages and programs that made the hardware usable.[26] A language and its software can modify the character of a computer. A programmer writing in a computer's lowest level machine language is addressing memory cells, registers, adders and so forth. The circuitry of a computer recognizes only the electronic representation of binary numbers, and a program stored in a form that can be executed is in machine code and is a series of such numbers. Some of them represent instructions to the central processor, some of them are data and some are addresses in memory. A programmer using a higher level language works with variables, formulas and files. The most influential scientific programming language, FORTRAN (for *FOR*mula *TRAN*slation), was developed in 1957 by Backus and colleagues at IBM for scientific and numeric calculations.[27] COBOL (*CO*mmon *B*usiness-*O*riented *L*anguage) was created in 1960 by a joint committee of computer manufacturers and users and has long been the principal language for business and accounting functions in hospitals. BASIC (*B*eginners *A*ll-purpose *S*ymbolic *I*nstruction *C*ode) was developed in 1965 by Kemeny and Kurtz at Dartmouth College (Hanover, NH) as a language for introductory courses in computer science. LISP (*LIS*t *P*rocessing) was developed in the late 1950s at MIT by McCarthy; it structures both programs and data lists and has been widely used by researchers in artificial intelligence. One of the most widely used programming languages for medical application has been MUMPS (*M*assachusetts General Hospital *U*tility *M*ulti-*P*rogramming *S*ystem). This was developed in 1966 by Pappalardo, Marble and Barnett of the Laboratory of Computer Science, Massachusetts General Hospital (Boston) to meet the needs for a modular hospital information system.[28,29]

To allow communications between computers and to gather and integrate data from more than one computer site, it was necessary to develop computer and communication interfaces and build both local-area and wide-area networking systems. A local-area network connects on-site computers and peripheral devices, integrates departmental computing facilities and may connect with a supporting computer center. By 1971 prototype local-area networks of distributed minicomputers were being proposed in a hospital environment.[30] The US took the lead in developing wide-area networks for academic research, and in 1969 the Department of Defense's Advanced Research Projects Agency began a project called ARPANET. This successful national network has gradually been expanded and is the major component of the new National Science Foundation's network, connecting 60 major research universities in the country.[31]

The Diffusion of Informatics in Medicine

The current director of the NLM, Lindberg, identified the beginnings of medical informatics in the United States with the work of the first NLM director, Billings.[19] In 1879 Billings, who earlier had conceived the punch card (see above), initiated the *Index Medicus*, a monthly NLM publication, cumulated annually, that provides a bibliographic listing of references to current articles in the world's biomedical journals. It is not surprising that informatics should have been first diffused into the field of medicine by medical librarians and educators. A major contribution to medical informatics occurred when NLM initiated computerizing the *Index Medicus* with the printing of the 1964 edition and implemented the Medical Literature Analysis and Retrieval System (MEDLARS).[32] This placed NLM in the forefront of applying computer technology to bibliographic information needs. MEDLARS expanded with the addition of nationwide communication networks linking seven regional medical libraries in the country. MEDLINE (MEDLARS on line) was initiated in 1971 and contains files dating back to 1966. Anyone using the MEDLINE regional networks can search and retrieve by Medical Subject Headings, by words in the title or in the abstracts, by publication date or by journal article. MEDLINE has made a monumental contribution to computerized medical literature retrieval.

A search through all MEDLINE citation titles between 1966 and 1985 (1985 being incomplete) using the search words "medic: or health" with "comput:" for English only—that is, excluding articles in foreign languages—shows the increase in the number of citations through the years (Table 1), with a total of 2,440 citations. A similar search for these three words appearing anywhere in any journal article would find perhaps several times as many articles. A recent analysis by the Technical Services Division Staff of the National Library of Medicine of the articles in the general field of medical informatics in just three published annual proceedings—MEDINFO 83, American Association for Medical Systems and Informatics (AAMSI 84) and the Symposium for Computer Applications in Medical Care (SCAMC-84)—and in one recent full year of the journals *Computers in Biomedical Research* (1983 to 1984) and *Methods of Information in Medicine* (1984) yielded a total of 5,850 citations.[33]

The earliest peer-reviewed journals in medical informatics published in the United States were *Computers in Biomedical Research* (started in 1967), *Computers in Biology and Medicine* (1970), *Journal for Clinical Computing* (1972) and the American Medical Association's *Computers in Medicine* (1972). Books on medical computing began to appear in the United States in the early 1960s.[34-37]

TABLE 1.—*MEDLINE Search Counts (in English Language Literature Only) for 'Medic: or Health' and 'Computer:' by Year, 1966-1985**

Year	Search Counts	Year	Search Counts
1966	36	1976	117
1967	30	1977	118
1968	34	1978	155
1969	41	1979	165
1970	22	1980	187
1971	46	1981	181
1972	44	1982	248
1973	41	1983	307
1974	20	1984	324
1975	113	1985	211 (incomplete)

*Data provided January 1986 by J. Parascandola, MD, Chief, History of Medicine Division, National Library of Medicine.

Professional Medical Informatics Associations

In a rapidly evolving technology where substantive advances can occur within a year, publications in traditional medical journals are often out-of-date, and books, by the time they are published, may describe obsolescent technology. Accordingly, the timeliest articles on computer applications to medicine often have been found in proceedings and transactions of meetings sponsored by professional associations and industry.

The Professional Group in Bio-Medical Electronics of the Institute of Radio Engineers (IRE) was organized in 1951 and in the 1950s was "the largest professional organization which is concerned with the broad area between the biological and medical field and the engineering and physical sciences."[38] It sponsored annual conferences in biomedical electronics and published the *IRE Transactions on Medical Electronics*, which in the 1950s was the main outlet for papers in biomedical computing. A 1955 review of the "progress of medical electronics" gave credit to the American Institute of Electrical Engineers (AIEE), later to become the Institute for Electrical and Electronic Engineers, for also sponsoring some of the earliest meetings on this subject.[39] The Association for Computing Machinery (ACM) was formed in 1947[40] and established its Special Interest Groups in 1960, one of which was Biomedical Computing (SIG BIO), which also provided an outlet for early articles on bioengineering. AIEE and ACM, with participation by the National Simulation Council, sponsored joint computer conferences, the first being held in 1951 (R. B. Frost, "NCC [National Computer Conference] at the Crossroads," *Datamation*, Jun 15, 1986, pp 169-172). At their fall Joint Computer Conference in 1961, these professional associations formed the American Federation for Information Processing Societies (AFIPS). AFIPS has been the US representative to the International Federation for Information Processing (IFIP).

The term "informatics" became internationally accepted as a result of its use by IFIP for its triennial international congresses for medical informatics (MEDINFO). The Fourth Technical Committee of IFIP organized MEDINFO 74, the First World Conference on Medical Informatics, held in Stockholm in August 1974. It is noteworthy that the term "medical informatics" appeared in the title of the proceedings of this congress and in only one paper by its originators.[41] MEDINFO 77, the Second World Conference on Medical Informatics, was held in Toronto in August 1977; the term "medical informatics" appeared in five articles in its proceedings. In the Third World Conference on Medical Informatics held in Tokyo in September 1980, only four articles in these proceedings contained the term "informatics." MEDINFO 83, the Fourth World Conference on Medical Informatics, was held in Amsterdam in August 1983, and the term "medical informatics" appeared in nine papers in its proceedings.

Conferences on Medical Informatics

The largest conferences in the United States completely dedicated to medical informatics have been the annual meetings of the Symposium for Computer Applications in Medical Care (SCAMC). The first SCAMC was held in 1977; since then SCAMC has been held annually in the fall on the East Coast. The Society for Advanced Medical Systems (SAMS) was organized in 1971 for the purpose of furthering medical systems, including computing systems, and it published the proceedings of its first annual meeting that year (D. Davies, "AAMSI's Forebears," *AAMSI News* 1985; 4:1-2). Its original focus was multiphasic health testing systems, but soon the major interest turned to medical computing systems. The first professional organization in the country committed entirely to medical informatics was the Society for Computer Medicine (SCM), also organized in 1971. SAMS joined with SCM to hold a joint conference in 1982,[42] and the result of this union was the American Association for Medical Systems and Informatics (AAMSI), which held its first annual conference in 1982.[43] The first conference in the United States that contained the words medical informatics in its title was held in 1982 in San Francisco; it was called the First Congress of the American Medical Informatics Association (AMIA Congress 82).[44] The idea for the AMIA Congress 82 developed during MEDINFO 80 in Tokyo, when some US participants decided to emulate the MEDINFO model of the International Medical Informatics Association. AAMSI took over the sponsorship of this congress on medical informatics in 1983 and has since conducted an annual spring AAMSI congress on the West Coast. In 1985 the American College for Medical Information was established to advance the field of medical informatics and to recognize experts in the field.

Professional, special-interest users groups have been very influential in diffusing medical informatics, especially for software. The MUMPS Users' Group began its annual meetings in 1972 and has grown to represent one of the largest groups of medical users of a specific programming language in the country. AAMSI has had several professional specialty groups (PSGs) interested in various medical computer systems and applications. In 1964 hospital users of IBM systems organized the Electronic Computing Health Oriented (ECHO) organization that since then has held regular meetings and shared the experiences of more than 1,000 hospitals.[45] Hardware vendors such as IBM and Technicon helped to advance early research and development in medical computing by supporting periodic conferences. The first IBM Medical Symposium was held in 1959 in Endicott, New York; these continued for ten years to be informative meetings for medical users of IBM computers. Technicon similarly sponsored a series of annual meetings on computer applications to clinical laboratories, beginning in 1965.

Informatics in Medical Research, Education and Practice

To support the proposed definition that medical informatics is computer and information science, engineering and technology in all fields of health and medicine, including research, education and practice, the outline given in Table 2 may be helpful.

The earliest published papers in medical informatics appeared in the 1950s when computer science was applied to biomedical research for simulation models and electrophysiology.[46-50] Later, the LINC computer's advanced engineering was exploited by medical researchers (*Wall Street Journal*, May 14, 1986, p 31),[24] and the ARPANET technology permitted medical researchers throughout the nation to work together.[31]

In medical education, information science soon permitted

TABLE 2.—*Some Early Examples of the Diffusion of Informatics in Medicine*

Medicine and Health	Computer and Information		
	Science	Engineering	Technology
Education	Case simulations	MEDLARS	MEDLINE
Research	Computer modeling	LINC	ARPANET
Practice	Computer diagnosis	Information systems	CT scanning

CT=computed tomography

teaching students with the use of computer simulations of case studies.[51-54] Information engineering produced the MEDLARS versions of the *Index Medicus*, and further advances in technology resulted in on-line literature retrieval by MEDLINE.

In medical practice, computer science attempted early to provide support in medical decision making and diagnosis. Hardware and software engineering produced a variety of medical and hospital information systems, and computer technology put computed tomographic (CT) scanning into most hospitals in the country.

In the United States, the early development and evolution of medical informatics was almost entirely supported by government grants and contracts. In 1960 the National Institutes of Health (NIH) established an Advisory Committee on Computers in Research that was responsible for the initial funding of many of this nation's leading academic centers in medical informatics.[55] NIH established its own computer center on campus and a Division of Computer Research and Technology.[56] In addition, other institutes, such as the National Institute of General Medical Sciences, supported projects involving the automation of clinical laboratories and the development of automated aids to diagnosis.[57] The National Heart and Lung Institute supported projects on modeling cardiovascular and respiratory physiology and the automated analysis of the electrocardiogram. It became apparent that the NIH categoric institutional structure was not particularly well suited to providing support for biomedical research tools, so in 1962 a separately budgeted special resources branch was established in an independent Division of Research Resources to provide funds for biomedical research computing facilities. In the 1960s, biomedical computing facilities were established in 45 universities, 6 hospitals and 4 research institutes throughout the US.[58]

Health Services Research Centers

Under the Heart, Cancer and Stroke Act of 1965, Regional Medical Program grants were authorized by the US Congress. By 1967 there were established 54 Regional Medical Programs, including clinical laboratory systems, clinical data collection studies, multiphasic screening systems and tumor registries.[59] In 1967 the National Center for Health Services Research and Development (NCHSRD) began to fund Health Services Research Centers, two of which—Kaiser Foundation Medical Centers, Oakland and San Francisco, California, and the University of Missouri-Columbia School of Medicine, Columbia, Missouri— had health care technology, including information systems, as their primary focus.[60]

Although in the 1960s, courses on digital computing were usually included in the curricula of bioengineering, usually within schools of electrical engineering,[38] the first academic department in the United States for teaching computing in medicine was established in 1960 at Tulane University School of Medicine (New Orleans), and Sweeney was designated as its first Professor of Computer Medicine. When asked what this title meant, he would jokingly counter, "Does this mean that I treat sick computers?"[61] In other American universities to follow, they were generally called Departments of Medical Information Science. Whereas in Europe the earliest "medical informatics" departments appeared in France, Belgium and the Netherlands, the first "Department of Medical Informatics" in the United States was established by Warner in 1986 at the University of Utah School of Medicine (Salt Lake City). (This information was gleaned from the masthead page of the February 1986 issue of *Computers and Biomedical Research*.)

An early example of a substantial effort to exploit computer and information science to improve medical practice was in computer-aided diagnosis. Although this area of medical informatics has continued to evolve through several stages of research and development, for both education and practice, its ultimate objective is to support the clinical practice of medicine. The first conference reported to be devoted solely to the problem of diagnostic data processing was held in Rockefeller Center (New York) in January 1959.[62] At this conference, most papers reported on the use of statistical probabilistic approaches to computer-aided diagnosis. Although sometimes achieving excellent diagnostic performance, these were constrained in scope and not sufficiently consistent with traditional clinical practice to be accepted by clinicians. By the 1970s, approaches more closely emulating the usual clinical decision-making process were sought and artificial intelligence methods began to be used for differential diagnosis and specialty medical consultation.[19,63]

Undoubtedly the broadest engineering applications of informatics to medicine have been in diffusing information systems into hospitals, clinics and their clinical support and ancillary services. In addition to Health Services Research Centers, the NCHSRD initiated grants and contracts to fund a variety of information systems in the 1960s. The status of NCHSRD-supported computer-based information systems at its peak of support in 1969 was summarized in a report that mentioned some of the following projects as being operational and providing patient care functions[64]: medical records projects, hospital information systems, clinical laboratory systems, x-ray information systems, physiologic monitoring systems, pharmacy information systems, a multiphasic screening system and patient interviewing projects. The NCHSRD report concluded that the then-available time-sharing computing technology could not support simultaneously the many divergent and data-rich requirements of services that existed in any relatively large hospital. What was technologically required was the development of a computer system that could adapt to an unevenly evolving need for computers among the several services in a hospital rather than a total frontal attack on all hospital services. The report predicted that networking computers would have more potential for the evolvement of hospital information systems than an attempt to solve the problem with one very large machine.

In graphics technology, the use of an electronic digital computer to plan dosage schedules for irradiation therapy for

cancer patients was reported as early as 1958,[65-67] and computer dosage planning for irradiating cancer patients soon became a routine procedure.

The first clinical prototype x-ray head scanner was developed in 1971,[68,69] and CT scanning technology was subsequently applied to ultrasound, radionuclide, positron emission and nuclear magnetic resonance images. CT scanning was called "the most important technical development in diagnostic radiology since the introduction of image amplification."[70]

A 1965 survey of the state of computer-based information systems for medicine in the United States listed 73 projects in hospital and clinic information systems, 51 projects in computer-aided diagnosis and 28 projects in storing and retrieving medical documents and information.[71] Other useful collections of articles for these first ten years of computer applications to medical practice can be found in the July 31, 1964, issue of *Annals of the New York Academy of Sciences* entitled "Computers in Medicine and Biology," and in the *Journal of Chronic Diseases*, volume 19, 1966. In addition, two books were published in 1965 that provide excellent reviews of the accomplishments of the first ten years of medical informatics.[72,73]

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