Computerized Bibliographic Services for Biomedicine

Library-based automated storage, retrieval, and publication of literature citations is feasible.

Leonard Karel, Charles J. Austin, Martin M. Cummings

The recording of medical knowledge dates back to the 3rd millennium B.C., when prescriptions of various drugs and other methods of dealing with diseases were written on Sumerian tablets and Egyptian papyri. Among the earliest evidence of logical classification of such records is the catalog of hieratical books graven on one of the walls of the ancient Egyptian library at Edfu (*1*).

Centuries elapsed before private collecting of books led to the establishment of public libraries, and before the ever-increasing volume of literature led to the establishment of specialized scientific and medical libraries. The National Library of Medicine (Fig. 1), at present the largest medical library in the United States and one of the largest in the world devoted to the biomedical sciences, had its origin in 1836 with the formation of the Library of the Surgeon General's Office, United States Army.

Price has stated (*2*) that both the number of scientific periodicals and the number of papers in them have increased tenfold every half century, beginning with 1750, when there were about ten scientific journals in the world. The biomedical literature has followed this trend.

Bearing on this growth is the rapid increase throughout the world of persons involved in medical and health-related activities. Indeed, in the United States alone, the number of people engaged in health professions multiplied by a factor of 5.8 between 1900 and 1960 (*3*), while the total population multiplied by a factor of only 2.4 (*4*).

The phenomenal increase in the volume of biomedical literature and in the numbers of contributors and users has not, however, been paralleled by equivalent growth of medical libraries. This lack of parallel growth of medical libraries and of information storage and retrieval methods and facilities adequate for today's needs has led to serious inadequacies in the capability of libraries to catalog, index, store, and retrieve published literature for the use of scientists, physicians, and others (*5, 6*).

The computer has been seized upon as a new means of assisting and supplementing the traditional library approach to management of the published literature. At the National Library of Medicine the computer has been successfully used for retrieval of reference material, and this success portends an exciting future for the entire field of information retrieval.

History of Bibliographic Control

The first comprehensive index of medical journal literature was the *Index Medicus* published by the Library from 1879 to 1927. Replaced from 1927 to 1956 by *Quarterly Cumulative Index Medicus*, published by the American Medical Association, *Index Medicus* reappeared as a monthly library publication in 1960, superseding the monthly *Current List of Medical Literature*.

The *Current List of Medical Literature* was prepared manually by typing citations on 7½- by 12½-centimeter cards, which were then mounted on a large panel for photographing. This laborious process was replaced in 1960 by a partially mechanized system. In this system special paper-tape typewriters were used to imprint citations on tabulating cards; these were then machine-sorted and automatically photographed, by a Listomatic camera, on rolls of film. The developed film was cut and assembled into pages for printing.

This partially mechanized system, although better than manual techniques for preparing *Index Medicus*, could not meet demands for quick retrieval of citations from the rapidly expanding biomedical literature. To provide better control of this literature (*7*), the National Library of Medicine in 1961 developed specifications for a computer-oriented information storage and retrieval system, which it called MEDLARS (Medical Literature Analysis and Retrieval System) (*8*). The objectives of this system were as follows.

1) To improve the quality of *Index Medicus* while increasing the number of journals indexed in it.

2) To reduce the time required for preparing the monthly editions of *Index Medicus*.

3) To provide for increased depth of indexing.

4) To provide for the production of compilations similar to *Index Medicus* in form and content but devoted to specialized subject fields.

5) To provide for prompt and efficient searching of a large computer store of information for citations to biomedical and biomedically related literature.

6) To reduce duplication of literature-screening activities carried on by academic and other institutions and organizations in the United States.

7) To provide for the incorporation of monographs and other nonjournal literature into MEDLARS (*9*).

The system design was completed in January 1962. The preparation of computer programs, installation of equipment, training of personnel, and detailed system testing took approximately 2 years. The new system went into operation in January 1964.

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Description of the System

MEDLARS has three major subdivisions (see Fig. 2): (i) an input subsystem in which the skills of professional indexers are used in connection with the capabilities of a large-scale digital computer; (ii) a retrieval subsystem in which the capabilities of professional literature searchers are used in connection with computer manipulations; and (iii) a publication subsystem that converts retrieved citations, and descriptors characterizing these citations, into photopositive film.

Input subsystem. Through the input subsystem, citations and other information are fed into MEDLARS. In the initial step toward storage of information, journals are analyzed by intensively trained literature analysts who assign to each article appropriate descriptors from the Library's controlled vocabulary, called "Medical Subject Headings."

After the journal articles have been indexed, Flexowriter typewriter operators prepare basic-unit records by converting information on the indexers' data sheets to codes on paper tape. The basic-unit record entering the computer consists of journal reference, article title, authors, and subject descriptors. Typewriter copy produced concurrently with the coded paper tape is checked for accuracy by a staff of proofreaders; then the tapes are spliced in batches and fed into the computer.

Through the computer's input programs, the information on the paper tape is recorded on reels of magnetic tape, edited, and incorporated into two major data files—the Compressed Citation File and the Processed Citation File. The Compressed Citation File contains highly coded citations that can be retrieved as "demand bibliographies"—that is, bibliographies intended not for publication but for individual use of the requester, and providing references on highly specific subjects (see Fig. 3). The Processed Citation File on the other hand, contains citations used in publishing *Index Medicus* and other "recurring bibliographies"—that is, bibliographies intended for serial publication and wide dissemination (see Figs. 4 and 5).

Retrieval subsystem. Through the retrieval subsystem, citations stored in the computer are recovered. Requests for bibliographic citations from physicians, scientists, librarians, and others are forwarded to a staff of specialists with extensive training in indexing and in the logic of computer searching. These search specialists analyze the requests, enumerate the relevant search elements, and formulate search statements linking these elements logically. Formulated statements designed to retrieve demand bibliographies are punched into paper tape and fed into the computer. Formulated requests for recurring bibliographies are punched into cards rather than paper tape. The retrieved citations, machine-edited and sorted, are recorded on magnetic tape and decoded into natural language prior to being printed, either on cards or on continuous tabulating paper, by the computer printer.

Publication subsystem. The publication subsystem (see Fig. 2) provides recurring bibliographies by processing citations for eventual printing from photopositive film. The magnetic-tape files of retrieved citations are used for preparation of print copy by a computer-driven phototypesetter called GRACE, an acronym for Graphic Arts Composing Equipment. GRACE is also used occasionally for preparing demand bibliographies.

Operating at a speed of about 300 characters per second, GRACE can use 226 different characters in preparing 23-centimeter-wide positive photographic film or paper. Character sets include a 6-point font of regular and bold-faced upper- and lower-case characters, a 10-point font of upper-case characters only, and a 14-point font of upper-case characters only. The exposed film is developed by an automatic film processor, inspected, and cut into page-sized sheets (see Figs. 4 and 5).

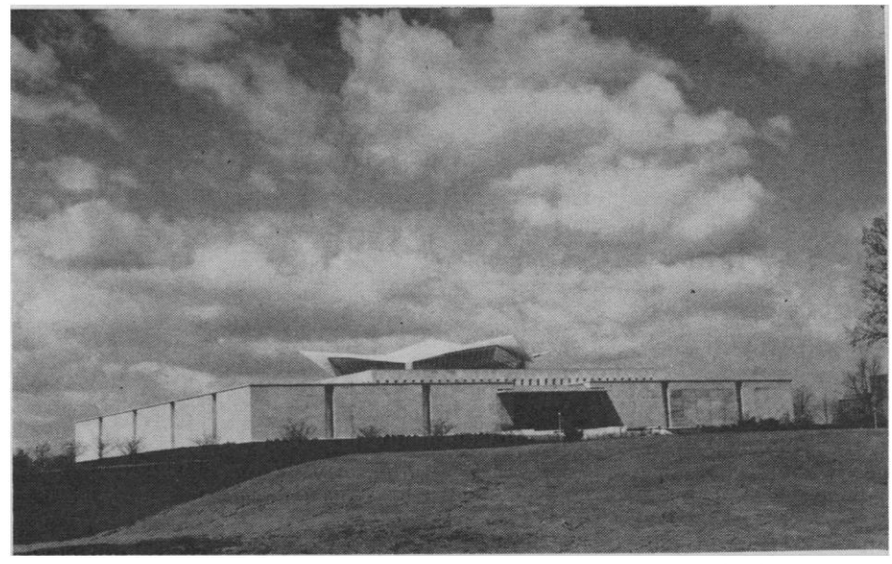


Fig. 1. The National Library of Medicine, Bethesda, Maryland.

Man-Machine Relationships

Because MEDLARS is a man-machine system, its success is directly dependent on the "intellectual input." Such input is provided by several kinds of specialists.

Specialists in medical subject headings are responsible for formulating the controlled vocabulary basic to consistent, efficient, and accurate analysis, indexing, and searching of biomedical literature. This controlled vocabulary, known as "Medical Subject Headings," is the dictionary to *Index Medicus* and its related publications. It is the key to retrieval of information for recurring and for demand bibliographies, and the base for most of the computer programs. Not only does it provide descriptors for indexing and for retrieving citations to the biomedical literature stored in the computer, it also provides descriptors for cataloging books and for preparing the public card catalog used at the National Library of Medicine and elsewhere.

The controlled-vocabulary list is developed from recommendations made by (i) trained professionals engaged in indexing and in searching the biomedical literature, (ii) users of *Index Medicus* and MEDLARS, and (iii) advisory panels composed of physicians, biomedical scientists, and other health specialists. Prior to its acceptance or rejection, a recommended medical subject heading is examined for potential usefulness, possible ambiguity, synonymity with existing controlled-vocabulary terms, and compatibility with subject headings in vocabularies of other organizations concerned with biomedical literature. Collaboration on development of subject headings is maintained with the American Medical Association, the American Dental Association, the American Rheumatism Association, and a number of other groups.

The 1965 edition of "Medical Subject Headings," published as part 2 of the January 1965 issue of *Index Medicus*, contains over 6300 subject headings, arranged in two sections: alphabetically with cross references, and in subject categories.

Despite the number of subject headings in the controlled vocabulary, there is still a deficiency of descriptors for categories such as psychiatry-psychology, public health, epidemiology, and environmental health, and these categories are currently being reexamined. Furthermore, because of increasing interdisciplinary research, demands are growing for development of more research-oriented descriptors; for development of descriptors in biophysics, biomathematics, veterinary medicine, and the social and behavioral sciences, among others; and for greater hierarchical structuring among the individual categories of headings. Activities to meet these needs are now in progress.

Other specialists engaged in preparing input for the computer are the indexers. Using the "Medical Subject Headings" list as a guide for accuracy, consistency, and specificity, trained indexers assign to each journal article those medical headings which best describe its subject content and ideas.

The magnitude and significance of the indexers' task may be seen from the fact that 152,030 articles were indexed in 1964, and that the library's Indexing Section plans to index 300,000 articles annually by 1970. Worldwide surveys have shown that some 15,000 biomedical and related serial publications are published annually (*10*). Of these, 6000 serial publications, containing over 300,000 articles annually, are regarded as worthy of being indexed by the National Library of Medicine. The magnitude and significance of the indexers' task may be further seen from the various publications that are dependent on indexing—*Index Medicus, Bibliography of Medical Reviews*, and a number of specialized bibliographies.

Preparation of the basic publication, *Index Medicus*, is a demanding and difficult task. In 1961 an average monthly issue of *Index Medicus* had 450 pages and contained references to more than 10,000 articles. The January 1965 issue of *Index Medicus* had 691 pages, cited 14,665 articles, and, in addition, contained two special features—(i) the latest revision of "Medical Subject Headings" and (ii) the "List of Journals Indexed in *Index Medicus*," giving the titles of the 2472 journals then indexed by the library. In 1961 the annual total of articles indexed was 132,154; in 1964 it was 152,030. In 1961, 12,661 journal issues were indexed; in 1964, the figure rose to 15,497.

Decisions on the inclusion of new journals or the omission of journals previously listed are made with the assistance of an advisory committee of medical librarians, physicians, and biomedical scientists. This committee also assists the library in establishing indexing policies.

Beginning with the March 1965 issue, *Index Medicus* contains a monthly "Bibliography of Medical Reviews."

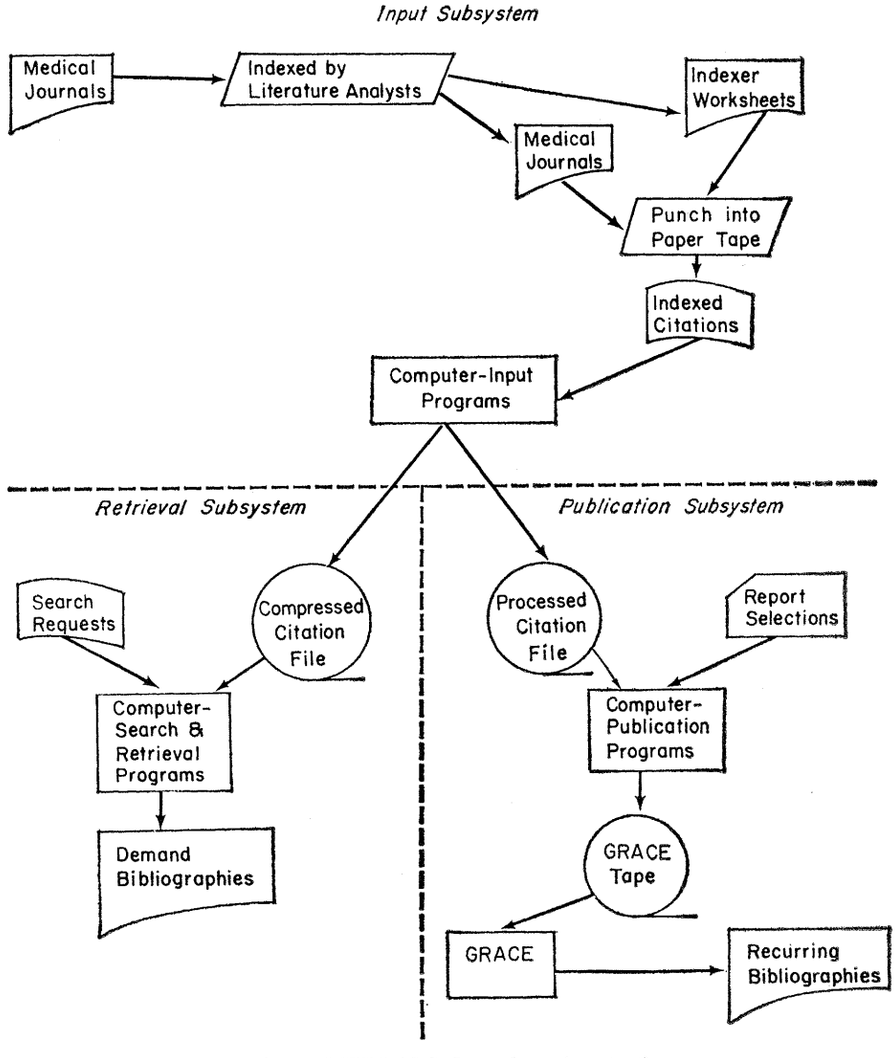


Fig. 2. MEDLARS flow chart (see text).

The March 1965 bibliography consists of selected articles indexed in the January, February, and March issues of *Index Medicus*. In subsequent months the bibliography will cite articles indexed in the current month's *Index Medicus*. As in the past, a *Bibliography of Medical Reviews* will be cumulated annually and published as a separate volume.

The annual *Bibliography of Medical Reviews* now being assembled will contain references selected from over 2400 journals regularly indexed in *Index Medicus* and from 539 journals not regularly indexed. Volume 10, a cumulation of review articles cited in 1964, contains references to 4270 articles taken from 2300 regularly indexed journals and 240 articles from other journals.

Still other specialists whose skills are used in connection with the computer are the searchers. After journal articles have been indexed and the citations have been fed into the computer, trained searchers formulate subject statements necessary for retrieving those citations that satisfy inquiries received from clinicians, scientists, teachers, and librarians.

References retrieved by computer search may be organized in various formats and printed. If desired, all subject headings assigned by an indexer to a given citation can be printed with the citation, thus providing a profile that aids the requester in judging the appropriateness of the citations retrieved (see Fig. 3).

Representative of recurring bibliographies are *Index Medicus* and *Bibliography of Medical Reviews*, both published by the Library; *Cerebrovascular Bibliography*, published by the National Institute of Neurological Diseases and Blindness and the National Heart Institute; and *Index of Rheumatology*, published by the American Rheumatism Association. Recurring bibliographies in various formative stages are "Index to Dental Literature" and bibliographies relative to fibrinolysis and thrombolysis, sudden death in infants and children, smoking and health, drug-induced abnormalities, and venereal diseases.

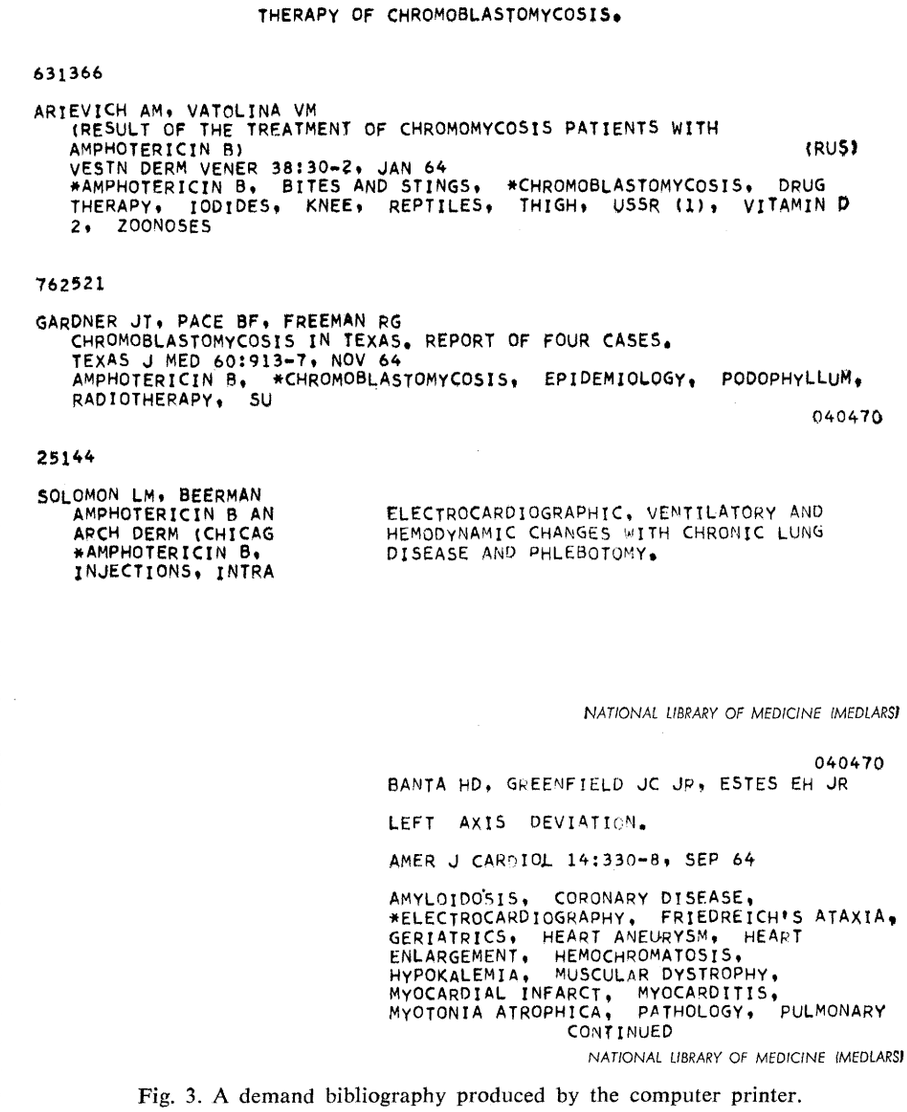
Of special interest is the *Index of Rheumatology*. As a result of cooperation between the American Rheumatism Association and the National Library of Medicine, this index is now being produced semimonthly by the library and published by the association (*11*). Expected to provide over 6000 citations annually from the periodicals now indexed by the library, the index is the first regular subscription bibliography, aside from the library's own publications, to be fully attributable to MEDLARS (see Fig. 5).

First Year's Experience

Of particular significance is the practical experience gained in the first year of MEDLARS' operation. Despite imperfections in the controlled-vocabulary list, need for improvements in indexing practices and techniques, and some retrieval difficulties imposed by these deficiencies, the results have been most heartening. Experience gained from more than 1300 searches made for physicians, scientists, teachers, librarians, and others has established the practicability of MEDLARS beyond question.

Appreciating that there is as yet no wholly satisfactory method of objectively evaluating the effectiveness of information storage and retrieval systems, the library has relied heavily on consumer reaction and appraisal. Evaluation of critical reports indicates that the percentage of missed entries is minimal; furthermore, the relevance of retrieved citations, as determined by the individual requesters' evaluation of demand bibliographies, appears to be satisfactory. New and more precise measurements of relevance are under study.

In some appraisals of demand bibliographies the inclusion of papers of



THERAPY OF CHROMOBLASTOMYCOSIS.

631366

ARIEVICH AM, VATOLINA VM
(RESULT OF THE TREATMENT OF CHROMOMYCOSIS PATIENTS WITH AMPHOTERICIN B) (RUS)
VESTN DERM VENER 38:30-2, JAN 64
*AMPHOTERICIN B, BITES AND STINGS, *CHROMOBLASTOMYCOSIS, DRUG THERAPY, IODIDES, KNEE, REPTILES, THIGH, USSR (1), VITAMIN D 2, ZOONOSES

762521

GARDNER JT, PACE BF, FREEMAN RG
CHROMOBLASTOMYCOSIS IN TEXAS, REPORT OF FOUR CASES,
TEXAS J MED 60:913-7, NOV 64
AMPHOTERICIN B, *CHROMOBLASTOMYCOSIS, EPIDEMIOLOGY, PODOPHYLLUM, RADIOTHERAPY, SU
040470

25144

SOLOMON LM, BEERMAN
AMPHOTERICIN B AN
ARCH DERM (CHICAG
*AMPHOTERICIN B,
INJECTIONS, INTRA

ELECTROCARDIOGRAPHIC, VENTILATORY AND HEMODYNAMIC CHANGES WITH CHRONIC LUNG DISEASE AND PHLEBOTOMY.

NATIONAL LIBRARY OF MEDICINE (MEDLARS)

040470
BANTA HD, GREENFIELD JC JR, ESTES EH JR

LEFT AXIS DEVIATION.

AMER J CARDIOL 14:330-8, SEP 64

AMYLOIDOSIS, CORONARY DISEASE, *ELECTROCARDIOGRAPHY, FRIEDREICH'S ATAXIA, GERIATRICS, HEART ANEURYSM, HEART ENLARGEMENT, HEMOCHROMATOSIS, HYPOKALEMIA, MUSCULAR DYSTROPHY, MYOCARDIAL INFARCT, MYOCARDITIS, MYOTONIA ATROPHICA, PATHOLOGY, PULMONARY
CONTINUED

NATIONAL LIBRARY OF MEDICINE (MEDLARS)

Fig. 3. A demand bibliography produced by the computer printer.

observed by difference spectrophotometry. Inada Y, et al. **Arch Biochem** 106:326-32, 20 Jul 64
Light-induced pH changes related phosphorylation by chloroplasts. Neumann J, et al. **Arch Biochem** 107:109-19, Jul 64
Kinetics of the hydrolysis of benzoylglycine ethyl ester catalyzed by papain. Sluyterman LA. **Biochim Biophys Acta** 85:305-15, 4 May 64
Effect of pH on extraction and activity of ox-kidney urate oxidase. Truscoe R, et al. **Biochim Biophys Acta** 89:179-82, 8 Jul 64
A discussion of the pH dependence of the hydrogen-deuterium exchange of proteins. Hvidt A. **C R Lab Carlsberg** 34:299-317, 1964
Intracellular pH of rat atrial muscle fibers measured by glass micropipette electrodes. Lavallée M. **Circ Res** 15:185-93, Sep 64
Observations on pH and haemolytic complement. Ibe EC, et al. **Immunology** 7:586-94, Sep 64
Effect of environmental CO2 and pH on glycerol metabolism by rat liver in vitro. Longmore WJ, et al. **J Biol Chem** 239:1700-4, Jun 64
Discrimination between alkali metal cations by yeast. I. Effect of pH on uptake. Armstrong WM, et al. **J Gen Physiol** 48:61-71, Sep 64
Relation of pH to preservative effectiveness. II. Neutral and basic media. Wickliffe B, et al. **J Pharm Sci** 53:769-73, Jul 64
The validity of pH and Pco2 measurements in capillary samples in sick and healthy newborn infants. Gandy G, et al. **Pediatrics** 34:192-7, Aug 64
[Acid-base equilibrium in acute experimental carbon monoxide poisoning] Marchiaro G, et al. **Rass Med Industr** 33:452-3, May-Aug 64 **(It)**

HYDROGEN PEROXIDE (D1, D3)

Generation of hydrogen peroxide in erythrocytes by hemolytic agents. Cohen G, et al. **Biochemistry (Wash)** 3:895-900, Jul 64
Generation of hydrogen peroxide during the reaction of nitrate with oxyhemoglobin. Cohen G, et al. **Biochemistry (Wash)** 3:901-3, Jul 64
Studies on the bioluminescence of Balanoglossus biminiensis extracts. 3. A kinetic comparison of luminescent and nonluminescent peroxidation reactions and a proposed mechanism for peroxidase action. Dure LS, et al. **J Biol Chem** 239:2351-9, Jul 64
Fluorometric study of antihistamines. Jensen RE, et al. **J Pharm Sci** 53:835-7, Jul 64
Preferential localization of radioisotopes in malignant tissue by regional oxygenation. Finney JW, et al. **Nature (London)** 202:1172-3, 20 Jun 64
[Enzymatic beta substitution of phosphoserine and cysteine by sulfite. Some remarks on the mechanism of beta substitution in the presence of pyridoxal phosphate enzymes] Fromageot P, et al. **J Biochem (Tokyo)** 55:659-68, Jun 64 **(Fr)**

HYDRONEPHROSIS (C6)

Experimental renal erythrocytosis; role of the juxtaglomerular apparatus. Mitus WJ, et al. **Arch Path (Chicago)** 78:658-64, Dec 64
The natural history of primary pelvic hydronephrosis. Roberts JB, et al. **Brit J Surg** 51:759-62, Oct 64
Multicystic and cystic dysplastic kidneys. Pathak IG, et al. **Brit J Urol** 36:318-31, Sep 64
Results of treatment of hydronephrosis. Balfour J, et al. **J Urol** 92:188-91, Sep 64
Solitary adenoma with hydronephrotic atrophy: xanthomatous papillary adenoma. Deniz E, et al. **J Urol** 92:263-6, Oct 64
The abdominal mass in infancy and childhood. **Urol Survey** 14:183-91, Oct 64
[Plastic operation (Boari-Küss) on the urinary bladder: technic, indications, results] Deuticke P, et al. **Urol Int** 18:100-12, 1964 **(Ger)**
[Rare complication following vesicovaginal fistula surgery] Pogorelko IP, et al. **Akush Ginek (Sofiia)** 40:127, May-Jun 64 **(Rus)**

HYDROPHTHALMOS (C11, C16)

[Tubular dysfunction and oculo-cerebral syndrome. Description of a new variety] Denys P, et al. **Bull Acad Roy Med Belg** 4:485-511, 1964 **(Fr)**

HYDROXAMIC ACID (D2)

Selective modification of uridine and guanosine. Kochetkov NK, et al. **Biochim Biophys Acta** 87:515-8, 22 Jul 64
Reactions catalyzed by amidases. Acetamidase. Jakoby WB, et al. **J Biol Chem** 239:1978-82, Jun 64

HYDROXIDES (D1, D8)

The solubility of heavy metal hydroxides in water, sewage and sewage sludge. I. The solubility of some metal hydroxides. Jenkins SH, et al. **Air Water Pollut** 8:537-56, Oct 64
[On the effect of gamma-aluminum hydroxide and gamma-aluminum oxide on the antigenic activity of

Fig. 4. Part of a page of *Index Medicus* printed from film produced by GRACE (see text).

inferior quality among the citations has been criticized. Since evaluation of literature for quality is not part of the indexing function of the library, this criticism cannot be met. Other criticisms relate to the library's present inability to store and retrieve references from monographs, books, abstracts, and other nonjournal publications. The library is attempting to acquire sufficient personnel to expand its coverage to include books and monographs in its automated system.

For the library to try to index all of the world's substantive biomedical literature in the depth required by specialized information centers seems impracticable. It is the library's intent, therefore, to avoid unnecessary duplication by supplying specialized information centers with relevant bibliographies on magnetic tapes. It is hoped that these centers will then analyze and refine the material in the light of their specialized requirements. Already, cooperative arrangements involving the library and several universities have been made to test this concept.

Because MEDLARS was designed to serve three purposes—to provide demand bibliographies, recurring bibliographies, and high-speed printing—it is likely to prove more economical and more utilitarian than a system designed to serve a single function. Also, its location in a research library increases the efficiency of the system, since the library can provide original documents or photocopies of the articles required by the user, and traditional reference services are available to supplement the services of the computer system.

Research and Development

The library realizes that MEDLARS is only an initial response to the need for improved documentation technology directed toward better biomedical communication and modernization of library techniques. It is in this spirit that the following activities have been planned for implementation within the near future.

Decentralization. In accordance with the library's legal responsibility for wide dissemination of scientific and technical information in medicine, a three-phase program to decentralize the MEDLARS search and retrieval capability was begun in late 1964. This program calls for production of compatible, duplicate tapes which would be made available to medical schools, research institutions, governmental organizations, and industry for use in their own computer facilities. These groups would then have the same search and retrieval capabilities as MEDLARS.

In the first phase of decentralization, the library has initiated two pilot studies, one at the University of California, Los Angeles, with computer equipment not compatible with that installed at the library, and the second at the University of Colorado, with compatible equipment. The University of California is reprogramming the library's Honeywell tapes for use on IBM computers and will test the concept of regionalization of services. It will also use the tapes to support the activities of a specialized brain research center. The contract with the University of Colorado provides for experimental use of MEDLARS, as in studies of selective dissemination of information.

The second phase will be the formation of a network of additional search centers in areas with large concentrations of scientific manpower. Interest in this part of the program is so high that requests for sharing in the MEDLARS' searching capability have already been received from more than 40 university medical centers, private corporations, and government agencies.

As an aid in the selection of additional search centers, the library has developed certain criteria: the service potential of the institution; its computer resources and consequent responsiveness to bibliographic demands generated by the automated system; its interest in conducting further research and development based on use of MEDLARS tapes; and its ability to provide services on a regional basis, such as distribution of specialized monthly bibliographies to physicians and scientists at local institutions.

The third phase of the decentraliza-

tion program will be the provision of data tapes and program tapes, at cost, to interested institutions within the United States and abroad, and experimentation with the linkage of established centers in the United States through the use of data transmission equipment.

Automated acquisitions and cataloging system. The acquisition of new books by a library is comparable to the purchase-order and accounts-payable function of a private firm. This library function and the related cataloging of acquisitions are obvious candidates for automation. A systems analysis of these functions has been made by the National Library of Medicine, and an automated system has been designed to improve the capacity and efficiency of these processes through the use of available computer equipment. Computer programming to implement the first step of this new system is now under way. Mechanization of the cataloging operation will produce: (i) a rapid cataloging service that can be used by other libraries for their acquisitions and cataloging activities; (ii) a printed book catalog listing all new acquisitions in the National Library of Medicine each year, with a cumulative list published every 5 years; and (iii) incorporation into MEDLARS of citations to selected monographs.

On-line input. In an effort to improve the quality and extent of bibliographic input into MEDLARS, the library is exploring a system for direct communication between the indexer and the computer. Such a system would have the following characteristics.

1) Simultaneous, direct, immediate, edited indexer-to-computer input, with resulting elimination of clerical work now required for punching paper tape and elimination of errors generated by this clerical work.

2) Visual display of each data record at each indexer's station.

3) Entry of corrected input records, on magnetic tape, into the main computer files within 24 hours of indexing.

Graphic storage and retrieval system. Plans are now under way for development of a graphic-image storage and retrieval system that will permit rapid photocopy retrieval of the full text of documents in the library's collection. The library envisions a system that will tie the bibliographic capabilities of MEDLARS to the graphic capabilities of this new photocopy system.

Conclusion

By its development of improved media for dissemination of information, the National Library of Medicine is fostering a greater awareness and a better understanding of research and development efforts in behalf of public health and clinical medicine, and a more rapid translation of research into clinical application. The library's transformation from a passive repository of information to an active ally of the researcher, teacher, and clinician has led to increased use of medical library facilities and has stimulated thinking through better communication of published informa-

ACETABULUM

Articular and fibrocartilage calcification in hyperparathyroidism: associated hyperuricemia. Vix VA. **Radiology** 83:468-71, Sep 64

ACHILLES TENDON

Triiodothyronine binding to red blood cells and Achilles tendon reflex as thyroid indices. Sabeh G, et al. **Amer J Med Sci** 248:253-9, Sep 64

Tendon repair using cohesive steel reinforcement. Myers HC, et al. **Amer Surg** 30:668-70, Oct 64

Tryptic peptides obtained from gelatins derived from normal and rheumatoid arthritic collagens. A preliminary study. Steven FS. **Ann Rheum Dis** 23:405-7, Sep 64

Achilles tendon areflexia in diabetic patients. An epidemiological study. Krosnick A. **JAMA** 190:1008-10, 14 Dec 64

[On the pathogenesis of hypercholesteremic xanthomatosis] Greiling H, et al. **Deutsch Med Wschr** 89:1887-91, 2 Oct 64 **(Ger)**

ALKAPTONURIA

[Alkaptonuria (observation on a 7-year-old boy)] López-Linares M. **Acta Pediat Esp** 22:744-52, Oct 64 **(Sp)**

AMYLOIDOSIS

Multiple myeloma with paramyloidosis presenting as rheumatoid disease. Goldberg A, et al. **Amer J Med** 37:653-8, Oct 64

A case of Still's disease with amyloidosis demonstrated at the Postgraduate Medical School of London. **Brit Med J** 5421:1384-7, 28 Nov 64

ANKLE JOINT

[On the joints around the talus, with special reference to the relation between the capsula articularis and vagina tendinis] Arai K, et al. **J Jap Orthop Ass** 38:515-6, Sep 64 **(Jap)**

ANKYLOSIS

Audiometric manifestations of pre-clinical stapes fixation. Carhart R. **Ann Otol** 73:740-55, Sep 64

Experimental cervical myelopathy. I. Blood supply of the canine cervical spinal cord. Wilson CB, et al. **Neurology (Minneap)** 14:809-14, Sep 64

Non-articular rheumatism. Parry CB. **Practitioner** 193:288-98, Sep 64

A controlled study of carisoprodol and aspirin in periarthritis of the shoulder and cervical spondylosis. Redding JH. **Practitioner** 193:331-3, Sep 64

[Arthrolysis in posttraumatic stiffness of the elbow] Deburge A. **Presse Med** 72:2933, 21 Nov 64 **(Fr)**

[Apropos of cervical arthrosis] Dry J. **Progr Med (Paris)** 92:605, 10 Oct 64 **(Fr)**

ARACHNODACTYLY

A genetical view of cardiovascular disease. The Lewis A. Conner memorial lecture. McKusick VA. **Circulation** 30:326-57, Sep 64

Marfan's Syndrome. Bayliss VD, et al. **Indian Heart J** 16:142-54, Apr 64

An etiologic concept concerning the obscure myocardiopathies. James TN. **Progr Cardiov Dis** 7:43-64, Jul 64

[Case of Marfan syndrome associated with some dermatological disorders] Mukai T, et al. **Acta Derm (Kyoto)** 59:175-84, Aug 64 **(Jap)**

ARTHRITIS

Role of lymph nodes in adjuvant-induced arthritis in rats. Newbould BB. **Ann Rheum Dis** 23:392-6, Sep 64

Parenteral vs. oral folic acid antagonists. Auerbach R. **Arch Derm (Chicago)** 90:553-7, Dec 64

Use of high-definition films and immersion technic in early diagnosis of metabolic and systemic disorders. Walker BQ. **Cleveland Clin Quart** 31:227-30, Oct 64

Vitallium patelloplasty in patellar chondromalacia. Coretti JH, et al. **J Amer Osteopath Ass** 64:164-9, Oct 64

Physical therapy in the treatment of temporomandibular arthritis. Altman I. **J Amer Phys Ther Ass** 44:1091-2, Dec 64

Physical medicine in chronic arthritis. Bowie MA. **Mod Treatm** 1:1299-312, Sep 64

Surgical treatment of chronic arthritis. Marmor L. **Mod Treatm** 1:1313-27, Sep 64

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Fig. 5. Recurring bibliography (from the *Index of Rheumatology*) printed from film produced by GRACE (see text).

tion. The library's success in using automation for bibliographic control of medical literature suggests that other disciplines that have not already developed automated techniques of literature-reference retrieval might profitably do so.

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Thoughts on Research

Curt Stern

The joys of the investigator have often been sung. The ecstasy which led Archimedes to rush from the bath into the street, naked and shouting "Eureka" (I have found it) has been felt by all discoverers even though their restraint in exhibiting their ecstasy made it less memorable.

To perceive a fact of nature which had never been seen before by any human eye or mind, to discover a new truth in any field, to uncover an event of past history or discern a hidden relation, these experiences the fortunate bearer will cherish throughout his life. But let the pains of research not be overlooked. Hardly has the new discovery been made when its author begins to question its validity. How the heart can seem to cease beating when a loophole is perceived! In such a moment the heaven-high jubilance of the discoverer turns into deathly sadness. And it is not sickly indecision which brings this sudden despair; rather it is the investigator's task to doubt and to doubt again.

Many supposed discoveries wither under the impact of such critique. Some, however, will finally withstand all tests. Now new questions arise. What is to be done next? Can one pursue further the lead which brought success, or has success itself closed the avenue to continued harvest in its area? Should one start somewhere else, and what are the chances that important insights will be gained in the new field?

"Knowledge is like a sphere in space" wrote Pascal, "the greater its volume the larger its contact with the unknown." This may indeed be true but contact with the unknown is not enough. It is of the essence not just to ask questions but to ask the right ones. There is rarely an answer to wrong or vague questions. No biologist has approached his subject successfully when he began by asking "What is life?" He did succeed in a more modest way when he posed such questions as "What is the chemistry of fermentation?" or "How does water ascend a tree?" New discoveries can be the end as well as the beginning of a period of research. Pascal's beautiful analogy has an ugly counterpart in another analogy, that of a piece of wood inhabited by termites, the wood representing the problem and the insects the researchers. When the termites have reduced the log to dust the problem is solved—and the search for another log may be long. Thus many physicists of the late 19th century felt that they had essentially solved the problems of their science and that little remained to be done. It is a happy thought that unexpectedly they became challenged again by the discoveries of radioactivity and x-rays.

Knowledge grows by the rare findings of great importance as well as by the accretion of minor ones. Unfortunately many minor findings do not simply add up to one major. Major and minor are labels which derive not from the facts or concepts themselves, but from their significance to the whole. Theodor Boveri, the great biologist, once wrote as follows: "The significance of a discovery is determined much less by its specific achievement than by subsequent investigations which show whether the validity of the findings is narrow or wide or even all-embracing."

This significance cannot be foreseen. Here the course of science resembles that of evolution. It may be pictured as an exploration of an unending series of mountain chains. When you enter a new valley you cannot know whether it will end blindly or lead to a pass through which one may reach a vast new area. There are few passes and many dead ends. Many species become extinct without having evolved into new ones. Those in existence now are the descendents of the few who happened to cross the barriers. Man himself had a very narrow escape from never coming into existence. If it is true that most explorations by investigators and species do not lie in the line which leads to the future it follows that the reward of such explorations is limited.

There are some fortunate minds whose fertility gives them an ample supply of new ideas. Yet, it is human fate that time passes on, and the river of knowledge is mightier than the mightiest single mind. Rarely do the later ideas of even the great possess the relevance of their earlier thoughts. And what of the less fertile minds who,

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