Report of the
Board of Regents

National Library of Medicine

Long Range Plan

U.S. Department of Health and Human Services
Public Health Service
National Institutes of Health

Overview of the NLM Long Range Plan

Cover:

A system for quantitative DNA analysis using image processing

The NLM Long Range Plan is published as a series of 7 reports:

An *Executive Summary* sketches the background against which the Long Range Plan may be viewed, and it extracts highlights from the Board of Regents Report.

The *NLM Long Range Plan (Report of the Board of Regents)* presents detailed and specific recommendations and estimated resource requirements over the next 3 years for accomplishing the Library's long range goals.

Panel reports 1 through 5 contain the substance of the five advisory planning panels' discussion in each of the five principal domains of NLM activity:

Panel 1: Building and organizing the Library's collection

Panel 2: Locating and gaining access to medical and scientific literature

Panel 3: Obtaining factual information from data bases

Panel 4: Medical informatics

Panel 5: Assisting health professions education through information technology

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January 1987

Foreword

It has been my privilege to serve on the Board of Regents of the National Library of Medicine (NLM) from 1982 to 1986. Succeeding Dr. Martin Cummings, Dr. Donald Lindberg began as the NLM Director in August 1984, the same month I began as Chairman of the Board of Regents. In our early informal talks together, Dr. Lindberg and I shared a belief in the importance of the NLM and the need for this great institution to prepare for its role in the changing scene of American medicine and science. The Library's distinguished history reflects its evolution as the world's greatest repository of biomedical information. Further, the Library staff has continually searched for ways to make its sources more available to scientists, clinicians and the public. Without question, the National Library of Medicine has become the intellectual center of the world's biomedical information network. To continue that role, some changes in mission and operations would be necessary.

In these early discussions, Dr. Lindberg and I agreed that the Library could best plan its future activities and resource requirements only after a careful examination of its mission and the requirements of its users. The new and different realities of the 21st century are coming into focus and changes to accommodate this new world are inevitable. At the direction of the Board of Regents a long range planning project was organized. It was presented to the Regents at the June 1985 meeting, and received their enthusiastic endorsement.

Consultants were identified, panels appointed, and the project launched in the Fall of 1985. The marvelous efforts of the panel members enabled each group to generate a report with recommendations. I believe that every user population was represented in the discussions held during the several meetings of the five panels and nothing overlooked in the long range plan.

This plan is intended to serve the public, the Congress, the HHS Secretary, future regents and the Director of NLM and staff in their decision making about the Library's future activities. Public and private financial support will be necessary to underwrite these enormously important functions. It is my hope that the plan and its interrelated component parts will be made known to the Secretary and the Congress and will help those leaders understand and appreciate the National Library of Medicine. Further, support from the private sector may be desirable for certain activities and the plan should help identify such areas.

In developing the plan, the Regents have been ably assisted by the Library staff and, particularly, its Director. The Board of Regents enthusiastically supports the plan and will help to encourage its successful implementation

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1985–1986

Preface

The responsibility of the National Library of Medicine is to 'assist the advancement of medical and related sciences, and to aid in the dissemination and exchange of scientific and other information important to the progress of medicine and to the public health.' The Library had done this well in the past. Yet rapid changes in science, in health care practices, in the uses of information technology, and in American public policy concerning all these issues bring us pause to re-study how best to fulfill our responsibility during the coming decades.

This Report embodies a central challenge to the National Library of Medicine to strive to be certain that health care in America and the advancement of biomedical research toward this end will benefit from the dazzling technological discoveries that are available to us now from computer and information science, telecommunications engineering, physics and chemistry. In the past, the Library has established a distinguished record of scholarly leadership in medicine. This Report emphasizes the present urgent need for improved access by health care professionals and scientists to the fast growing scientific literature of newly discovered biomedical concepts, treatments, and preventatives—across a wide range of practical and theoretical problems. The most encouraging aspect of this Report is the recommendation that the Library move as quickly as possible to translate the existing ''raw'' technology of computers, information, and engineering sciences into products and services that through its insight and understanding of the special biomedical practices and needs can improve health care in America.

No one doubts that even finer developments await us in the coming years. Yet even today there exist outside of medicine, advanced systems for knowledge representation, country-wide inquiry and communication, and decision support for military, financial, industrial, and intelligence applications. What seems needed now is to adapt these general and useful technologies to the specific jobs of biomedicine. Progress might eventually come in any case, but a concerted effort on the part of the National Library of Medicine could speed this up, bringing laboratory advances and discoveries closer to the bedside and the clinic.

A word must be said about priorities among the current, the enhanced, and the new activities that this Report recommends. It does not prescribe a fixed sequence of steps by which the entire plan and all its objectives are to be accomplished. The construction of a functioning operational plan will be developed by NLM and its Board of Regents within resource limitations. This Report is more a map for the future and a set of opportunities that await NLM action and program development. The advisors and the Board of Regents are no doubt fully aware that the urgency of the need to support NLM's planned programs for the Nation's good must necessarily be balanced by the Congress and the Executive against all other needs for resources. In addition, many of the proposed programs are dependent upon full understanding and enthusiastic endorsement and support by the constituencies of the Library most affected.

Yet, the Report clearly recognizes several outstanding considerations. NLM's fundamental priority certainly is to sustain the collections of the Library and to provide better access; or, stated another way, to provide high quality library and information services to the biomedical community. Actions toward this goal include continued refinement of collections and preservation programs, improvements to the electronic system for end-user access, and modernization of our information support services.

The top priority for our discretionary efforts must be to prepare the Library and the Nation's health professionals for the optimal utilization of the burgeoning electronic technologies for knowledge management. Of the numerous initiatives the plan proposes as components of this preparation, one in particular stands out. This is the "window of opportunity" presented to the Library in the field of molecular biology and biotechnology. Attention to this opportunity—through the provision of advanced information handling services—will permit NLM to contribute significantly to discovery of new principles and treatments by health-care professionals and scientists.

As a direct result of the insight gained through the long range planning efforts embodied in this Report, NLM is already giving prime emphasis within the bounds of our current resources to research efforts to develop integrating and coordinating systems for the factual data bases in molecular biology/biotechnology. These efforts now involve a number of advanced techniques recommended in the Report, including extension of the Unified Medical Language System to molecular biology, interconnectivity of the existing data bases through electronic gateways and networks, and new knowledge representation designs.

I welcome the Report and its recommendations. On behalf of the National Library of Medicine staff, I wish to thank most sincerely all those who so graciously contributed their time, effort, and thoughts to this careful and salient statement.

Donald A.B. Lindberg, M.D.
Director, National Library of Medicine

Contents

Report of the Board of Regents

Summary of Long Range Goals and Resources

The Board of Regents of NLM have adopted a long range plan for the Library's future activities and resource requirements. Drawing upon the advice of external consultants from the Library's user communities, the Regents have identified 16 major goals. These are summarized in the list which follows. Chapter 3 describes these goals in greater detail and presents the specific actions recommended to achieve them.

Domain 1:

Building and Organizing the Library's Collection

1.1. Continue to serve as the 'library of record' for medicine and related sciences.

1.2 Improve the organization and description of the biomedical literature.

1.3. Adapt NLM's methods for acquisition, organization, and preservation to accommodate new electronic forms of the scholarly record for biomedicine.

Domain 2:

Locating and Gaining Access to Medical and Scientific Literature

2.1. Make information more accessible to health professionals.

2.2. Provide enhanced information products and services to assist health professionals and biomedical scientists.

2.3. Continue to support the training of medical librarians and other information specialists to prepare them to adapt new technologies to the needs of the biomedical community.

2.4. Review the public's need for and access to health information.

Domain 3:

Obtaining Factual Information From Data Bases

3.1 Expand information for public health and environmental protection.

3.2 Establish information services and linkages for biotechnology information.

3.3 Support the development of medical practice-linked data bases.

Domain 4:

Medical Informatics

4.1 Support extramural research on information and knowledge structure in the health sciences.

4.2 Strengthen medical informatics research at NLM.

4.3 Strengthen competence in medical informatics in the health professions.

Domain 5:

Assisting Health Professions Education Through Information Technology

5.1 Develop, demonstrate, and assess educational applications of computer technology in health sciences curricula.

5.2 Develop and evaluate prototype knowledge management systems for use by persons in health sciences.

5.3 Evaluate possible NLM role as reference resource in support of automated systems for enhancing learning in the health sciences.

Summary of Additional Resources Needed to Implement Goals
(Dollars in Thousands)

Domains and Goals	FY 88	FY 89	FY 90	Personnel
	Incremental Resources			
Domain 1: Building and Organizing the Library's Collection				
1.1 Be the "Library of Record" for the Biomedical Literature	$2,345	$2,805	$2,825	6.5
1.2 Improve the Organization and Description of the Literature	1,200	1,225	1,175	5.0
1.3 Adapt NLM Methods to Accommodate New Forms of Information	100	100	100	1.0
SUBTOTAL DOMAIN 1:	$3,645	$4,130	$4,100	12.5
Domain 2: Locating and Gaining Access to Medical and Scientific Literature				
2.1 Make Information More Accessible to Health Professionals	$7,800	$9,800	$11,800	6.0
2.2 Provide Enhanced Information Products and Services	935	905	925	3.5
2.3 Support Training of Medical Librarians and Information Specialists	1,000	1,000	1,000	0
2.4 Review Public's Need For and Access to Health Information	150	50	50	0.5
SUBTOTAL DOMAIN 2:	$9,885	$11,755	$13,775	10.0
Domain 3: Obtaining Factual Information From Data Bases				
3.1 Expand Information for Public Health and Environmental Protection	$1,235	$1,235	$1,235	10.5
3.2 Establish Information Services and Linkages for Biotechnology Information	9,720	9,720	9,720	34.0
3.3 Develop Medical Practice-Linked Factual Data Bases	1,800	1,800	1,800	5.0
SUBTOTAL DOMAIN 3:	$12,755	$12,755	$12,755	49.5
Domain 4: Medical Informatics				
4.1 Support Extramural Research on Information and Knowledge Structure	$3,000	$6,000	$9,000	0
4.2 Strengthen Informatics Research at NLM	7,400	9,900	13,045	18.0
4.3 Strengthen Competence in Medical Informatics in Health Professions	9,050	10,300	11,550	3.0
SUBTOTAL DOMAIN 4:	$19,450	$26,200	$33,595	21.0
Domain 5: Assisting Health Professions Education Through Information Technology				
5.1 Develop Educational Applications of Computer Technologies	$6,350	$4,450	$4,450	12.0
5.2 Develop and Test Prototype Knowledge Management Systems	750	900	1,050	0
5.3 Evaluate NLM Role as Resource in Support of Automated Systems	250	250	0	0
SUBTOTAL DOMAIN 5:	$7,350	$5,600	$5,500	12.0
SUBTOTAL DOMAINS 1-5:	$53,085	$60,440	$69,725	105.0
Research Management and Support				
Extramural Management	$250	$250	$250	5.0
Program Management	150	150	150	3.0
SUBTOTAL RESEARCH MANAGEMENT AND SUPPORT:	$400	$400	$400	8.0
TOTAL INCREMENTS:	$53,485	$60,840	$70,125	113.0

Past and Current NLM Programs

The Library traces its origin to the U.S. Army Surgeon General's office which in 1836 budgeted $150 for "medical books" for officers. That seed money could not have fallen on more fertile ground. From that simple beginning has evolved the world's largest and most dynamic collection of health science literature — the National Library of Medicine.[1]

The single most important figure in the Library's history did not come on the scene until 1865, when Civil War surgeon John Shaw Billings took charge of the collection. He directed its fortunes for the next 30 years, guiding it to a position of preeminence among medical libraries that the institution has held ever since. The *Index Medicus,* begun by Billings in 1879, is still published by the Library and used by medical professionals around the globe.[2]

If the Library's Golden Age was the Billings era, its Renaissance began in 1965 with the introduction of MEDLARS (Medical Literature Analysis and Retrieval System) and continues today.[3] One event that stands out in the 70 years between Billings and MEDLARS is the 1956 legislation (Public Law 84-941) that gave the Library its current name and placed it under the U.S. Public Health Service. Setting a broad mandate to improve the nation's health through improved information services, the legislation also created a Board of Regents to guide the Library in matters of policy.

1965: The Beginning of the Library's Modern Age

Notwithstanding that landmark 1956 legislation, the year 1965 may for several reasons be designated as the revitalization of the National Library of Medicine.

First, it marked the beginning of the computerized MEDLARS system, which grew out of the Library's manual indexing of journal articles. Its inauguration allowed publication of the references in *Index Medicus* to be undertaken at a speed previously unimaginable.[4] Other bibliographies, catalogs, and indexes soon followed, all made possible by MEDLARS and the pioneering computer-driven phototypesetter called GRACE (Graphic Arts Composing Equipment) developed for the Library at the same time.

The importance of this event and the effect it was to have, and continues to have, on the American medical community cannot be overestimated. MEDLARS marked NLM's first major foray into the world of computer technology. And its success gave the Library the confidence it needed to continue developing innovative information services for the health sciences.

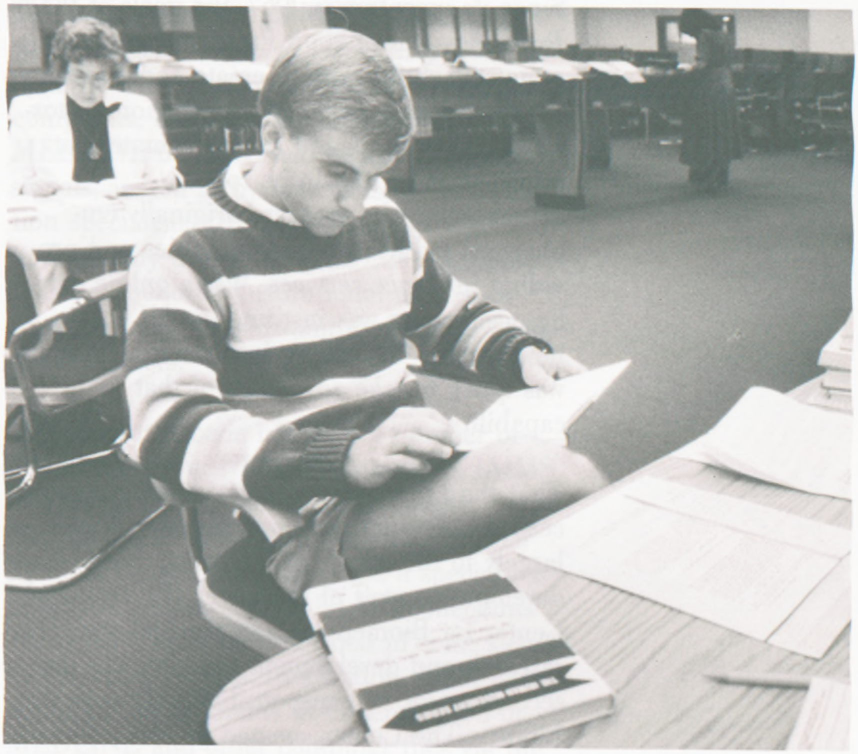
Second, 1965 saw the passage of the MLA Act (Medical Library Assistance Act,) which reflected the strengths and weaknesses of the biomedical information environment in 1965: On the strength side, there existed a health science library community with a strong spirit of cooperation. Added to that was NLM, which provided a nexus of leadership. On the other side, the weak status of individual health science libraries was well documented. It was common knowledge that increasing demands for information services, corresponding to the large growth in research and education, could not be met by existing library resources.[5] A critical imbalance existed. The MLA Act provided the means to unite librarians and libraries, health professionals and institutions, and NLM in achieving the common goal of improving health information access.[6]

Progress under the Act has been significant, and the Congress has renewed the legislation repeatedly. By 1986, some $150 million had been awarded to more than 1,000 institutions for the development of library resources, services, and networks; the education and training of specialists to manage and deliver biomedical information, including medical librarians and medical informatics researchers; the preparation and publication of important scientific publications that are not commercially viable; and the conduct of research in library and information science and medical informatics.

Perhaps the most lasting contribution of the Medical Library Assistance Act, however, was to mandate the creation of a national biomedical information infrastructure in the form of a RML (Regional Medical Library) Network. To that end, the Act actually authorized NLM to construct "branch" libraries, but the authorization was never put to use.

Instead, it was decided to form a hierarchical network with four levels of institutions. At the base of the network are the hospital and other local libraries used by health professionals in their day-to-day practice. These libraries turn for help to "resource libraries" — primarily those at medical schools. The next level comprises seven Regional Medical Libraries, each responsible for a geographic portion of the United States. Finally, there is the National Library of Medicine itself, serving as a resource for materials not available elsewhere in the Network.

Each year, some 2 million copies of journal articles, books, and other library materials are lent expeditiously among the libraries in the Network. Requests frequently are routed



electronically from one institution to another. The result is that American health professionals, no matter where they are located geographically, have rapid and comprehensive access to the literature of biomedicine.[7,8]

New Responsibilities

The publication in 1962 of Rachel Carson's *The Silent Spring*[9] was a powerful spur to the public and its elected representatives to take action to protect the environment. A report to the President in 1966 by his Science Advisory Committee found an urgent need for computer-based environmental and toxicological information to be made widely available to health professionals and scientists. As a result of recommendations in that report, the Department of Health, Education, and Welfare directed the National Library of Medicine to establish a Toxicology Information Program.[10]

Since its inception in 1967, the goals of the Toxicology Information Program have been quite straightforward: to create and maintain automated data banks of information on toxicological subjects and to disseminate that information widely. In its role as disseminator, the program originally emphasized publishing bibliographies and providing reference services. When online data base searching was instituted at NLM, however, the Toxicology Information Program was quick to take advantage of that capability.

That the Library was able to develop a successful online retrieval program was due largely to the efforts of the research and development staff of the Lister Hill National Center for Biomedical Communications. This research and development function was the second major new responsibility given to the Library. The Center, created in 1968 by the U.S. Congress, is named after Senator Lister Hill who, with Senator John Kennedy, sponsored the 1956 National Library of Medicine Act.

The Lister Hill Center pioneered in the application of space-age technology for experimental networks.[11] One of the first was the prototype of the NLM online retrieval system, MEDLINE. Others included radio and television communication via NASA satellite linking remote Alaskan villages with Public Health Service physicians,[12] a two-way microwave television network tying together outlying health facilities in New England, and a national network for accessing computer-based health education materials.[13]

At present, the Lister Hill Center is involved in a variety of projects that may be characterized as falling into three groups: those concerned with improving educational techniques in the health sciences (example: the TIME—Technological Innovations in Medical Education—project); those involving artificial intelligence or expert systems (example: AI/RHEUM—artificial intelligence in rheumatology); and those which will improve the storing, processing, and dissemination of library-based information (example: the EDSR—Electronic Document Storage and Retrieval—project).

The MEDLARS/MEDLINE Network

In the early 1970s, the Lister Hill Center successfully experimented with an online information retrieval project known as AIM-TWX. This combined a modest computerized data base of references (those appearing in the *Abridged Index Medicus)* with the communications network—TWX (Teletype-writer Exchange Network). The resulting experimental network was so successful that the Library offered an expanded nationwide service, MEDLINE, in October 1971. Today, the MEDLINE data base (and its backfiles to 1966) contain more than 5 million references, many with abstracts. It is an expanded, electronic *Index Medicus.*[14]

MEDLINE was soon joined by other online data bases — TOXLINE (toxicology information online), CATLINE (NLM catalog online), CHEMLINE (chemical information online), AVLINE (audiovisuals online), and so forth. Today, more than 20 online data bases are available to thousands of institutional and individual users in this country. In 1986, those users will do more than 3 million bibliographic searches on NLM's computers. In addition, several U.S. commercial networks lease NLM's data bases and make them available for online searching to their customers.

Internationally, MEDLINE is available via formal arrangements between the National Library of Medicine and major institutions in 16 nations. Some of those foreign centers have direct access to NLM's computers in Bethesda; others provide search services on their own computers from tapes of the data base provided by NLM; some do both. The foreign partners in turn provide search services to health professionals in neighboring countries. The result is that NLM's MEDLINE has a high reputation throughout the world's health community.

The newest addition to MEDLARS is a software program known as GRATEFUL MED. A floppy disk system designed for personal computers, it allows simple, direct access to MEDLINE by individual health professionals, as well as by librarians and information specialists. GRATEFUL MED will undoubtedly transform MEDLINE's traditional audience of institutional users to a mixture including substantial numbers of individual users.

The present decade has seen a number of new initiatives at NLM. Examples are IAIMS (the Integrated Academic Information Management Systems), UMLS (the Unified Medical Language System, and a special emphasis on preserving the NLM's collections. These initiatives are described in some detail in the Panel reports. In addition, NLM is encouraging experiments in dissemination of MEDLINE and other computer files via the new CD-ROM disk technology (compact disk-read only memory) through agreements with a number of domestic and foreign commercial information vendors.

Recognizing the importance of the recent discoveries in molecular biology, NLM has already initiated a number of experiments. These include an advanced scientific workstation that facilitates access by NIH research scientists to GenBank computer records of nucleic acid sequence data, MEDLINE bibliographical records in molecular biology, protein products sequence data, and online access to "Mendelian Inheritance in Man," the genetics text.

Further experiments include efforts to link NLM users via electronic gateway functions to these and other information networks.

2 A Vision of the Future

Planning for the Library's future demands a forecast of the environment in which it will function. What sort of technology will be available for information management in the early part of the 21st century? What social and economic circumstances will underlie the provision of health care? How will the patterns of health professional education change? How will scientific work — research, communication, and decision making — be carried on?

Some parts of the future may be clearer than others. There is always uncertainty in prediction, but even an incomplete vision of the future can serve as a general guide for planning. The following scenario seeks to illuminate the ways in which information will be collected, organized, transferred, and used in the future.

Scenario 2006: An Industrial Accident

At a remote industrial plant in rural Virginia, where rocket fuel research had been performed in the 1950s and 60s, workers are detoxifying old cylinders containing unknown gases. Some gas is accidentally released, engulfing three men. The rescue squad and the company environmental protection officer are immediately summoned. By the time the air ambulances arrive, the men are gasping for breath. One experiences a violent convulsion followed by loss of spontaneous neurologic function. As the emergency medical technicians rush the men to the helicopters, the environmental protection officer samples the gases in the cylinders for assay in a gas chromatograph/mass-spectrograph. Within 20 minutes, 12 rescue workers, 2 bystanders and the officer are showing similar but milder symptoms. What is the gas and how toxic is it? What is the immediate treatment? Will there be long-term effects?

The air ambulance data analysis unit is fully equipped for video/voice/digital data communications and analysis. While one medical technician connects the men to monitoring systems and takes blood samples, another establishes communications links with the person performing the gas assay, the Toxicology Information Bank, and the receiving hospital. She reports the patients' signs and symptoms and the location of the accident. As she speaks, the computer simultaneously processes her words and the patients' physiologic data. The computer in the helicopter, which has received these data automatically from the auto-analyzer, makes recommendations regarding the emergency treatment. When the gas chromatograph-mass spectrograph assay has been completed, the results are reported to the medical crew and the receiving hospital: probable B5H9 (pentaborane.) The computer recommends confirmatory studies, with complementary spectral analysis, when the patients reach the hospital. All these data become available while the air ambulance is en route.

The men's personal ID wallet cards, magnetically coded like bank cards, carry critical personal data including such health information as their medical history and baseline laboratory data. The cards are inserted into a special emergency reader, which unscrambles the privacy-protection code and displays the information, including a photograph and dental x-rays for positive identification. At the same time, an admission record is automatically created at the hospital. Immediate relatives are contacted automatically and told what is happening. The families arrive at the hospital shortly after the helicopters.

The hospital's decision support system recognizes pentaborane toxicity as the likely cause of the syndrome and automatically searches its files for similar cases. It finds none, but the Hazardous Substances Data Base at the National Library of Medicine identifies three cases, reported in the literature 10 years earlier. In that incident, one patient died on the way to the hospital. His autopsy report documented widespread damage to the central nervous system. The other two victims recovered during the first week, with few residual effects. Several animal studies in the data base report selective reaction of pentaborane with nervous tissue.

In the emergency room, the physician in charge and two residents have been observing the emergency crew at work. Information from the helicopter has been transmitted to the emergency room's video monitor and personal computer workstations, which are the size and shape of the clipboards the doctors once used for note taking and record keeping. Two of the patients have required blood pressure and ventilatory support. One patient has just gone into cardiac arrest. Eighteen people have been exposed; it appears that at least two will die.

Because no information is available on long-term effects, the hospital's decision support system establishes an individualized follow-up protocol for everyone involved. With the same terms and search procedures used to search the Hazardous Substances Data Base and the hospital's decision support system, the medical librarian calls up the National Library of Medicine's literature search system. Three relevant articles are immediately available in full text on the computer screen for the physician's scrutiny. Though the emergency room is quietly tense, the treatment team is now as fully informed as possible about the probable cause, optimal treatment, and likely outcome of the patients the helicopters are rushing to their care.

Four months after the disaster, the internist assesses the damage. One patient — the man who initially lost neurologic function — never recovered consciousness and died on the eighth day. Another is quadriplegic, blind, partially deaf, and no longer sentient. The third man has been luckier: He had been the farthest away and had been able to cover his face and hold his breath. Twelve weeks after the accident, he and seven others who were exposed still evidence mild brain dysfunction and psychiatric symptoms. The fact that these findings are not consistent with earlier data in the Hazardous Substances Data Base, is not surprising. Post-trauma monitoring was not as easy and sophisticated 10 years ago, when the previously reported accident had occurred.

The internist, the emergency room physician, and a nurse epidemiologist have asked the victims to take part in a long-term follow-up study. Most agree because participation requires their coming to the hospital only one day a year, for physical examinations and biochemical assays. Other data (such as psychological performance) can be collected over the phone after voice prints have been made. The patients will be called and interviewed by a computer program that is both polite and able to answer their questions.

The nurse-epidemiologist makes home visits part of his routine follow-up protocol. His clipboard workstation is equipped with a microrecorder that tapes all interviews. A pressure-sensitive screen allows him to follow the interview guide and code the responses easily. Later, the stored responses are "uploaded" to a machine "trained" to accept both voice and digital input. A series of programs presort the information for later review by the research team. The data are compiled and available in the Toxicology Information Bank, labeled as preliminary because additional data are still coming in. Toxic spills are still not commonplace, but far too many hazardous chemicals were buried years ago to be sure the data won't be needed again.

At home, one of the patients is glad to see the nurse. Neither he nor his wife was confident about the details of his treatment and what he had to do. The nurse shows them how to use a small computer, about the size of a book, that he plans to leave with them. It takes its program from a compact digital video disk that includes moving pictures showing the patient how to care for himself. Everyday, it lists what needs to be done. When the patient finishes a procedure, all he needs to do is run a finger across the instruction. If the patient forgets, the next day the instruction will flash. And if he skips a procedure more than once, the computer will alert a visiting nurse to call.

If nothing is done for more than a day, an emergency alert will contact the hospital medical information system. If the couple needs something explained, all they have to do is activate the 'Help Panel.' The computer can distinguish between an urgent need for help and a reminder or information need. If the need is urgent, the call is immediately referred to a nurse or a physician. Otherwise, the appropriate instruction is displayed on the screen. The instructions are resident in the computer's disk memory. The computer can also be used to contact the patient's physician and to get prescriptions renewed.

The patient settles back, reassured by the skill and technology available to him. In time, he makes a full and uneventful recovery.

3 Goals and Recommendations

Domain 1:

Building And Organizing The Library's Collection

The National Library of Medicine is the 'library of record' for medicine and the allied health sciences. Over the past 150 years, the Library has assembled, organized, and preserved the world's largest collection of biomedical literature. Housed within the Library is a wide variety of media: books, journals, theses, pamphlets, historical pictures, manuscripts, and audiovisuals.

The NLM collection serves as a backup for all U.S. biomedical libraries. The assurance that NLM's comprehensive collection will be maintained and preserved allows other biomedical libraries to concentrate their resources on current materials of particular interest to their primary clientele. Those libraries rely on NLM for items that are infrequently needed by their users and for the long-term preservation of the scholarly record of biomedicine.

To make the information contained in its vast collection readily accessible to current and future generations, NLM catalogs or indexes items. Toward that end, the Library has developed a thesaurus and a classification scheme that reflect the special information needs of health practitioners, researchers, educators, and students.[15] By using NLM's authoritative cataloging and indexing data to organize and describe the biomedical literature in their own collections, other health sciences libraries save millions of dollars in staff time each year and can offer faster, more efficient service.

NLM periodically examines the scope of its collection and indexing system to ensure they reflect the changing frontiers of biomedical knowledge, the increasing interdependence of medicine and other fields of knowledge, and the availability of biomedical information in new formats.[16] NLM also has continually refined its procedures for enlarging and organizing its collection. The creative use of automation and new technologies has enabled the Library to provide timely access to a growing volume of biomedical literature. The Library has been a pioneer in the expanded use of processing services from subscription agents[17] and book dealers; in the automation of acquisition, receipt processing,[18,19] cataloging, and indexing activities; and in the conversion of retrospective cataloging records to machine readable form.[20]

Today, NLM faces the prospect of an increasing array of electronic publications that, at least initially, will extend the range of information resources the Library must acquire and organize, rather than replace more traditional print formats. Furthermore, as the borders between biomedicine and other areas of research become ever more blurred, the task of defining the appropriate boundaries for NLM's collection and services becomes more difficult and the need to link the Library's collections and services to other institutions' is increasingly apparent. To meet the challenges presented by changes in information packaging and in the nature of biomedical research, NLM must adopt new strategies for maintaining and enhancing the traditional excellence of its collection and its methods for organizing and describing the biomedical literature.

Goal 1.1
Continue As The "Library Of Record" For Medicine And Related Sciences

To remain the "library of record" for biomedicine, NLM must continue to perform its basic functions of acquiring and preserving the biomedical literature. As it has in the past, the Library must adapt the methods used to perform those core activities to respond to changes in biomedical publishing and information technology.

In particular, NLM should continue to periodically review its policies for selecting materials to ensure the collection remains comprehensive and useful. As part of that process, the Library must review the information needs of the full range of health professionals and monitor new and expanding research areas. A special concern over the next few years will be defining NLM's coverage of electronic publications and data files, as well as reassessing selection guidelines for all types of media and images.

The Library should acquire the worldwide biomedical literature that meets its selection criteria, irrespective of the physical format of that literature. This may well involve acquisition of media not currently represented in the NLM collection. It will certainly involve increased acquisition of computer-based materials. To keep pace with the increasing volume and complexity of the biomedical literature, NLM should continue to improve the automated systems that support acquisition, inventory control, and preservation.

In addition to acquiring materials for use today, NLM should ensure the future availability of the scholarly record of biomedicine through an expanded preservation program. The Library has devoted considerable resources to preserving its collection in the past and a plan recently approved by the Board of Regents outlines future steps in this area.[21]

Recommendations

1.1.1. Expand acquisition of appropriate electronic media as well as the historically significant records of modern biomedical research and practice.

1.1.2. Carry out the recommendations of the recently developed NLM preservation plan, which include:

- Preservation of the materials in the NLM collection.

- Coordination of a national program to preserve important biomedical literature held in other libraries and institutions.

- Continued research in NLM's Lister Hill Center on the preservation characteristics of new storage media, such as optical disk formats.

- Active encouragement of the publishing industry to use more permanent materials in the production of the biomedical literature.

Goal 1.2:
Improve The Organization And Description Of The Biomedical Literature

NLM should increase its cooperative efforts with publishers and other organizations involved with the organization and description of literature, as well as continue to improve the quality and efficiency of its own operations. The MeSH (Medical Subject Headings) and the NLM Classification, for example, the Library's essential tools for cataloging and indexing, should be enhanced not only for NLM's own use, but also for the benefit of other biomedical libraries and information providers.

To ensure that the information most critical to health professionals and researchers is available in NLM data bases, the Library should improve its mechanism for identifying relevant biomedical literature to be indexed by NLM. Statistical indicators of the use and importance of specific journals should be considered, as well as the advice of experts in the field. In selecting titles to be indexed, the Library should seek to complement access to the literature provided by other indexing and abstracting services.

The Library's cataloging records should remain compatible with national and international standards so they can be readily merged with those created by other cataloging agencies. NLM should also increase efforts to make the application of those cataloging standards realistic and responsive to the needs of library users.

The Library should develop more automated assistance to cataloging and indexing decisions. The goal would be to reduce the time and effort required for this labor-intensive activity and to assure quality and uniformity in NLM's cataloging and indexing data. The Library should also continue to engage in cooperative programs with publishers to speed access to new publications by making them available in machine-readable formats. In addition, the Library should explore the feasibility and desirability of increasing the amount of information made available through its cataloging and indexing data bases.

Although the Library must exploit new technologies as much as possible, it should continue to distribute its indexing and cataloging data widely in a variety of formats: printed publications, direct online service, and an array of other electronic forms. It is critical that this information be readily available to health professionals and researchers irrespective of their geographic locations or levels of technological sophistication.

Recommendations

1.2.1. Experiment with the use of machine-readable citations and abstracts received from publishers as direct input to the cataloging and indexing processes.

1.2.2. Investigate the feasibility and desirability of indexing articles in the journal literature more specifically to cover signs, symptoms, procedures, research populations, clinical values, etc.

1.2.3. Experiment with the use of artificial intelligence techniques and expert systems to improve cataloging and indexing productivity and consistency.

1.2.4. Investigate the feasibility and desirability of including table of contents data in NLM cataloging records for books.

1.2.5. Improve the process by which NLM selects journals for indexing. Improved procedures should augment rather than replace the current method of obtaining advice from expert consultants.

1.2.6. Support research projects in automated or semi-automated methods for the integration of the content of individual articles to produce useful summaries of knowledge in particular areas.

Goal 1.3:

Adapt NLM's Methods For Acquisition, Organization, And Preservation To Accommodate New Electronic Forms Of The Scholarly Record For Biomedicine

Electronic publications do not yet represent a significant proportion of the scholarly biomedical literature acquired by NLM, but they can be expected to increase dramatically over the next 20 years. As yet, virtually no standards or generally accepted practices govern the production, distribution, and allowable use of electronic publishing. Some work has been done regarding standard bibliographic description of electronic publications, but the problems of distinguishing between multiple versions of a continually updated machine-readable publication have not been resolved. Nor has a coherent strategy been developed for the long-term preservation of data available only in electronic form.

Of the electronic publications currently available, only a relatively small number are of interest to NLM and its constituency. Given that and the lack of standards for such publications, NLM has a unique opportunity to influence the publishing industry to develop electronic formats that will facilitate, or at least not hamper, the Library's mission to acquire, organize, and preserve the scholarly record for biomedicine. While modifying current acquisition and organization methods to handle electronic formats, NLM should work with other groups to gain maximal societal advantage from emerging forms of publication.

Recommendations

1.3.1. Work with other interested institutions to define the special technical and policy problems created by electronic publishing and to develop strategies for minimizing those problems. Specific issues that NLM and others must address include:

- Future availability of material published in electronic form.
- Standards for the production of electronic media.
- Retention and storage of raw data (text, numeric, and graphic) files.
- Potential disappearance or alteration of information through updating of electronic publications in the scholarly record.

Budget

Estimates of resources needed to implement these recommendations are given in Chapter 4.

Domain 2:

Locating and Gaining Access to Medical and Scientific Literature

The fundamental rationale for the NLM's mission recognizes that health is a national priority and that health research is a national investment. To realize the full benefit from that investment, every possible means must be taken to stimulate the effective dissemination of research results. Therefore, NLM is responsible not only for collecting and organizing the biomedical literature, but also for ensuring access to it.

Traditionally, NLM has aided the dissemination of biomedical research results through the distribution of its authoritative indexing and cataloging information, which enables health professionals to identify the literature relevant to their information needs, and through systems and services which help health professionals locate and obtain the relevant documents they have identified. Today, NLM's descriptions of the content of the biomedical literature are readily available to health professionals throughout the world and are consulted millions of times each year. DOCLINE, an NLM-developed automated document request and referral system,[22] facilitates the process by providing automatic routing of information requests through the national RML (Regional Medical Library) Network.[23]

Although access to information by health professionals has improved dramatically through the efforts of the NLM and the RML Network,[24] technological advances of today and the future present new opportunities for more effective and efficient information service. Increasingly, biomedical information is being created and maintained in electronic format by an overwhelming variety of sources. Enhanced networks that provide the health professional with gateways to relevant information on a variety of

disparate computer systems will be required, as will specialized networks that provide integrated information for health science centers such as those being studied under the IAIMS (Integrated Academic Information Management Systems) program.[25,26] Since health professionals will be accessing these networks directly, search software needs to be adapted to the knowledge and terminology of the user. Overall, information services to health professionals must become more flexible and intelligent.

The libraries of the future must evolve into a powerful interlocking system of networks that will coordinate and facilitate the linking of relevant information resources and the users of this information. Both the information providers and the health professionals will need training to take full advantage of new electronic storage and dissemination tools.

Goal 2.1:
Make Information More Accessible To Health Professionals

The continued growth in the biomedical literature and the increasingly interdisciplinary nature of scientific research require that health professionals have access to a wide range of information from many different sources. A strong and effective communications network that provides access to all that information is essential.

The Regional Medical Library Network has been an invaluable tool for facilitating access to the literature for health professionals. It will have a far greater potential if the Network takes advantage of the new technologies and serves as a test bed for new health information delivery systems. Working together, NLM and the RMLs can expand the existing document delivery system into a nationwide automated document request and routing system.

While the RML Network is interinstitutional, the IAIMS initiative is developing integrated networks and linkages within institutions. There is widespread recognition that health sciences libraries across the country will need to assist in the development of such networks for biomedical institutional environments. These networks, however, need not be identical or even parallel since institutional and individual needs differ from location to location.[27,28]

The strength of the communications networks of the future will depend on the use of appropriate standards and principles for storing and transmitting information that are broadly accepted in the biomedical information world so that internodal access and transfer of data and knowledge can be efficient, reliable, and speedy. NLM will be in a position to establish standards in some areas, and to support the efforts of national and international bodies to do so in others.

For NLM to remain a leader in applying new technologies, it must continue strong support of research and development activities, and undertake projects using the technologies to solve some of its own problems. The development of gateways (composed of a set of computer commands that permit a user to access relevant data bases) will provide the kind of easy information access that is essential to meet the needs of tomorrow's health professionals.

Recommendations

2.1.1. Enhance the Regional Medical Library Network to assure that it is able to use emerging technologies and to serve successfully as a test bed for new communications systems.

2.1.2. Continue to support IAIMS planning, model development, and implementation efforts in a limited number of institutions, and disseminate information about the experiences of these institutions.

2.1.3. Make research grants and contracts for the development of intelligent interfaces for gateways to increase access to information. Expand the intramural research program in this area.

2.1.4. Work cooperatively with selected relevant data base producers to create linkages, reduce production costs, and to otherwise facilitate access to relevant health information.

2.1.5. Develop an electronic gateway function that will link users of the MEDLARS system to information in a variety of relevant data bases.

Goal 2.2: Provide Enhanced Information Products And Services To Assist Health Professionals And Biomedical Scientists

NLM should expand its existing reference and document delivery services. The traditional pattern of referring unfilled requests to larger collections may not be the most effective model for locating and obtaining information in the coming decades. Specialized collections and special expertise may be identified at many points in the network. While this is currently done informally, sources of knowledge for reference referral should be identified more systematically. In addition, the existing document delivery network could be improved by allowing the user to request an actual copy of a journal article in the course of a MEDLINE search. Links to other networks (not only in biomedicine) might also enhance document delivery service to the user.

NLM should develop systems to improve access to electronic information. These systems will simplify access to bibliographic data by assisting with the formulation of information queries and will help health professionals obtain quick, inexpensive, accurate answers to specific questions. GRATEFUL MED,[29] NLM's software for helping health professionals search MEDLINE[30] easily using a personal computer, should be enhanced.

NLM should continue to explore the information needs and information seeking behavior of health professionals and biomedical research scientists. Each such user requires different information depending on the type of practice, type of disorder seen or studied, characteristics of the patient or phenomenon observed, and the pace of new scientific discovery in the field. For NLM to enhance its products and resources, these factors, as well as the relationships between access to information and the quality of patient care and discovery in science, must be examined.

It is also important to recognize that many of NLM's users are from outside the United States. The Library's international programs not only extend access to NLM information services beyond U.S. borders, but they also make worldwide information available to U.S. users.[31]

Recommendations

2.2.1. Enhance GRATEFUL MED and develop other user cordial systems to facilitate direct access to biomedical information.

2.2.2. Explore the development of special knowledge-based systems to help information providers develop improved methods of information access.

2.2.3. Provide more systematic ways to refer requests for scientific information from individuals and organizations to the sources of relevant information.

2.2.4. Expand the existing document delivery system to provide more comprehensive resources and to make effective use of technologies such as telefacsimile, laser disk, and textual material in electronic form.

2.2.5. Provide an online index to special knowledge-based systems in biomedicine.

2.2.6. Encourage basic and applied research to identify health professionals' need for, access to, evaluation of and use of biomedical information, and where feasible, examine the relationship between access to information and the quality of patient care.

2.2.7. Provide assistance to other countries in identifying and gaining access to biomedical information in the U.S. Also assist U.S. health-care professionals in accessing information developed outside this country.

Goal 2.3:
Continue To Support The Training Of Medical Librarians And Other Information Specialists To Prepare Them To Adapt New Technologies To The Needs Of The Biomedical Community.

The evolving electronic environment will require medical information providers to develop new specialized knowledge, skills, and expertise. NLM should continue support as necessary to prepare information providers to adapt the new electronic storage and dissemination methods to the needs of the biomedical community. New prototype educational programs that emphasize integrated information concepts and the application of new technologies to information dissemination are necessary. Master's-level library and information science programs should be upgraded to provide the knowledge needed to develop and use automated libraries and data bases in biomedicine. Practicing information professionals need continuing education opportunities to upgrade their knowledge base.[32]

Recommendation

2.3.1. Institute new prototype programs containing special curricula in U.S. library and information science schools that emphasize integrated information concepts and the application of new technologies to information dissemination.

Goal 2.4:
Review The Public's Need For And Access To Health Information

Given the current emphasis on individuals assuming a stronger role in their own health care, and the shift in emphasis from disease treatment to prevention, the lay public's need for and access to health information should be reviewed. If feasible, NLM should apply limited resources to improving public access to health information.

There are many sources of health information for the lay public, including other agencies within the Department of Health and Human Services, other government agencies, professional societies, hospitals, and popular literature. Much of that literature takes the form of pamphlets and other publications for which bibliographic control is not easily achieved. Furthermore, it is often difficult to determine if the information provided is authoritative and current.

Recommendations

2.4.1. Study the current sources of health information for the public and the potential role for NLM in this area.

2.4.2. Augment DIRLINE (NLM's online directory) to provide a more complete directory of sources of health information for the lay public.

Budget

Estimates of resources needed to implement these recommendations are given in Chapter 4.

Domain 3:

Obtaining Factual Information From Data Bases

Factual data bases consist of structured knowledge that is acquired, processed, stored, and disseminated through automated electronic systems. Factual data base systems are "fact providers." They differ from bibliographic data bases, which are "fact locators," pointing to information found elsewhere. The differences between factual data bases and bibliographic data base systems are often substantial, including the methods used to construct the two types of files, the safeguards needed in choosing their content, the requirement for rigorous assessment of quality, and the desirability of repeated updating as new information replaces old. Large-scale factual data bases in computers are relatively new; the explosion of medical information and the technology to deal with it have come together only in the last 15 years.

The factual data base applications related to NLM's mission fall into three general classes: data bases for the protection of the public health and the environment, data bases providing information of special interest to research scientists in biomedicine, and data bases linked in some fashion to the provision of health care and the practice of the health professions. In addition, these data bases are often assembled to support expert systems or modeling systems. User-cordial linkages from factual data bases to such systems are becoming increasingly important resources in several areas of biomedicine.[33]

Data Bases For The Protection Of Public Health

The Library's commitment to factual data bases for the protection of the public health and the environment is exemplified by the TOXNET online toxicology information system.[34] The data bases in that system describe the effects of chemical substances on humans, other biological systems, and the environment. The number of chemicals that could pose a public health hazard is relatively small (less than 10,000) compared with the total number of known chemicals (over 7.5 million.) Consequently, substantial economies can be achieved, nationally and internationally, by collecting authoritative descriptions of the biological and environmental effects of hazardous chemicals in one central data base or in a few well-coordinated data base building and maintenance efforts. Dissemination of the resulting body of data can then take place through various public and private sector channels. To avoid duplication of expensive efforts, collaboration with other federal and state agencies through the sharing of funding and other resources—including intellectual resources—is particularly important.

Clearly NLM will not—and should not—be the sole provider of information about hazardous chemicals. However, the existence of multiple data bases, local as well as national and international, located on different computer systems and using different query systems, makes it difficult for even an experienced information specialist to access all the relevant online services.

The liability issues identified in connection with the provision of factual data base services in general are especially important here. Risk assessment and risk management decisions made on the basis of data provided by factual data base services in toxicology can have major impacts on human health, the environment, and the economy. The responsibility the Library carries for the accuracy and currency of the data in such data bases, therefore, is substantial. Conventional methods of content review to assure accuracy and currency are based on consensus of expert panels and are effective, but slow, cumbersome, and expensive. While the Library has made a good beginning in employing modern electronic measures—such as computer conferencing—for the peer review of data base content, technologies are available to enhance those methods even further.

Computer-based modeling that attempts to predict the biological activities of chemicals based on the known activities of structurally related chemicals can play an important role in developing data for risk assessment, synthesis of new pharmaceutical or agricultural products, and reduction in the number of animals needed for biological research and testing.[35] There is a need, therefore, to foster the development and operation of such modeling systems by ensuring that the content and structure of applicable data bases are suitably organized.

Increasingly, the Library's factual data bases in this category will be used by persons responsible for responding to emergencies involving hazardous chemicals. Under such conditions, emergency responders will need selected, simplified, or summarized effects and treatment data. It is likely that some responders will lack experience in computer searching and data manipulation. Therefore, highly user-cordial information systems will be required by all those using data for human and environmental protection from hazardous chemicals.

Biomedical Research Data Bases

The field of molecular biology is opening the door to an era of unprecedented understanding and control of life processes. Automated methods are now available to analyze and modify biologically important macromolecules. The effects of this research are already evident in clinical medicine. The prenatal diagnosis of blood disorders, such as thalassemia and sickle cell disease, has only recently been made possible through newly acquired genetic knowledge and the production of therapeutic agents, such as interferons and interleukins, depends on DNA and protein sequence information assembled in accessible data bases.

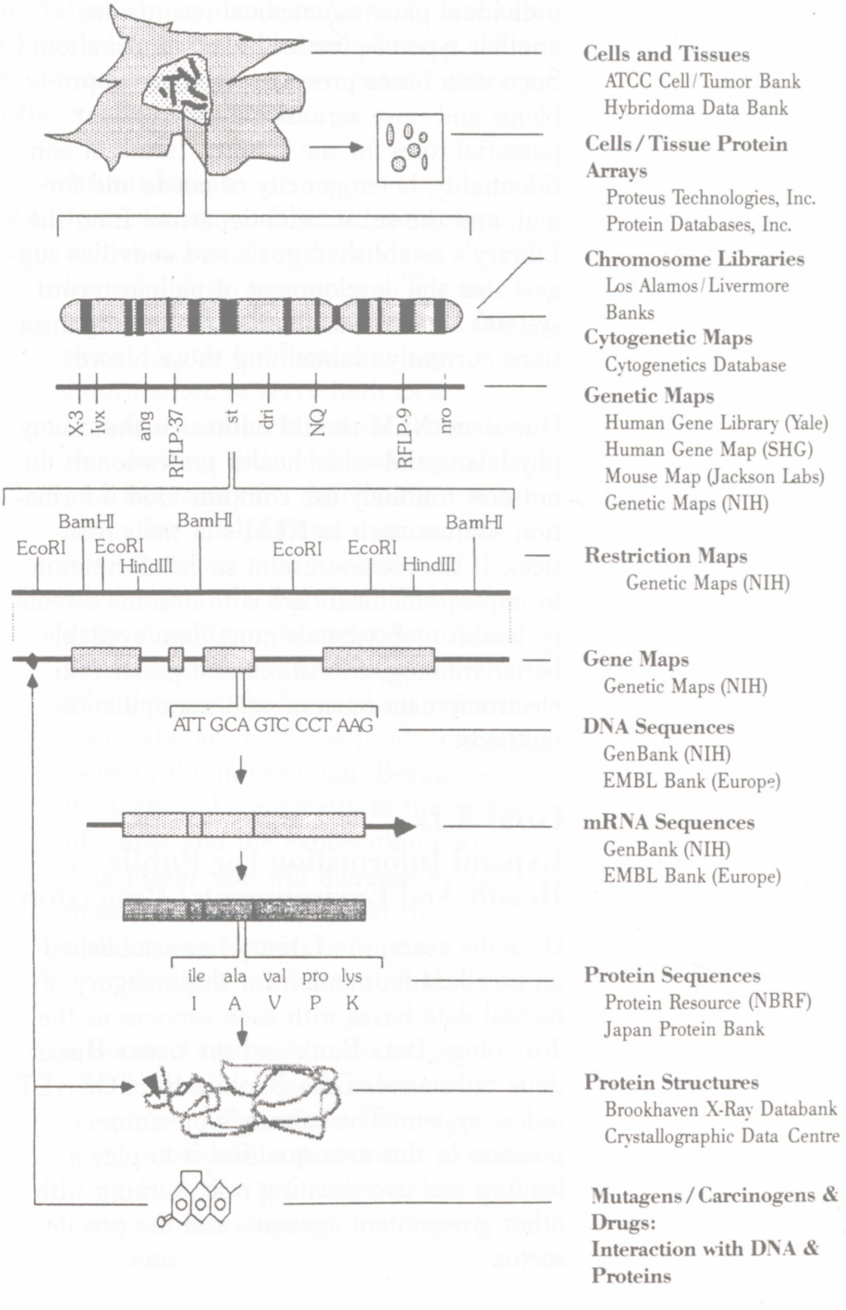
In molecular biology, factual data bases have become a necessity for scientific research.[36] Because of the complexity of biological systems (for example, the human genome is thought to be made up of 3 billion DNA base-pairs) basic research in the life sciences is increasingly dependent on automated tools to store and manipulate the large bodies of data describing the structure and function of important macromolecules.[37] Factual data bases have been developed to store data relating to each level of the natural hierarchy, from cells through successively smaller genetic units, to base-pair sequences.[38] However, the relatively isolated design of the various data bases contrasts sharply with current research activities in molecular biology, where an investigator will commonly report findings involving data at the cellular, chromosomal, gene, amino acid, and DNA sequence levels within a single scientific paper. Although the critical scientific questions being asked can often be answered only by relating one biological level to another, methods for automatically suggesting links across levels are non-existent.

Currently, no organization is taking the leadership to promote keys and standards by which the information from the related research data bases can be systematically interlinked or retrieved by investigators. The full potential of the rapidly expanding information base of molecular biology will be realized only if an organization with a public mandate such as the Library's takes the lead to coordinate and link related research data bases, and make them easily accessible to the U.S. and international research community.

Practice-linked Factual Data Bases

Health care professionals must have access to a vast and rapidly changing body of knowledge concerning the proper management of human illnesses. Traditional paper-based methods of information transfer in the health sciences are inadequate at present and will become more so in the future. Thus, providing authoritative information to help health-care professionals make decisions will become an increasingly important activity for government health agencies and professional societies.[39,40] Such information should be complemented, where appropriate, by appendiceal data files of selected pre-clinical and clinical research results. In addition to being useful repositories of facts for practitioners, factual data bases can also provide the basis for expert systems such as those developed experimentally for making diagnoses and determining treatment regimens in medicine.[41,42,43]

Biology Knowledge Bases



Biomedical Data Bases in a Universal Hierarchy of Nature: cells—chromosomes—genes—proteins.

Factual data bases containing all or part of individual patients' medical records are another type of practice-linked information. Such data bases present some special problems and raise serious questions about potential roles for the Library. Issues of confidentiality, heterogeneity of needs and format, and the substantial departure from the Library's established goals and activities suggest that the development of patient record systems be left with the health care organizations currently maintaining those records.

One issue NLM should address is that many physicians and other health professionals do not now routinely use computerized information sources such as NLM's in their practices. If the routine use of such information to improve medical care is to become a reality, health professionals must have available better training, education, and practice in electronic data retrieval and manipulation methods.

Goal 3.1:

Expand Information For Public Health And Environmental Protection

Over the years, the Library has established an excellent foundation for this category of factual data bases with such services as the Toxicology Data Bank and the newer Hazardous Substances Data Bank in the TOXNET online system. The Library's preeminent position in this area qualifies it to play a leading and coordinating role, working with other government agencies and the private sector.

The Library should accommodate public health needs as far as possible in data base content organization and in developing computer methodologies, including the use of artificial intelligence. Special attention should be given to tailoring data representation and retrieval to emergency and occupational safety applications. For such activities, NLM should be provided with the required resources—including guidance about requirements and close cooperation in implementation—by those agencies specifically charged with chemical emergency response and occupational health and safety. The Library should then actively try to share the resulting access and delivery methods with other interested agencies at all levels of government, including international organizations.

Recommendations

3.1.1. Continue the maintenance and enhancement of the Hazardous Substances Data Bank and the other factual data bases now provided through the TOXNET system. Ancillary factual data bases of particular utility for occupational safety and health should be acquired from other sources (both nationally and internationally) or built by the Library when required. Wherever possible, file building and enhancement costs should be shared with other federal agencies that have specific mandates in these areas.

3.1.2. Continue the mutually useful collaboration with the ATSDR (Agency for Toxic Substances and Disease Registry) on the information requirements of CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act, or Superfund) as reauthorized in 1986. The focus should be on preparation of extensive profiles of selected hazardous chemicals. NLM's work on the profiles should be compensated by CERCLA through ATSDR.

3.1.3. Take a national coordinating role for Federal and State activities in building and maintaining factual data bases on the biological and environmental effects of hazardous chemicals. Such coordination should lead to efficiencies making the resulting products more widely useful and cost effective.

3.1.4. Continue to develop gateway systems to facilitate access to and use of data about hazardous chemicals located in different public and private systems. Because such systems will be used in chemical emergency situations, partial support for their development should come through CERCLA.

3.1.5. Continue and increase its efforts to ensure the quality of its factual data bases through ongoing content review by subject experts. The Library should also research and develop ways of further improving the efficiency of this process, perhaps using electronic methods to eliminate the need for panel meetings altogether.

3.1.6. Support national and international modeling and analytical activities particularly as they pertain to relating biological activities to chemical structures. Toward that end, NLM should maintain relevant data bases and user-cordial gateways to existing modeling activities.

Goal 3.2:
Establish Information Services and Linkages For Biotechnology Information

A singular and immediate window of opportunity exists for the Library in the area of molecular biology information. Because of new automated laboratory methods, genetic and biochemical data are accumulating far faster than they can be assimilated into the scientific literature. The problems of scientific research in biotechnology are increasingly problems of information science. By applying its expertise in computer technologies to the work of understanding the structure and function of living cells on a molecular level, NLM can assist and hasten the Nation's entry into a remarkable new age of knowledge in the biological sciences. This should remain a high priority for the Library in the coming two decades.

Recommendations

3.2.1. Immediately establish an intramural and extramural program for biotechnology information. The intramural component should be a National Center for Biotechnology Information, to serve both as a repository and distribution center for this growing body of knowledge and as a laboratory for developing new information analysis and communications tools essential to continued advancement in this field. The program should emphasize collaboration between computer and information scientists and the biomedical researchers who are both the producers and users of the information. Because of the technical complexity in this scientific area and the expectation that data production will increase by a thousand times in the next five years, a major new activity is required. Specifically, the Library should:

- Conduct research in the areas of molecular biology data base representation, retrieval-linkages, and modeling systems while examining analytical interfaces based on algorithms, graphics, and expert systems.

- Provide repository, directory, and distribution services in the areas of data collection and quality control, as well as online data delivery through linked regional centers and distributed data base subsets.

- Develop and implement training workshops, information clearinghouse activities, and documentation programs.

3.2.2. Sponsor meetings that include a broad representation of the scientists responsible for designing and maintaining of current research-oriented, genetic factual data bases. The purpose of those meetings will be to develop a consensus regarding the best methods for information sharing and retrieval from related molecular biology data bases.

Goal 3.3: Support The Development Of Medical Practice-linked Data Bases

As the nation's health care practitioners become more familiar with the inherent advantages of computer-based data systems and more willing to use them, practice-linked factual data bases can be expected to become more numerous. Now is the time to begin a coordinated approach to designing and implementing those systems The work should be based on standards that make optimal use of the emerging technology and of the information contained in the data bases themselves.

The Library is best positioned to take a principal, coordinating role in this developing area because of its acknowledged leadership in the area of biomedical information and communications.[44] The Library's role should be to provide the system design team and technical expertise for other organizations that would be responsible for the content of the data bases. Because the program will place additional responsibilities on the Library without diminishing its traditional mandate, funding should be sought from new appropriations rather than reprogramming existing resources. Wherever feasible, program costs should be shared with the organizations responsible for data base content.

An important component of increasing the usefulness of such information sources will be research into the design and construction of full-text, natural language retrieval systems with visible links among related data bases.

Recommendations

3.3.1. Establish an intramural program capable of developing practice-linked data bases in collaboration with public and private health care agencies, including other institutes of the NIH. The program should promote factual data base standards; for example, the Unified Medical Language System.

Once established, the program's services should be actively promoted within the NIH and to the academic medical community. The Library should also develop models for sharing the development costs of new factual data bases and for ongoing cost reimbursement through licensing agreements with public agencies and private vendors.

3.3.2. Develop specialized pseudo-English or menu-driven interfaces for certain factual data bases. Initially, one practice-linked and one biomedical research data base should be chosen. The medical data base interface may, in fact, be subsumed by work on a Unified Medical Language System, and its development costs be viewed as an integral part of that effort.

3.3.3. Signify NLM's willingness to store and make available appendiceal data files of selected published research.

Budget

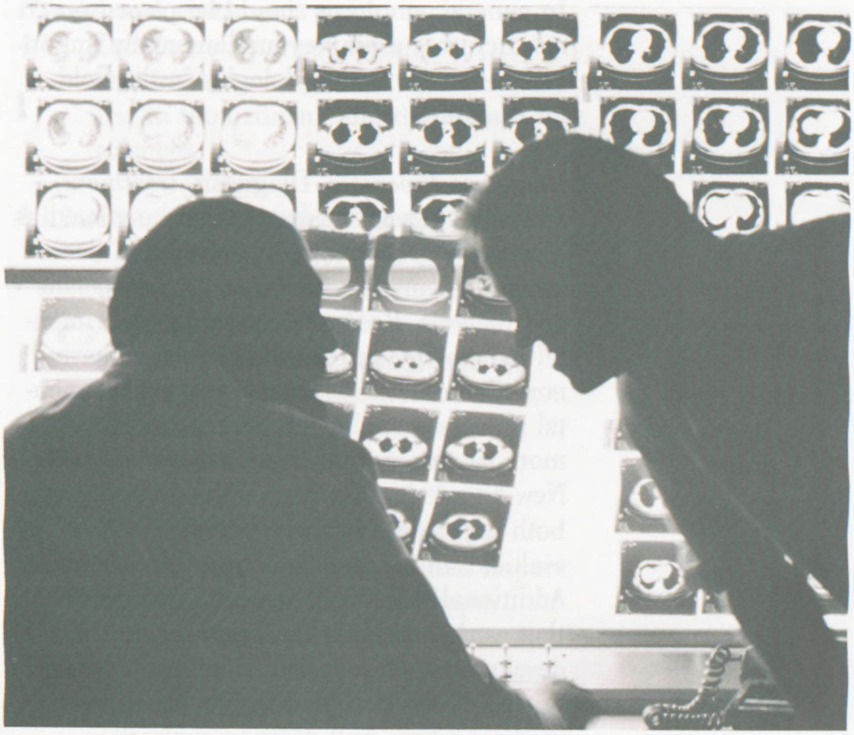
Estimates of resources needed to implement these recommendations are given in Chapter 4.

Domain 4:
Medical Informatics

Medical informatics attempts to provide the theoretical and scientific basis for the application of computer and automated information systems to biomedicine and health affairs. Inherently an interdisciplinary field, its practitioners and faculties currently come from the health professions, computer and information science, engineering, and management science.[45]

Medical informatics studies biomedical information, data, and knowledge—their storage, retrieval, and optimal use for problem-solving and decision making. It touches on all basic and applied fields in biomedical science and is closely tied to modern information technology, notably in the areas of computing and communication. The emergence of medical informatics as a new discipline is due in large part to advances in computing and communications technology, to an increasing awareness that the knowledge base of medicine is essentially unmanageable by traditional paper-based methods, and to a growing conviction that the process of expert decision making is as important to modern biomedicine as are the facts on which clinical decisions or research plans are made.[46]

Medical informatics is oriented toward the invention and dissemination of powerful information management tools. Those include frameworks for organizing and encoding medical knowledge, methods for acquiring and representing judgmental knowledge based on medical experience rather than formal studies, computer networks to permit efficient communication among health personnel, and systems to provide customized advice that give a practitioner access to expertise that might otherwise not be available when and where it is needed.



Processing information faster or more efficiently—which today's technology can easily accomplish—is not sufficient. More intelligent processing, logical aggregation of information, synthesis and analysis, and the development of knowledge systems that serve purposeful ends are needed. That is the fundamental task of medical informatics.

Goal 4.1:
Support Extramural Research on Information And Knowledge Structure In The Health Sciences

With funding and leadership provided by NIH and NLM, a community of researchers has been active for over two decades in wide-ranging applications of computers to medicine. This research has greatly advanced the capabilities of the computer as a research tool and medical decision support system and has laid the groundwork for the substantial work yet to be done. However, currently available funds for this purpose have left many highly rated research proposals approved, but unfunded.

In general, emphasis should be placed on research that examines fundamentally important issues and methodologies in the field, for example:

Cognitive Processes. Diagnosis, treatment, and management of disease can be viewed as a series of problems to be solved and decisions to be made—involving both clinicians and patients. Recent advances in experimental psychology and computer science have now made it possible to study complex mental processes of clinical decision making more rigorously than ever before imagined. New knowledge has been gained about how both expert and novice clinicians process, evaluate, and respond to clinical information. Additional research is needed to continue that work, especially as it pertains to the development of so-called "intelligent" computer systems designed to provide expert medical advice and decision support.

Medical Decision Making. Health care providers have a wealth of information available to them. The problem is picking from among the many options and making the right decision—the one that will result in the best treatment for the specific patient. Automated decision support systems that consider variables such as probable outcome, risk, cost efficiency, and patient satisfaction can be valuable tools for medical practitioners faced with hard choices. Further research into the development of such systems should address, among other things, decision making strategies; types and amount of clinical, experiential, and other data to be included; and factors influencing system acceptance and use by the medical community.

The Human-Machine Interface. Automated medical information systems ultimately involve a working relationship between a computer and a biomedical researcher or a medical decision maker. Interface research in medical informatics addresses that relationship, the interaction between human and machine. An interface mediates between the machine world (input/output devices, computer graphics, the mechanics of computer use) and the cognitive world (use modeling, natural language interaction, explanation.) Continued research into improving this connection is vital to ensuring that biomedical information users have the information they need, when they need it, in a form they can understand and use.

Knowledge Representation. Human beings and computers speak quite different languages when it comes to assimilating information. Each requires knowledge to be structured and depicted in specific ways before it can be processed and transmitted. Ideally, humans and computers should be able to function in their preferred states while communicating directly with each other at the same time. Ongoing research is required to identify a technology that can simultaneously translate between the two forms of biomedical knowledge representation.

Knowledge Acquisition. The central issue facing medical informatics today is how to structure and organize the vast amounts of knowledge being generated in biomedicine, how to store and retrieve that knowledge, and how to update and apply it—all in a timely, accurate, and cost-effective manner. A small number of true knowledge bases have been built manually through intensive interaction between subject matter experts and information system experts.[42,43,47,48] The first important steps have been taken with the development of automated methods for indexing and reorganizing knowledge bases.[49,50] Text understanding promises to speed up the process of knowledge acquisition for large, comprehensive knowledge bases.[51] Toward that end, a uniform system of medical terminology and language must be developed as well as standard formats for the collection and reporting of clinical and laboratory data.

Information Storage and Retrieval. If NLM's collection of biomedical literature were transferred to magnetic storage units today, over 4,000 disks would be required to contain it. And that does not include the enormous quantity of clinical and research data (images, instrument data, descriptions) generated each year. The problem for medical informatics is how to organize and structure this knowledge and retrieve it as needed in an efficient and cost effective fashion. As our knowledge continues to increase and computers come into more widespread use as information processers and managers, the problem can be expected to grow proportionately. What is needed are new approaches to the management of this information, especially more intelligent retrieval systems that will find information more discriminately.

Recommendations

4.1.1. Increase support of extramural research into knowledge structure and use in biomedicine and the health sciences.

4.1.2. Encourage research that addresses issues and methodologies of fundamental importance to medical information. Special emphasis research areas, NLM-sponsored conferences, program projects—all should be considered as possible mechanisms to achieve this goal.

4.1.3. Divide funding so that within five years each area of fundamental importance receives appropriate support.

Goal 4.2:
Strengthen Medical Informatics Research At NLM

In addition to its support of extramural research, NLM has devoted in-house resources, particularly from the Lister Hill National Center for Biomedical Communications, to research and development in medical informatics. A key activity is the development of the UMLS (Unified Medical Language System) recently initiated with special Congressional funding. When complete, the UMLS will provide a single logical path to the growing variety of machine-readable biomedical information.

The obstacle to progress in medicine presented by its bewildering and eclectic terminology has long been recognized; indeed, it has often been ridiculed. This problem is especially serious when combined with the linguistic shortcomings of existing automated information systems. Many lack knowledge even of misspellings and misstatements, pluralizations, common synonym forms, and standard abbreviations. The majority fail to understand the full contexts of queries, the use of colloquialisms, and technical jargon. All lack the human linguistic ability to understand homologies, metaphors, ellipses, and exemplars.

NLM's MeSH (Medical Subject Headings) thesaurus for cataloging and indexing the literature offers promise for the future, however. MeSH is systematic; it is controlled, yet evolves with changing times; and it has a responsible proprietor in NLM. Although MeSH was not designed to solve the linguistic problems of the biomedical field, it can serve as a starting point for UMLS.

The Unified Medical Language System project should be viewed as a major institutional initiative. This work should include fundamental research into methods for thesaurus construction, automatic linking of scientific and clinical vocabularies, methods for information retrieval in support of clinical decision-making and scientific discovery, and other appropriate basic and methodological research and development. The work should be conducted at NLM and in collaboration with appropriate scientific research and professional groups.

The Library should also continue its work on artificial intelligence systems for modeling medical expert decision making. Such systems, particularly in the fields of diagnosis and management, represent the current cutting edge of medical computer-science research. Rather than building the maximum number of expert systems, NLM's goal should be to remove obstacles from the creation and validation of such systems by the many relevant scientific and professional groups in the United States. Where possible, NLM should contribute as well to the evaluation of expert systems in real-world settings. The importance of this work will likely derive from the understanding it yields of fundamental processes rather than from its effect on the particular medical or scientific applications chosen for the experiments.

Having established automated systems for expert advice and decision support often proves less than satisfactory if their users must function in isolation. The inability of individual systems to communicate with one another is a frequently voiced problem reflected by complaints such as, 'the lab computer doesn't talk to the library computer.' To be most effective, automated information resources need to work together in ways that strengthen health care institutions and scientific collaboration.[52]

Excellent examples of partial solutions to this problem exist outside the health sciences. First, commercial computer time-sharing and electronic messaging systems and services already have met a warm reception from the business community. Even though the existing commercial systems lack features relevant to health care or biomedical research (privacy, large file transfer, data integrity, format conversions, image archiving, and high-resolution displays), they have already achieved much. For instance, they show that once the investment has been made to adopt electronic technology to business requirements, industrial and commercial processes are enhanced (made more economical and efficient) through electronic networking.

Recommendations

4.2.1 Continue development of the Unified Medical Language System by:

- Creating an internal research management team to participate in the research and to manage and coordinate extramural contributions.
- Providing for formal collaboration with appropriate extramural research groups.
- Establishing formal collaboration with appropriate medical and scientific professional associations.
- Announcing a special emphasis research grants program in areas relevant to the goals of the Unified Medical Language System. Seek to support up to eight investigator-initiated basic research projects at an average cost of $250,000 each.
- Reporting publicly on progress that enhances access to knowledge in the biomedical scientific literature.

4.2.2 Facilitate development and evaluation of expert systems by:

- Developing 2-6 expert systems at NLM.
- Encouraging strong interactions of these in-house research efforts with clinical collaborators as well as with appropriate extramural research teams.
- Seeking realistic test sites for one or more of these systems.
- Conducting research into methods of validating and evaluating the resulting systems.

4.2.3 Test a prototype national communications system for research in medical informatics by:

- Forming a management group within NLM focused on this experiment.
- Convening appropriate collaborative biomedical investigators and institutions from within the U.S.

- Providing a locus for discussion with private and industrial groups that might assist this development.
- Funding such developmental and evaluative work internally and extramurally as may legitimately contribute to testing the prototype.

4.2.4 Sponsor conferences, workshops, and symposia that advance thinking in domains of fundamental concern to the Library by:

- Strengthening existing arrangements to create or host regular public meetings.
- Creating a management system for choosing topics and schedules.
- Establishing a formal plan for such events to cover a two-year period, including a mechanism for evaluating the benefits and cost effectiveness of this strategy.

Goal 4.3:
Strengthen Competence In Medical Informatics in The Health Professions

The biomedical sciences and the health-care professions can best make use of current information services and the emerging advanced automated systems by becoming involved in their development and use. To play an active role and to choose wisely among possible developments will require a cadre of health professionals properly educated in medical informatics at a level sufficiently scholarly to match medical judgments with technical judgments.

Assistance is needed to strengthen the institutions that support such efforts. Departments, centers, and other academic units are needed to provide independent loci for scholarship and research at a number of selected institutions throughout the United States. Assistance is also needed to promote collaborative efforts among senior scholars in medical and computing fields.

The establishment of productive, stable centers of excellence conducting basic research and training in the fundamental problems of medical informatics is crucial to the growth of the field as a scientific discipline. This goal can be achieved only through commitment of national resources over a sustained period of time. The growth of the field, and of its potential contributions, has been impeded by past uncertainties of support. The field has also suffered from unrealistic expectations about the length of time needed to produce stable sources of basic support for top research and training institutions while permitting encouragement of focused centers in subareas of the medical informatics field.

An important goal for the Library for the next 10 years should be the establishment of centers of excellence in medical informatics at major academic health institutions. Each center of excellence should have a strong research emphasis and significant educational and training components. The centers should provide a leadership role in stimulating use of information technology and should develop a working relationship with the operational health-delivery system, practicing professionals from all health disciplines, and the health-science library community. The emphasis in all centers should be on academic activities.

There is also a growing need for research investigators in academic settings as well as in the rapidly enlarging medical informatics industry. Those who will seek to take their places as health-science faculty and to teach medical informatics in the professional and university setting must themselves have been qualified by appropriate pre- and post-doctoral education. Such special training is most easily provided by university-based research training projects with the appropriate special focus. Already supported in small numbers by NLM, such projects should be increased.

The Library should seek additional resources in order to expand its successful grant program for training in medical informatics. The training offered should be academic in character; support for vocational training should be sought from other sources. Training ought also to be offered at the Library on a short term basis or as an 'in-house' sabbatical for an academic year.

Recommendations

4.3.1. Strengthen institutional development of medical informatics within universities by:

- Initiating six centers of excellence in medical informatics as soon as possible through a competitive extramural grants program that would assure a minimum of five years support to grantees.

- Encouraging ongoing applications for center grants until there are 15 active centers at the end of 10 years.

4.3.2 Support research training and research career development for individuals in medical informatics by:

- Increasing immediately the number of NLM training programs in medical informatics from five to ten institutions.

- Gradually increasing the number of training grants, by an increment of approximately one per year, until 20 institutions are receiving support at the end of the next decade.

- Expanding support for young investigators through current programs for New Investigator Awards, and Research Career Development Awards.

4.3.3 Strengthen collaboration and scholarship at NLM by:

- Introducing a formal visiting scholar program that would bring medical informatics investigators and trainees to the Library for periods of 3, 6, or 12 months.

- Establishing stipends to support sabbaticals at NLM for up to five mid-career professionals.

Budget

Estimates of resources needed to implement these recommendations are given in Chapter 4.

Domain 5:

Assisting Health Professions Education Through Information Technology

Knowledge Base of Health Sciences

Within the last few decades, powerful forces have radically changed the scope and complexity of the health sciences and the delivery of health care. These forces are continuing to influence the shape of health care, adding to and altering the body of medical knowledge, changing the way health professionals practice their craft, and modifying the system of health care delivery.

It can be argued that we are at the beginning of a new age of health care. Recent advances in medicine—particularly in molecular and cell biology, immunology, and neurobiology—have opened new paths to preventive, diagnostic, and curative strategies of astonishing power and subtlety. Progress in the fields of dentistry, nursing, pharmacy, and other health professions has yielded new approaches to maintaining health and dealing with illness.

This explosion of knowledge—combined with the aging of the population, the shift from acute illness toward chronic disease, the emphasis on cost containment, the increasingly corporate nature of health care delivery, and the availability of information processing technology—is radically changing the way health professionals function today. These factors will surely alter even more radically the way health professionals of the twenty-first century practice.

One obvious effect of the expanded knowledge base is that any single individual can master only a decreasing fraction of the total spectrum of the available information. As a result, there has been a rapid growth in the number of health disciplines and of specialties within disciplines, yielding an increasingly fragmented clinical practice.

Education of Health Professionals

Despite major advances in the science and technology of health care, and despite the new challenges to health care, the education of health professionals remains grounded in the past. The methods used to train physicians, for example, are little different today from what they were a half century ago. For all of the health disciplines, the structure of education still primarily consists of lectures in which a procession of teachers relate large quantities of scientific material to a passive student audience.

Current methods of instruction in the health sciences cannot meet the challenge of the exponentially increasing flow of new discoveries. The explosion in medical knowledge has placed impossible time demands on the curriculum and has far outstripped the ability of our students to memorize the quantity and complexity of scientific knowledge. It is not practical to increase the duration of professional education; we should not encourage the increasing trend toward narrow specialization; and we cannot depend on continuing education to fill the gap.

Information Technology and Health Sciences Education

One valid response to the problem of information overload is to take advantage of information technology to facilitate learning and to provide easy access to appropriate information sources for the practicing health-care professional. Computer-based educational applications can help users acquire essential knowledge and master problem-solving skills. Comprehensive training and experience with modern methods of information management during the students' formative years will greatly enhance their effective functioning as health care practitioners and as professionals committed to life-long learning.

In emphasizing the importance of information technology in the education of the health professional, we recognize the inherent tension between the changing and unchangeable aspects of health care. Information technology has the potential to address the ever-changing and ever-broadening mass of knowledge concerning the etiology, prevention, and treatment of disease as well as the maintenance of health. This use of technology, however important, must not distract from the fundamental human aspect of care: the relationship of an individual health professional to an individual patient.

The role for information technology concerns content, but even more importantly, concerns the method of education. Students should be given fewer answers and more tools—tools for self-teaching and for synthesizing, framing, and revising knowledge.[53] They should have the opportunity to practice, from the earliest days of professional education, the skills of seeking out information, of testing hypotheses, and of solving problems. The underlying objective in the use of information technology in health sciences education is not so much transferring current information as it is providing an environment that encourages the student to become an independent learner, capable of understanding and applying the knowledge gained.

The use of information technology in health sciences education is not a new idea. Significant advances have occurred since the early applications of drill-and-practice computer-aided instruction of two decades ago. In the interval, a number of institutions have developed prototype projects for using information technology in health-sciences education.[54] Advances in the educational applications of information technology have been made possible by a number of factors. Among them are improved understanding of the learning process and of the potential roles for the use of computer technology, more detailed specification of the information requirements in the academic and clinical settings, more powerful tools for creating computer programs, and advances in technology—all undreamed of 20 years ago. As a result, there are now very useful applications that support bibliographic retrieval, education, information management, and clinical decision making.

Finally, computer-based personal knowledge management systems can combine and integrate a number of important information resources, including: support for recording clinical information during routine care; access to knowledge bases and continuing education programs; and routine quality assurance capabilities. Those personal knowledge systems will be simply extensions of the automated aids proposed for the new health science curricula. Then the concept of life-long learning and the true continuum of health-science education will move a step closer to realization.

Goal 5.1

Develop, Demonstrate, And Assess Educational Applications Of Computer Technology In Health Sciences Curricula

At least part of the answer to the problems created by overcrowded health sciences curricula may be automated information methods. Such automated systems have the potential to encourage independent learning by the student, to spare faculty from some teaching chores, and to prepare the student for lifelong learning. An early step toward this goal is to increase awareness about the value of educational technology. Health-sciences faculty and the administration of academic health centers need to see more examples of educational technology successfully incorporated into curricula like theirs.[25]

Educational applications of computer technology currently take many forms, from simple presentation of text material to complex simulations of biomedical phenomena. In the future, computer-based patient simulations will be used extensively to facilitate the student's acquisition of skills in clinical problem-solving; to help the student learn to deal with the inherent uncertainty, ambiguities, and contradictions in clinical data; and to challenge the student to learn how to collect and interpret data.[55] All of the computer-learning activities will be available to the student at any time and from the most convenient location, whether it be within or away from the institution.

The focus of health professional education will be on training students in problem-solving, critical thinking, and analytical skills—not on memorizing factual information. There will be an equal emphasis on helping the student gain experience in how to use technology for acquiring, storing, and managing information. The evaluation of student performance will use these automated systems to focus on problem-solving rather than short-term memory recall.

The educational technology goal implies not only better means of acquiring and using knowledge, but also better means of pinpointing the individual learner's needs. Computerized methods of self-assessment can reveal areas where the student needs special help and diagnostic remedial programs can provide it. The capacity of computers to store and access large bodies of information and to call into play multimedia materials, such as high-resolution graphic displays and computer-controlled videodisk presentations, will enable individualized instruction and self-assessment.

Recommendations

5.1.1. Support the development of promising, innovative forms of information technology applications (for class instruction, patient management simulations, self-assessment and testing, etc.).

5.1.2. Promote awareness of and access to computer-based educational resources by disseminating information about existing programs and through such means as the creation of demonstration centers where faculty may observe and use applications.

5.1.3. Support the testing of computer-based learning materials both to determine their efficacy and to determine their roles in the health science curricula.

Goal 5.2:

Develop And Evaluate Prototype Knowledge Management Systems For Use By Persons In Health Sciences

NLM should stimulate the development of functioning prototype knowledge management systems and make them available to selected users, gain experience with the use of those prototypes, and obtain feedback about problems, limitations, and needed capabilities. The systems should be designed to be used directly by health professionals in daily practice and should integrate routine clinical information processing with knowledge retrieval. They should include user-interface methods and tools to facilitate targeted knowledge retrieval, browsing, and decision support.

The Library should seek additional resources to permit funding of an extramural grants program that would focus on issues related to the development of a knowledge management system for use by individual health scientists. Special emphasis should be given to:

- Understanding the information-seeking behavior and needs of practicing health-care providers.[56]
- Recognizing the behavior involved in targeted, problem-solving knowledge retrieval versus that for browsing versus that for decision support.
- Developing alternative strategies for transforming health sciences information into 'electronic textbook' formats that incorporate mechanisms for content revision as needed.
- Addressing the problems of individual versus communal authorship.
- Delineating the software engineering considerations related to the computer storage and access of large and complex health science knowledge bases.

Recommendation

5.2.1. Develop an extramural grants, special initiative program for research, development, demonstration, and assessment of knowledge management systems for use by health science professionals.

Goal 5.3:

Evaluate Possible NLM Role As Reference Resource In Support Of Automated Systems For Enhancing Learning In The Health Sciences

It is clear that instruction in the health sciences curricula, whether by traditional methods or those incorporating information systems, will inevitably be accomplished by the schools and faculty themselves. The Library cannot and should not develop standard curricular materials for use by the educational institutions. Still, it can and should provide technical assistance in the form of prototype systems, new ideas or methods, or even devices.

Many health educators have expressed a strong interest in a registry or data base that lists and describes new automated instructional support systems. Despite past difficulties in developing such listings for educational audio-visual materials, NLM could make a major contribution by attaining even partial success for computer-based instructional materials.

In addition, visual images are central to a number of research projects attempting to provide educational assistance through optical and video disk technology, sometimes coupled with relatively sophisticated computer systems. Those projects have involved initial studies in histology, neuroanatomy, pathology, radiology, rheumatology, and dermatology. They have raised substantial questions concerning the lack of technical specifications for color fidelity, image resolution, effective indexing, rapid retrieval, and transmission or dissemination. If it proves possible and practical for NLM to serve as a library of biomedical images, continued research will be required to develop the necessary specifications. Toward that end, the Library should work closely with technical specialists, subject matter experts, and medical educators.

Recommendations

5.3.1. NLM should investigate the technical requirements for and feasibility of a registry or data base of computer-based health education materials.

5.3.2. NLM should thoroughly and systematically investigate the technical requirements for and feasibility of instituting a biomedical images library.

Budget

Estimates of resources needed to implement these recommendations are given in Chapter 4.

Resource and Budget Data

As noted in the Preface and Chapter 1, NLM has already gained much improvement in understanding of future requirements and opportunities through the year of intensive planning. Changes are already taking place in the direction of programs within current budgetary and personnel allocations. That is, NLM is already moving in the direction pointed to by this Report. Yet a number of the recommendations for achieving the Board's long range goals clearly are for advanced or expanded activities above and beyond NLM's current workload and commitments. Thus, while all are logical extensions of current activities, the majority will require additions to both NLM's fiscal appropriations and Full Time Equivalent personnel allocation in order to fulfill the responsibilities and opportunities identified in this plan.

The following budget tables present the Board's estimates of:

- Resources needed to implement individual recommendations within the five planning domains, projected over the next three years;
- Budgetary resources aggregated by domain;
- Effect of additional resources according to budget activities.

Additional Resources Needed to Implement Individual Recommendations
Domain 1: Building and Organizing The Library's Collection

(Dollars in Thousands)

Goals and Recommendations		Incremental Resources			
		FY 88	FY 89	FY 90	Personnel
1.1	**Continue as The "Library of Record" For Medicine and Related Sciences**				
1.1.1	Expand acquisition of appropriate electronic media and historically significant records of modern biomedical research and practice.	$195	$255	$275	1.5
1.1.2	Carry out the NLM preservation plan:				
	Preserve materials in the NLM collection;	700	1,100	1,100	2
	Coordinate a national preservation program for the biomedical literature held in other libraries and institutions;	1,000	1,000	1,000	0
	Research the preservation characteristics of new storage media;	350	350	350	2
	Encourage use of permanent materials.	100	100	100	1
	Subtotal:	$2,345	$2,805	$2,825	6.5
1.2	**Improve the Organization and Description of The Literature**				
1.2.1	Experiment with data from machine-readable publications in the cataloging and indexing processes.	$75	$75	$75	0.5
1.2.2	Investigate indexing the literature to cover signs, symptoms, procedures, research populations, clinical values, etc.	150	150	150	1
1.2.3	Experiment with artificial intelligence techniques and expert systems to improve cataloging and indexing.	175	200	225	2
1.2.4	Investigate including table of contents data in cataloging records.	75	75		0.5
1.2.5	Apply bibliometric techniques to the problem of selecting journals appropriate for indexing.	225	225	225	1
1.2.6	Support research into methods for producing useful summaries of knowledge in particular areas.	500	500	500	0
	Subtotal:	$1,200	$1,225	$1,175	5
1.3	**Adapt NLM Library-Methods to Accommodate New Electronic Forms of Information**				
1.3.1	Define and resolve issues raised by new electronic media.	$100	$100	$100	1
	Subtotal:	$100	$100	$100	1
	TOTAL DOMAIN 1:	$3,645	$4,130	$4,100	12.5

Additional Resources Needed to Implement Individual Recommendations
Domain 2: Locating and Gaining Access to Medical and Scientific Literature

(Dollars in Thousands)

		Incremental Resources			
	Goals and Recommendations	**FY 88**	**FY 89**	**FY 90**	**Personnel**
2.1	**Make Information More Accessible to Health Professionals**				
2.1.1	Enhance the RML network ensuring its ability to use new technologies.	$3,050	$3,050	$3,050	1
2.1.2	Support IAIMS planning, model development, and implementation efforts, and disseminate this information to other institutions.	2,000	3,000	4,000	0
2.1.3	Make research grants and contracts to develop intelligent interfaces for gateways to increase access to information.	500	500	500	0
2.1.4	Work cooperatively with selected data base producers to create linkages, reduce costs, and facilitate access.		no cost		
2.1.5	Develop an electronic gateway function to link relevant data bases.	2,250	3,250	4,250	5
	Subtotal:	$7,800	$9,800	$11,800	6
2.2	**Provide Enhanced Information Products and Services**				
2.2.1	Enhance GRATEFUL MED and develop other user-cordial systems.	$200	$200	$200	0
2.2.2	Explore development of knowledge-based systems for information providers.	250	250	250	1
2.2.3	Provide systematic reference referral linkages.	50	80	100	0
2.2.4	Expand document delivery system.	250	250	250	2
2.2.5	Develop online index to special knowledge-based systems.	100	40	40	0.5
2.2.6	Examine health professionals' need for, access to, and use of biomedical information; examine the relationship between access to information and patient care.	75	75	75	0
2.2.7	Promote the international exchange of biomedical information.	10	10	10	0
	Subtotal:	$935	$905	$925	3.5
2.3	**Support Training of Medical Librarians and Information Specialists**				
2.3.1	Support new programs to create special curricula.	$1,000	$1,000	$1,000	0
	Subtotal:	$1,000	$1,000	$1,000	0
2.4	**Review Public's Need For and Access To Health Information**				
2.4.1	Examine current sources of health information and NLM role in this area.	$100	0	0	0
2.4.2	Augment DIRLINE to provide a directory of public health information.	50	50	50	0.5
	Subtotal:	$150	$50	$50	0.5
	TOTAL DOMAIN 2:	$9,885	$11,755	$13,775	10.0

Domain 3: Obtaining Factual Information From Data Bases

(Dollars in Thousands)

Goals and Recommendations	Incremental Resources FY 88	FY 89	FY 90	Personnel
3.1 Expand Public Health and Environmental Data Bases				
3.1.1 Maintain and enhance the TOXNET data bases.	$700	$700	$700	5
3.1.2 Develop profiles for hazardous chemicals with ATDSR.	150	150	150	3
3.1.3 Assume coordinating role for building and maintaining data bases related to hazardous chemicals.	60	60	60	0.5
3.1.4 Continue to develop gateway systems to hazardous chemical data bases in public and private systems.	200	200	200	1
3.1.5 Increase review of NLM data bases by subject experts.	125	125	125	1
3.1.6 Support modeling activities which relate biological processes to chemical structures.	0	0	0	0
Subtotal:	$1,235	$1,235	$1,235	10.5
3.2 Establish Information Services and Linkages For Biotechnology Information				
3.2.1 Institute a program of biotechnology information services: Research data base representation for molecular biology, retrieval-linkages, modeling systems and interfaces based on algorithms, graphics and expert systems.	$5,000	$5,000	$5,000	14
Provide repository, directory, and distribution services.	4,000	4,000	4,000	14
Implement workshops, clearinghouse and documentation programs.	400	400	400	4
3.2.2 Sponsor consensus meetings on information sharing and retrieval from molecular biology data bases.	320	320	320	2
Subtotal:	$9,720	$9,720	$9,720	34
3.3 Support the Development of Medical Practice-Linked Data Bases				
3.3.1 Establish an intramural program capable of developing practice-linked data bases.	$1,500	$1,500	$1,500	5
3.3.2 Develop menu-driven interfaces between factual data bases.	Resources contained in 3.1 above			
3.3.3 Signify NLM's willingness to store and make available appendiceal data files of selected published research.	300	300	300	0
Subtotal:	$1,800	$1,800	$1,800	5
TOTAL DOMAIN 3:	$12,755	$12,755	$12,755	49.5

Additional Resources Needed to Implement Individual Recommendations
Domain 4: Medical Informatics

(Dollars in Thousands)

	Goals and Recommendations	Incremental Resources FY 88	FY 89	FY 90	Personnel
4.1	**Support Extramural Research on Information and Knowledge Structure**				
4.1.1	Increase support in information and knowledge structure.	$3,000	$6,000	$9,000	0
	Subtotal:	$3,000	$6,000	$9,000	0
4.2	**Strengthen Medical Informatics Research**				
4.2.1	Continue development of the Unified Medical Language System:				
	Create an internal research team.	$1,050	$1,050	$1,050	11
	Collaborate with extramural research groups.	1,000	1,000	1,000	0
	Collaborate with appropriate associations.	500	500	500	0
	Support investigator-initiated research projects.	2,000	2,300	2,645	0
4.2.2	Facilitate development and evaluation of expert systems.	2,300	4,300	6,300	6
4.2.3	Test a prototype communication system for medical informatics.	300	500	1,300	1
4.2.4	Sponsor conferences, workshops, and symposia.	250	250	250	0
	Subtotal:	$7,400	$9,900	$13,045	18
4.3	**Strengthen Competence in Medical Informatics in the Health Professions**				
4.3.1	Strengthen institutional development within universities by:				
	Immediately initiating six centers of excellence and,	$6,000	0	0	0
	Encouraging applications until there are 15 centers at the end of 10 years.	0	$7,000	$8,000	0
4.3.2	Support research training and career development through:				
	Increased funded training programs from 5 to 10 institutions.	1,250	1,250	1,250	0
	Increased training grants until 20 institutions are supported by the end of the next decade, and,	0	250	500	
	Increased support for:				
	New Investigator Awards	1,000	1,000	1,000	0
	Research Career Development Awards.	500	500	500	0
4.3.3	Strengthen collaboration and scholarship at NLM by:				
	Introducing a formal visiting scholar program.	150	150	150	3
	Supporting sabbaticals at NLM for up to 5 mid-career professionals.	150	150	150	0
	Subtotal:	$9,050	$10,300	$11,550	3
	TOTAL DOMAIN 4:	$19,450	$26,200	$33,595	21

Additional Resources Needed to Implement Individual Recommendations
Domain 5: Assisting Health Professions Education Through Information Technology

(Dollars in Thousands)

	Goals and Recommendations	Incremental Resources FY 88	FY 89	FY 90	Personnel
5.1	**Develop Educational Applications of Computer Technologies**				
5.1.1	Support development of information technology applications:				
	Intramural projects	$1,400	$1,400	$1,400	8
	Extramural projects	1,400	1,400	1,400	0
5.1.2	Promote awareness of computer educational resources:				
	Intramural projects	450	450	450	4
	Extramural projects	2,100	700	700	0
5.1.3	Support testing of computer-based learning materials.	1,000	500	500	0
	Subtotal:	$6,350	$4,450	$4,450	12
5.2	**Develop and Test Prototype Knowledge Management Systems**				
5.2.1	Develop an extramural grants, special initiative program for research and development, demonstration, and assessment.	$750	$900	$1,050	0
	Subtotal:	$750	$900	$1,050	0
5.3	**Evaluate NLM role as Resource in Support of Automated Systems**				
5.3.1	Investigate feasibility of a registry or data base of computer-based educational materials.	$250	0	0	0
5.3.2	Investigate the feasibility of establishing a biomedical images library at NLM.	0	$250	0	0
	Subtotal	$250	$250	0	0
	TOTAL, DOMAIN 5:	$7,350	$5,600	$5,500	12

Board of Regents Planning Budget for the National Library of Medicine FY 1986–FY 1990 by Domain

(Dollars in Thousands)

	1986 Actual			1987 Conference Allowance		
	Extramural	Intramural	Total	Extramural	Intramural	Total
Domains						
1: Building and Organizing the Library's Collection	$ —	$17,243	$17,243	$ —	$19,214	$19,214
2: Locating and Gaining Access to Medical and Scientific Literature	6,646	7,354	14,000	7,263	7,434	14,697
3: Obtaining Factual Information from Data Bases	357	2,540	2,897	400	3,437	3,837
4: Medical Informatics	5,251	3,250	8,501	6,567	3,680	10,247
5: Assisting Health Professions Education Through Information Technology	—	2,976	2,976	—	3,100	3,100
Subtotal	12,254	33,363	45,617	14,230	36,865	51,095
Research Management and Support						
Extramural Management			1,316			1,473
Program Management			4,090			4,376
Subtotal			5,406			5,849
NIH Management Fund			4,250			4,894
Total, NLM			$55,273			$61,838

Board of Regents Estimate

	1988			1989			1990		
	Extramural	Intramural	Total	Extramural	Intramural	Total	Extramural	Intramural	Total
Domains									
1: Building and Organizing the Library's Collection	$ —	$22,859	$22,859	$ —	$23,344	$23,344	$ —	$23,314	$23,314
2: Locating and Gaining Access to Medical and Scientific Literature	13,763	10,819	24,582	14,763	11,689	26,452	15,763	12,709	28,472
3: Obtaining Factual Information from Data Bases	400	16,192	16,592	400	16,192	16,592	400	16,192	16,592
4: Medical Informatics	20,467	9,230	29,697	25,017	11,430	36,447	29,612	14,230	43,842
5: Assisting Health Professions Education Through Information Technology	5,250	5,200	10,540	3,500	5,200	8,700	3,650	4,950	8,600
Subtotal	39,880	64,300	104,180	43,680	67,855	111,535	49,425	71,395	120,820
Research Management and Support									
Extramural Management			1,723			1,723			1,723
Program Management			4,526			4,526			4,526
Subtotal			6,249			6,249			6,249
NIH Management Fund			4,894			4,894			4,894
Total, NLM			$115,323			$122,678			$131,963

Board of Regents Planning Budget for the National Library of Medicine FY 1986–FY 1990 by Budget Activity

(Dollars in Thousands)

	1986 Actual	1987 Conference Allowance	*FTEs*	Board of Regents Estimate 1988	1989	1990	*FTEs*
Extramural Programs							
Medical Library Assistance	$7,530	$9,410		$22,410	$21,910	$23,310	
Medical Informatics	4,724	4,820	—	17,470	21,770	26,115	—
Subtotal	12,254	14,230		39,880	43,680	49,425	
Intramural Programs*							
Library Operations	25,384	27,791	*304*	33,746	35,076	36,041	*322*
Lister Hill Center	8,915	10,386	*78*	20,861	23,086	25,661	*120*
Toxicology Information Program	3,314	3,582	*31*	4,867	4,867	4,867	*42*
Biotechnology Information	—	—	—	9,720	9,720	9,720	*34*
Subtotal	37,613	41,759	*413*	69,194	72,749	76,289	*518*
Research Management and Support							
Extramural Management	1,316	1,473	*19*	1,723	1,723	1,723	*24*
Program Management	4,090	4,376	*72*	4,526	4,526	4,526	*75*
Subtotal	5,406	5,849	*91*	6,249	6,249	6,249	*99*
Total, NLM	$55,273	$61,838	*504*	$115,323	$122,678	$131,963	*617*

**Includes NIH Management Fund*

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In January, 1985 the Board of Regents of the National Library of Medicine resolved to develop a long range plan to guide the Library in wisely using its human, physical, and financial resources to fulfill its mission. The Board recognized the need for a well-formulated plan because of rapidly evolving information technology, continued growth in the literature of biomedicine, and the need to make informed choices of intermediate objectives that would lead NLM toward its strategic, long range goals. Not only would a good plan generate goals and checkpoints for management, actually a map of program directions, but it would also inform the various constituencies among the Library's users about the future it sought and could help to enlist their support in achieving that future.

At the Board's direction, a broadly based process was begun involving the participation of librarians, physicians, nurses, and other health professionals; biomedical scientists; computer scientists; and others whose interests are intertwined with the Library's. A total of 77 experts in various fields accepted invitations to serve on one of the five planning panels. Each panel addressed the future in one of the five domains that encompass NLM's current programs and activities. The domains, which provided the panels a framework for thinking about the future are:

1. Building and organizing the Library's collection
2. Locating and gaining access to medical and scientific literature
3. Obtaining factual information from data bases
4. Medical informatics
5. Assisting health professions education through information technology

The Library chose a planning model with three components. First, it incorporates a general, somewhat indistinct vision of the future 20 years from now in medicine, library and information science, and computer-communications technology. That environment cannot be forecast precisely, but we can speak of a "distant" goal. That goal is seen as a societal objective whose attainment involves many organizations and agencies. NLM has a major role to play in achieving the goal and must plan its part. Second, while the 20-year goals are indistinct, there are opportunities for and impediments to achieving them. The opportunities and impediments can be more clearly envisioned because they appear to lie roughly 10 years away. Third, the specific steps that should be taken to remove the impediments and take advantage of the opportunities should be programmed for 3 to 5 years.

The planning process also involved participation within the Library. The Director provided his version of the future in the form of a "Scenario: 2005," which was distributed to panel members and Library staff. NLM staff prepared background documents that reported NLM achievements in the five domains, and reviewed current planning. Senior NLM staff members also acted as resource persons to the planning panels.

At the end of the planning process, each panel formulated recommendations and priorities for future NLM programs and activities in the domain under its purview. The five panel reports were reviewed by the Board of Regents in June 1986. The Board then asked the NLM staff to analyze and reconcile their findings, eliminating any duplications and consolidating the recommendations. Together with the planning panel reports, this synthesized plan presents the official Long Range Plan of the Board of Regents of the National Library of Medicine.

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