Indexes and Index Mechanization in Biomedicine*

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The rather diffuse area of scientific endeavor which constitutes biomedicine embraces a large variety of disciplines, many of which are of paramount importance to the chemist. The rapid acceleration of research activity in this field has resulted in an unprecedented increase in the published literature. Accordingly, efforts have been made to develop new methods of handling this volume. In fact, documentation research has already contributed greatly to the partial solution of the problems posed by the "literature explosion." Although research is continuing actively and new techniques are in the developmental process, it is possible to delineate some of the problems and their solutions. An excellent introduction to recent progress is provided by a number of published reports in which the discussions of problems and solutions are not limited to biomedicine.[1-6]

ABSTRACTS AND INDEXES

Historically, the abstract represents the initial attempt on the part of scientists to solve the problem of a literature output beyond the capacity of the individual to read. *Chemical Abstracts* represents the largest and most successful of such attempts. Since approximately one-quarter of the abstracts in *CA* are of biomedical interest, this secondary publication becomes a major tool in this field of science. The *Index to Chemical Abstracts* is of particular importance to biochemists, pharmacologists, and other biomedical scientists who are concerned with the role of chemical compounds.

The other large abstracting service, *Biological Abstracts*, is also indispensable to biomedicine. The strictly biological literature is extensively abstracted, but the indexes, at least during the past few years, have been slow to appear. There is, admittedly, a good deal of overlap between the coverage of *BA* and *CA*. Although efforts have been made to minimize this "redundancy," it has been argued that if overlapping of coverage were reduced, a greater total of journals would be abstracted. It is difficult to understand this argument unless either of two assumptions is made:

1. The abstracter simply paraphrases the authors' summary. At least one study of so-called "subject slanting" has revealed this to be the case.[7]
2. The educational background of the abstracter has little or not relation to his appraisal of the paper which he is called upon to abstract. Our own studies lead us to believe that this is not the case at all.[8] In fact, this is also true of indexers, notwithstanding reams of specific instructions, examples, etc. A biologist will abstract a biochemical paper from a point-of-view differing from that of an organic chemist.

This point is being stressed in this discussion of indexes because "subject-slanting" of abstracts must result in subject-slanted indexes. The only alternative is to index the original paper and not its abstract.

There are numerous abstract publications in specialized areas of biomedicine, those published by the *Excerpta Medica Foundation* being the most numerous. Most of these are classified according to scientific discipline or are based upon disease entities. Almost invariably they are unable to keep up-to-date in the indexing of the abstracts even when such indexing is relatively shallow and superficial.

The time-lag between the appearance of abstracts and the indexes to them and the serious problems which this produces are too well known to merit discussion.

PERMUTED TITLE INDEXES

As a result, there has appeared in recent years, a new species, the so-called permuted title index of Keywords in Context as exemplified by "Chemical Titles," a publication of the Chemical Abstracts Service and Biological Abstracts' Subjects in Context published by *BA*. Carefully controlled studies are needed to provide adequate proof that keyword indexes are not the answer. Their information is quite meager. In the medical field, for example, where many papers contain a tremendous variety of data, titles have very little bearing upon the substance of a given document. To-date, such indexes have not received acceptance from the biomedical community as a whole. However, since large sections of *CA* and *BA* serve the medical scientist, keyword indexes will undoubtedly exert great influence upon his pattern of information retrieval in the future. It is hoped that as a result of this newly-recognized importance of titles, authors of papers will attempt to improve them, to make them more pertinent, and to increase their information content. The increasing use of a table of contents publications, such as "Current Contents," probably works in this same direction.

It is possible to consider titles, annotated bibliographies, indicative abstracts, informative abstracts, permuted title

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indexes, conventional indexes, and "the combined index-abstract"[9] as a continuous spectrum so closely interrelated that it is often difficult to decide what sort of bibliographic species one is dealing with. More often, it is a hybridized species. To illustrate, if an author decides upon an informative, meaningful title and finds that several sentences are needed for this purpose, he is really providing an annotation or a brief author abstract.

SUBJECT HEADINGS

However, the main distinction between the conventional index and the keyword index, whether it be of the title or of the complete paper, lies in the choice of terminology. Which terms are to be used as "handles" or "avenues of access" to the document, the author's or the indexer's?

During the past decade of feverish activity in the field of documentation, great emphasis has been placed upon the use of the exact terms found in a document. Without going into details concerning the original uniterm concept or its many modifications, we can agree that undue emphasis was placed upon the author as an expert in the field of communication as well as in his own specialized scientific discipline. The well known failings of the scientist as a writer and as an expert in the communication process make such a thesis quite untenable. Organic chemists may think that they have difficult terminology problems, with a specialized language embracing over a million terms, represented by organic compounds. There are, at least, rules and regulations for the construction of new words and a superb, universally accepted symbolic representation *via* structural formulas. Pity, therefore, the poor biologist, reeling in utter confusion amidst a plethora of unstandardized terms, especially with regard to pathology, disease entities, symptoms, side effects, and what have you. In fact, the only wholehearted attempts to standardize the bewildering array of terms has been in taxonomy, with a history going back to Linnaeus, several hundred years ago. Even here there is doubt and uncertainty. Only very recently has some sort of an enzyme classification and nomenclature been standardized.[10] What about viruses, when new ones are being added so frequently? This dificiency may explain the poor reception given to permuted title indexes and similar approaches to the control of the biomedical literature.

Instead, biomedicine, and especially clinical medicine, have relied mainly upon conventional indexes with relatively rigidly standardized subject headings, the so-called "thesaurus" approach. The subject heading list, the designation preferred in the present discussion, has been successfully used by the largest and most important of the retrieval weapons in biomedicine, the National Library of Medicine's "Index Medicus" formerly known as the "Current List of Medical Literature." A new list, much larger and more comprehensive than that available heretofore, is now available.

Ideally, the preparation of such lists is the responsibility of the scientists publishing papers in a particular area and represented by discipline-oriented societies. In chemistry, for example, it is clearly the function of the International Union of Pure and Applied Chemistry in the international area, and of the American Chemical Society in this country, to do "something" about the problem. An outstanding example of such a function, carried out successfully in spite of language barriers, is in the naming of the elements and the assignments of symbols for their representation in formulas. In medicine, there are several classifications of diseases, such as that of the World Health Organization and the Standard Nomenclature of Disease, compiled by the American Medical Association. The latter has recently been revised, cross-referenced, and published with the aid of a computer. These efforts represent an excellent beginning.

On the other hand, the librarian, documentalist, or information scientist, heretofore responsible, in the main, for the development of such lists, has been by-passed. What is needed is a cooperative effort involving both scientists and information people, with an efficient feedback mechanism from the user to the generator of subject heading lists. Better still would be the development of such lists by competent subject matter specialists who are also capable of handling scientific information. Even then, a number of such individuals, each expert in his own discipline, would necessarily have to cooperate in producing an authority list encompassing a large area of scientific endeavor such as biomedicine.

The active participation of practicing scientists in the standardization of indexing terms would result in their wide acceptance, instead of the resistance usually shown by the scientific community to lists generated exclusively by librarians for their own use. The scientist-author and user of the information must be taken into partnership by those whose responsibility consists of manipulating scientific data.

PERSONNEL

In spite of numerous quotations from the literature of scientific documentation that "machines can only retrieve information which has been put into them," there is still a strong belief or feeling that mechanization will solve all, or at least most, problems.

It cannot be too strongly emphasized that trained personnel are in exceedingly short supply, particularly in the area of biomedicine. The recipient of a bachelor's degree with a strong major in chemistry usually has the requisite subject matter background to do a creditable job of indexing the chemical literature. This is definitely not the case in most of biomedicine. Basic courses, such as those in pharmacology, are taught exclusively in the graduate or medical school. Clinical courses are open only to medical students. It is therefore necessary to recruit individuals with a higher level of academic attainment for information handling in biomedicine. The supply of available potential indexers has actually decreased as commercial concerns, such as the drug industry, have become increasingly aware of the benefits of information systems. These factors have resulted in an increase in the cost of indexing, hence the reliance on punch-card systems, tape typewriters, and computers. Unfortunately, all "hardware" presently available is designed to replace relatively routine clerical operations involved in the input and output of scientific information. The indexer himself can be helped by the machine to a certain extent. The "look-up" function, especially where cross-references are

involved, can be efficiently mechanized. In general, "dictionary" or "thesaurus" compilation is amenable to machine handling and may conserve the time of the indexer.[5,6]

The indexing function represents the highest intellectual effort of which scientists are capable. The ability to read the literature critically, to grasp quickly what points are being emphasized, to determine the originality of a contribution; all of these may call upon the total scientific and technical resources of an individual. In this day and age of automation of laboratory procedures, an especially good case may be made for the challenge of indexing as an important and primary function of the research scientist.

It is generally agreed that the scientists is responsible, not only for the generation of ideas but for their development as a guide to laboratory experimentation and for the actual performance of experimental work. He must publish his results in a effort to communicate with the rest of the scientific community. As a result of the increase in the amount and variety of scientific publications, his responsibility does not cease at this point. In the language of the communication engineer, it might be said that he is transmitting information by means of some carrier, usually a journal but often a formal talk or by more informal means.

When he publishes, he has no idea whether his signals are being received or for that matter, whether anyone is tuned in on his frequency. The indexing process, to continue this analogy, involves the "tuning" function. When many radio or television stations broadcast in a relatively narrow spectrum, receiving sets must provide fine tuning mechanisms to increase selectivity and to reject extraneous information which represents "noise." Some sort of feedback mechanism should be provided in order to inform the sender that his message has indeed been received, and by the audience for which it was intended.

Strong-willed editors have, by insisting on author-abstracts accompanying submitted papers, forced the scientist-author to become more closely involved in the information handling process. If titles of papers are carefully studied, it can be easily seen that their composition is, in reality, a part of an indexing process. In order to write a meaningful title, rich in information content, the author must carry out the same intellectual procedures as a good indexer would be called upon to perform. With the increasing use of "table of contents" and "permuted title indexes," this function becomes increasingly important. It is no exaggeration to state that the author becomes responsible for the retrievability or lack of retrievability of his published papers and hence for the accurate and efficient dissemination and communication of his ideas and experimental data to those of his colleagues throughout the world who might benefit from them.

The success of *Chemical Abstracts, Biological Abstracts,* and the *Excerpta Medica* publications as indispensable tools for the biomedical scientist has stemmed largely from their use of highly qualified, subject matter specialists as abstracters. Similarly, selected abstracts published by various medical journals, such as the *Journal of the American Medical Association,* have been provided as a "labor of love" by physicians and medical scientists as by-products of their personal reading habits.

Unfortunately, this situation does not obtain with regard to indexing. For the most part, this is still being carried on by relatively junior personnel. The reasons for this state of affairs have been discussed previously, *i.e.,* the shortage of personnel and the costs and the absence of a suitably standardized language. In certain discrete areas, as was mentioned earlier, it is possible to develop such a language and to train authors to use it.[5,6]

The use of part-time, nonresident subject matter specialists as indexers in a manner analogous to their employment as abstracters, is another possibility which our group has investigated and found quite promising, although the "correspondence school" type of instruction has its obvious shortcomings.[11] The use of retired scientists who, as part of a life-long habit, continue to read the literature of their chosen fields, may provide a partial solution to the severe shortage of qualified and adequately-prepared personnel.

In summary, it appears reasonable that the important problem of user-requirements would be best solved by the employment of actual or former users of the literature with years of experience in the retrieval of scientific information, as key figures on the input side.

CITATION INDEXES

The need for authors to become more intimately associated with the future progress of the "brain-children" fathered by them, is particularly important in biomedicine where discoveries in one area may have profound effects upon another, distantly-related as to subject matter. Communication between disciplines is gravely hindered by the existence of such a complex array of specialties. The use of numerous medical specialists as consultants in the treatment of a single patient is an example of this state-of-affairs. This emphasizes the need for some sort of feed-back system which would enable the contributor of scientific information to learn what sort of impact his findings may have had in another area of biomedicine.

A recent approach to the partial solution of this problem is the citation index. Here, computers and associated "hardware" have been used imaginatively and for the purposes for which they were designed. Although it is still too early to evaluate the role of citation indexes in providing a degree of feed-back to authors, some "fringe-benefits" are already "in-the-works," such as computer techniques for the standardization of abbreviations of the many thousands of journals in biomedicine. There usefulness to the student of history of medicine is obvious.[12]

THE INDEXING PROCESS

The most challenging research problem in this entire area is the nature of the indexing process itself. How do people index? What intellectual procedures are involved? What parts of the process are amenable to mechanization and what aspects are not? Time and cost studies have been carried out, admittedly, but quality evaluation is a very difficult enterprise.

Since we are dealing here with a broad spectrum of subject-matter, there can be no experts in all of biomedicine. It is as futile to have an anatomist index pharmacology as it is to expect an inorganic chemist specializing in, for example, the "rare earths," to index the drug literature. The background, training and qualifications of a prospective indexer, including the thorny language problem, must be correlated with the subject matter of the articles which are to be assigned to him. Since a perfect "match" is a rare phenomenon, it is helpful to arrange the various biomedical specialties in the form of a spectrum with a certain degree of overlap. As a result, an available cardiovascular physiologist may be assigned to index cardiovascular pharmacology and so forth.

The assignment of specific journals for indexing by one particular individual often gives rise to a number of problems. Some journals contain a wide range of subject material, so that more than one indexer may be needed to cover it. The polyglot journals also require multiple assignments. Indexers, we feel, must make a conscious effort not to be unduly influenced by the title or summary of a paper in order to concentrate on the pertinent information contained within the body of a paper itself. Here the question of "deep indexing" comes into play. A rough measure may perhaps be provided by the following expression:

depth of indexing (as percentage) = [no. of access points (index entries) to a document (indexer's choice)/no. of "bits" of pertinent information in document (user's choice)] × 100.

It cannot be emphasized too strongly that user requirements determine both the depth of indexing and the kind of information indexed. An attempt to "be all things to all men," that is, to cover a very large field of science such as biomedicine, results in relatively "shallow" indexing,[13] hence the justification for the existence of small, specialized indexing endeavors.

Our own experience has demonstrated that the most time-consuming aspect of indexing involves the careful reading of the document in order to extract from it indexable information. It is, we believe, unfortunate and indeed, wasteful, to limit index entries to single words or to the ambiguous "effect upon" type of entry. Index entries can convey information in their own right. This not only helps to "pin-point" the paper or group of papers which contain the sought-for information, it also tells the user that certain papers contain negative data or that they need not be examined at all, for the index entry contains all the usable information.

The Cardiovascular Literature Project[15] developed the so-called combined abstract-index approach some 8 years ago which has now been used for the indexing of over 45,000 papers. Our approach yields "informative index entries," slanted, admittedly, toward a particular group of users. Since our approach has been discussed many times before[8, 9, 14, 15] it is not necessary to go into details, except to emphasize that such entries are similar in their information content to titles of papers and are easily amenable to permutation by mechanized equipment. In other words, there are perhaps a dozen alternative titles for a document.

This approach has very recently been utilized for the preparation of a new type of index entitled "Chemical-Biological Activities" (CBAC), computer-produced and devoted to the rapid indexing of the current literature on the biological activity of organic compounds. A product of the Chemical Abstract Service of the American Chemical Society, its development is described in a paper by Dyson and Lynch.[16] In many respects, this excellent new publication is a descendant of the defunct Chemical-Biological Coordination Center[17] since coding techniques are employed in order to take maximum advantage of the computer capabilities.

INDEX MECHANIZATION

In spite of exciting developments such as CBAC, mentioned previously, as well as storage and retrieval systems which, at least ideally, can provide information "on demand," the main tool in biomedicine, as in other fields of science, is still the conventionally-printed index. However, recent developments in computer technology, photographic equipment, and in the graphic arts in general, have given the published index a new "lease on life" and have greatly altered its economics.[2, 3]

Tape typewriters, step-and-repeat cameras, and rapid computer print-outs have greatly reduced the necessity for repetitive typing or type-setting, coupled with many stages of expensive, time-consuming, and tedious proof-reading. Manipulation of entries, including the filing of the same entry under different headings has been taken over by the machine.

Before machines came into the picture, the usual procedure involved typing out individual entries on 3 × 5 or similar cards or slips of paper and interfiling them according to some system. For page make-up, each card was then placed on top of the preceding one in some sort of holder so that empty spaces were eliminated and entries appeared in a pre-determined sequence. This process, known in the trade as "shingling," was a relatively slow and exacting process and usually did not produce a neat looking page. Each page of "shingled" entries was photographed, and plates were produced by photo-offset. Following this, the entire page of entries was disassembled and a new page set up. At the present time, a number of ingenious "mats" for shingling are available commercially, with scalloped edges and so on.

However, some 5 or 6 years ago, when our group was faced with this "bottleneck," shingling was out of the question as a result of our lack of manpower. We then turned to the step-and-repeat camera as a solution. Although the Fotolist and Compos-o-Line machines were available, we chose the Kodak Listomatic camera. The advantages of this camera to us were as follows:

1. Index entries can be typed on IBM cards immediately after the final editing of the index sheets, one entry per card with directions for filing entered below the camera field. The cards are pre-punched. Typed cards are proofread, corrected, alphabetized, and filed periodically.

2. As the information is accumulated, the file can readily be consulted for the answering of questions and photocopies of index entries made by the Xerox process.

3. When publication time arrives, the alphabetized deck is run through the camera, the film is processed, and columns stripped up for publication.

4. Cumulated indexes can be prepared by interfiling decks of cards.

5. Following photography, index entries may be rearranged to provide for a different sequence and then re-photographed.

Entries are typed on IBM cards upon IBM-typewriters equipped with special card-holding platens. Since a maximum of three typewritten lines can be accommodated on each card and only positions 3 and 4 of column 52 are punched for programming the camera, the rest of the card can be punched for conventional collating or sorting or other means of mechanized card manipulation. For a small collection (less than 100,000 index entries to be published per year), manual filing is satisfactory, so that mechanized sorting equipment is unnecessary. In addition, the blank portion of the IBM card is available for subsequent punching of any coded information which may be desired, such as the chemical structures of compounds contained in the index entry.

Unfortunately, the use of the Listomatic camera on a service basis is not very widespread. The economics of the situation can best be summarized by the cost of film and film-processing which comes to less than $100 for a 400-ft. roll of 4-in. wide film. In this instance, if no reduction of the original typewritten material is made, and a foot-long page contains two 4-in. wide columns, $0.50 per page covers the cost of film and film processing. Machine-time at the rate of 230 cards or an average of 460 lines per minute is not included in these figures.

The most sophisticated and elegant index publication which involves the Listomatic Camera, IBM card-punching and handling equipment, and the Friden Justowriter (tape-typewritten with a justified right hand margin) is that developed by the National Library of Medicine for its "Index Medicus," the successor to the "Current List of Medical Literature." This important development is discussed in great detail in a monograph by Taine.[1] Consequently, only a brief description is necessary.

Bibliographic citations, author entries, and subject headings are punched into paper tape by Justowriter operators and proofread. The use of the tape permits the automatic duplication of entries upon a number of IBM cards.

There are a number of cards for each entry. Different types of information are punched into each by IBM punch-card equipment. The collating and sorting equipment then comes into play for the purpose of producing a mechanically-sequenced deck of cards. Proofreading is carried out on a positive paper print produced by the camera. After corrections have been made, the film is run through, processed, and columns stripped up for page make-up. The monthly publications are published by photo-offset press. In addition, the 12 monthly decks of cards are interfiled by IBM equipment to produce the annual "Cumulative Index Medicus," published by the American Medical Association, which last year (1961) ran to some 1577 pages of authors entries and 2741 pages of subject entries.

It should be mentioned that the "Index Medicus" differs considerably from its predecessor, the "Current List of Medical Literature." Complete citations are provided under the senior author and under pertinent index entries, instead of short descriptions of the contents of papers followed by accession numbers. In other words, the "Index Medicus" does not contain a "table of contents" section as did its predecessor and it is no longer possible to refer to it by accession number in order to find the journal citation and title. On the other hand, the "Index Medicus" assumes that the title together with the subject heading are sufficient within themselves as a retrieval tool.

Although the "Index Medicus" has been in existence for less than 3 years, the growth of the medical literature is so great that a computer-produced index will become available within a year or so. The MEDLARS Project (Medical Literature Automatic Retrieval System) is nearing completion and will result not only in a computer-produced index but will also make it possible for the bibliographic services of the National Library of Medicine to provide "custom" bibliographies. Montgomery and Swanson[13] have recently published the result of a study of the type of indexing carried on by the staff of "Index Medicus." These data, it is expected, will influence the type of indexing which will be carried out in relation to the MEDLARS approach.

The "Chemical-Biological Activities" publication, referred to previously[16] represents the most sophisticated use of a computer and associated print-out in the preparation of "indexes-in-depth." Each paper generates a number of telegraphic "extracts" or "lines of data" describing in some degree of detail the effects of specific compounds upon specific biological systems under specific circumstances. These, as well as the titles, are permuted and printed-out (with upper and lower-case letters!) by the computer. The codification of each "line of data" will doubtlessly lead to computer-compiled "thesauri" and to a genuinely standardized "language" not only involving chemical compounds and biological entities but encompassing commonly-used verbs, adjectives, adverbs, and so on.

Thus, the mechanized published index in biomedicine will become part of an over-all information system complex. Obviously, exciting developments are ahead for biomedical documentalists.

SUMMARY

Mechanization of biomedical index publications has greatly increased the scope of such activities. It is now possible to provide general, shallow indexes to the entire field as well as specialized, deep indexes tailored to the needs of specialized research workers or practitioners. The computer can permute any term or combination of terms according to its programming. Only paper and printer's ink limit the number and variety of index entries.

However, with these increased capabilities and the decreased costs per published item, the qualified information scientist becomes even more important to this man–machine interrelationship, for as an indexer, he controls the nature of the input and by his knowledge of user needs, he monitors its output.

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Information Retrieval at the New Monsanto Information Center*

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In June, 1961, a large and widely scattered group of information services in Monsanto were centralized as a newly established Information Center. The Center consists of a Central Technical Library, a Central Business Library, a Central Reports and Chemicals Library, and a small group working on the introduction of New Methods of Information Handling to our operations. Because of the great strides presently being made in the area of information handling plus the ever-growing need for better and cheaper methods, we were prompted to include this small group doing research on new methods as part of the over-all Information Center. A brief diagram of the organization of the Information Center is shown in Fig. 1.

The establishment of the Center seemed to be an appropriate time for making changes to certain of the traditional but now outworn methods of information handling by more up-to-date ones. Outstanding among the changes were the introduction of a machine-prepared book catalog and the conversion of the indexing of Monsanto reports to a computer-based operation. The third area in which improvements were made was a Union List of Serials for all Monsanto libraries.

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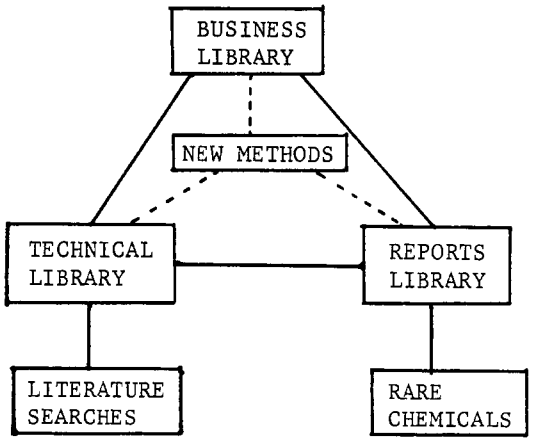

Section Heads:

Business Library	-	Charlotte Perabo
Technical Library	-	William A. Wilkinson
Reports Library	-	Margaret E. Madden
New Methods	-	Paul Logue

Fig. 1.—Organization of the Monsanto Information Center. The organization is led by an annually rotating chairman chosen from the section heads.