Understanding and Using the Medical Subject Headings (MeSH) Vocabulary to Perform Literature Searches

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The United States National Library of Medicine's (NLM) MEDLINE database is the largest and most widely used medical bibliographic database. MEDLINE is manually indexed with NLM's Medical Subject Headings (MeSH) vocabulary. Using MeSH, a searcher can potentially create powerful and unambiguous MEDLINE queries. This article reviews the structure and use of MeSH, directed toward the nonexpert, and outlines how MeSH may help resolve a number of common difficulties encountered when searching MEDLINE. The increasing importance of the MEDLINE database as an information resource and the trend toward individuals performing their own bibliographic searches makes it crucial that health care professionals become familiar with MeSH.

(*JAMA*. 1994;271:1103-1108)

THE UNITED STATES National Library of Medicine's (NLM)[1] Medical Subject Headings (MeSH) vocabulary is used to index a number of important computer-based biomedical databases such as MEDLINE. The MEDLINE database, created and maintained by NLM, contains more than 7 million references to the biomedical literature since 1966. MEDLINE covers more than 3500 journals. Approximately two thirds of these references contain English-language, author-written abstracts. When properly used, MeSH can be a powerful tool, improving access to the medical literature. Until recently, most MEDLINE searches were performed by specially trained individuals who of necessity became experts on MeSH. However, with the trend toward end users' performing their own searches,[2,3] a review of the structure and use of MeSH, directed toward the nonexpert, appears timely. This article provides an introduction to MeSH, including some important principles used in selecting MeSH terms for searching MEDLINE and other MeSH-indexed biomedical databases.

THE INFORMATION EXPLOSION IN BIOMEDICINE

Physicians as primary clinical decision makers have a significant impact on the cost and quality of care. However, the current information explosion[4] in biomedicine makes it progressively more difficult for physicians to access the information necessary to make intelligent and cost-effective clinical decisions. More than 20 000 biomedical journals and approximately 17 000 new biomedical books are published annually.[5] Covell et al,[6] in their landmark study of information needs in the office setting, found that only 30% of physicians' information needs were met during the patient visit. They observed that traditional paper-based references played a minor role in problem solving with most questions being answered by other health professionals. In 1979 Stross and Harlan[7] documented a serious problem with the dissemination of new medical information to practicing physicians. More recently, Williamson et al[8] conducted a survey of more than 700 physicians and concluded that "primary practitioners require substantial help in meeting current science information needs."

What is needed is a new model of medical knowledge acquisition that emphasizes the importance of knowledge-seeking skills and the ability of widely available computer technology to augment the physician's cognitive potential. Currently the most striking example of the use of computer technology to support the physician's need for medical knowledge is the retrieval of information from a wide variety of on-line biomedical databases such as MEDLINE.[9] Proud et al[10] recently concluded that "when [medical] students were taught the skills of accessing MEDLINE by computer, they could formulate a question, retrieve current information, critically review relevant articles, communicate effectively, and use these skills to contribute to patient care."

THE MEDLINE DATABASE

Access to MEDLINE[11,12] is widely available through NLM's computer-based Medical Literature Analysis and Retrieval System (MEDLARS)[13] and from a variety of commercial vendors.[14-16] MEDLARS is often used in conjunction with NLM's Grateful Med[17-19] software, which provides an easy-to-use system for formulating and executing MEDLINE queries using inexpensive microcomputers. Approximately 5.5 million searches were performed on NLM's MEDLARS system in 1992. The decreasing costs of optical storage technology has resulted in the emergence of systems offering MEDLINE on CD-ROM.[20,21] Teaching the skills required to conduct computer-assisted literature searches is now a part of the curriculum in many US medical schools.[22-24] Accessibility and awareness are no longer major impediments to the widespread use of on-line biomedical databases.

The NLM carefully indexes each new MEDLINE citation[25] with a number of terms from its MeSH vocabulary. Almost all MEDLINE retrieval systems support the use of MeSH when search-

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Table 1.—Major National Library of Medicine Databases Indexed With Medical Subject Headings (MeSH)*

Database	Contents
AIDSLINE	Citations to the AIDS literature
AIDSTRIALS	Active and closed clinical AIDS trials
AVLINE	Audiovisual materials for health professionals
BIOETHICS	Citations to biomedical ethics literature
CANCERLIT	Citations to the cancer literature
HEALTH	Health care administration and planning
MEDLINE	Citations to the biomedical literature
TOXLINE	Citations to the toxicology literature

*AIDS indicates acquired immunodeficiency syndrome.

ing for citations. Using MeSH, a searcher can potentially create powerful and unambiguous MEDLINE queries. MeSH is therefore an important gateway to the medical literature. The increasing importance of the MEDLINE database as an information resource makes it crucial that health care professionals become familiar with MeSH.

THE MeSH VOCABULARY

The MeSH vocabulary is a controlled thesaurus of almost 17 000 terms maintained by NLM.[26] MeSH is used to index citations in a number of biomedical databases produced by NLM. Table 1 lists a sample of these databases that use MeSH vocabulary.

Each MeSH term represents a single concept appearing in the biomedical literature. As important new concepts or significant modifications of existing concepts appear in the literature, NLM adds new terms to MeSH. When a new citation (a citation is the MEDLINE representation of an article and includes information such as title, authors, source, abstract, MeSH indexing terms, and the like) is added to MEDLINE, NLM indexers choose and attach the appropriate MeSH terms (usually 10 to 12)[26] representing the contents of the article. A searcher can then use these MeSH terms to rapidly retrieve that citation and others indexed with the same terms.

Figure 1 shows a MEDLINE citation with its MeSH terms used to index an article on screening strategies for colorectal cancer. The abstract is not included in this example.

To retrieve this citation from MEDLINE a searcher could use the MeSH terms COLORECTAL NEOPLASMS and MASS SCREENING. The MeSH terms preceded by an asterisk in this sample citation are those judged by NLM indexers to represent the main concepts covered by this article and it is under these headings that the citation can be located in *Index Medicus* (the printed index of MEDLINE citations produced monthly by NLM). The MeSH terms not flagged with an asterisk are used to identify concepts that are discussed in the article but are not its primary topics.[26]

When searching MEDLINE, one can take advantage of this "Major Concept" designation to limit the retrieval of potentially less irrelevant citations. For example, a recent search of the last 5 years of MEDLINE using the terms COLORECTAL NEOPLASMS and MASS SCREENING produced 144 citations when the Major Concept designation was used with each term vs 245 citations if the Major Concept designation was not used to limit the search. This strategy effectively screened out 101 potentially less irrelevant articles (approximately 41% of the total retrieved when the Major Concept designation was not used).

If all MEDLINE citations indexed with a specific term must be retrieved (as might be the case when preparing a grant request or writing a review article), then the searcher would not use the Major Concept designation to limit retrieval. Similarly, many expert MEDLINE searchers would initially execute a search without using the Major Concept designator and if the number of citations retrieved exceeded some arbitrary limit, then the searcher would reduce the number retrieved by repeating the search using the Major Concept designator with one or more MeSH terms.

The Scope of MeSH

The MeSH vocabulary reflects the scope of the biomedical literature in that NLM adds terms as new concepts appear in the literature and removes or modifies terms as concepts change. MeSH is updated on a yearly basis to reflect these changes. For example, the 1994 version of MeSH contains 716 new terms representing concepts with no directly corresponding terms in the 1993 MeSH. For the 1994 MeSH, NLM also replaced 263 terms with more up-to-date terminology and deleted 44 terms.[26]

MeSH terms are organized into a set of 15 hierarchies called the "MeSH Tree Structures" (described later in this article. Figure 2 lists the major MeSH Tree categories. Each of these categories is the root of a complex hierarchical arrangement of increasingly specific MeSH terms. These categories provide an overview of the general concept areas covered by MeSH.

Special MeSH Terms

MeSH contains some special types of terms that are never designated as Major Concept headings but can be used when searching. These special MeSH terms are "Publication Types," "Check Tags," and "Geographic Terms."

Publication Types.—This group of 47 MeSH terms was introduced in 1991 to replace and extend the group of terms formerly known as "Citation Types." These terms provide an additional classification dimension for citations in MEDLINE and other NLM databases. MeSH terms designated as Publication Types characterize the type of a publication rather than what it is about (Table 2). The MEDLINE searcher can use Publication Types to limit retrieval of citations to specific types of publications. For example, the addition of the term REVIEW to our search on COLORECTAL NEOPLASMS and MASS SCREENING reduced the number of retrieved citations from 144 to 21. Each of these 21 citations had been designated as a formal review article by NLM indexers.

Check Tags.—This group of MeSH terms designates very broad attributes of the content of journal articles (Table 3). These terms may be useful to MEDLINE searchers. Examples of their use include: MYOCARDIAL INFARCTION and FEMALE, PANCREAS TRANSPLANTATION and HUMAN, LAPAROTOMY and COMPARATIVE STUDY.

Geographics.—Includes terms identifying individual geographic regions, continents, countries, states, and selected cities. These terms can be used to restrict retrieval to articles dealing with concepts in specific geographic areas. For example: AIR POLLUTION and LOS ANGELES, INFANT MORTALITY and SOUTH AFRICA, HEALTH CARE RATIONING and OREGON.

MeSH Subheadings

MeSH contains a group of 80 terms called MeSH Subheadings (Table 4). Subheadings are used to qualify the use of MeSH terms and allow the searcher to limit retrieval to citations that deal with a specific aspect of a biomedical concept. For example, in the sample citation shown in Fig 1, the term COLORECTAL NEOPLASMS is qualified with the subheading PREVENTION & CONTROL. Use of this subheading allows the searcher to limit retrieval only to those citations dealing with the prevention and control of colorectal neoplasms. MeSH contains "Scope Notes" that aid the searcher in selecting appropriate subheadings. For example, the MeSH Scope Note for the subheading PREVENTION & CONTROL states: "Used with disease headings for increasing human or animal resistance against disease (eg, immunization), for control of transmission agents, for prevention and

Title: Strategies for screening for colorectal carcinoma.
Authors: England WL; Halls JJ; Hunt VB
Source: Med Decis Making 1989 Jan-Mar;9(1):3-13
MeSH: Barium Sulfate/DIAGNOSTIC USE
Colonoscopy
Colorectal Neoplasms/*PREVENTION & CONTROL
Comparative Study
Cost Benefit Analysis
*Decision Making, Computer-Assisted
*Decision Trees
Enema
Human
*Mass Screening
Occult Blood
Risk Factors
Support, U.S. Gov't, P.H.S.

Fig 1.—Sample MEDLINE citation.

Analytical, Diagnostic and Therapeutic Techniques (including Anesthesia)
Anatomical Terms, Body Regions, Organs & Systems, Cytology and Embryology
Anthropology, Education, Human Activities and Social Sciences
Biological Phenomena, Genetics, Physiology, Occupations and Public Health
Chemicals, Drugs, Biomedical Materials, Hormones and Pollutants
Human & Animal Diseases, Symptoms and General Pathology
Geographicals (Continents, Regions, Countries, States and Some Cities)
Health Care, Demography, Organizations and Population Characteristics
Humanities, Art, History, Literature, Philosophy, Ethics and Religion
Information & Library Sciences, Medical Informatics and Communications
Named Groups (e.g., Age, Disabled, Ethnic, Occupational Groups etc.)
Algae, Fungi, Bacteria, Invertebrates, Plants, Vertebrates and Viruses
Physical Sciences (Specific Disciplines and Methods)
Psychiatry and Psychology
Technology, Materials, Industry, Transportation, Agriculture and Food

Fig 2.—Medical Subject Headings (MeSH) Tree categories.

control of environmental disease. It includes preventive measures in individual cases."[26]

Most MEDLINE retrieval systems support the use of subheadings to limit retrieval to specific aspects of a subject. For example, subheadings can be used to focus on citations dealing with the Complications, Diagnosis, Epidemiology, Etiology, Genetics, Mortality, Pathology, Prevention & Control, Rehabilitation, or Therapy of Disease States. In general, the searcher should, if possible, use a MeSH heading/subheading combination rather than a MeSH heading/MeSH heading combination to search for citations dealing with a specific aspect of a topic. For example, to search for citations dealing with the surgical treatment of COLORECTAL NEOPLASMS use COLORECTAL NEOPLASMS/SURGERY rather than combining the MeSH terms COLORECTAL NEOPLASMS and SURGERY, OPERATIVE.

Clearly not all MeSH term/subheading combinations are valid. For example, HEART/TRANSMISSION makes no sense. The valid combinations of MeSH terms and subheadings are governed by a set of "allowable category" rules built into the MeSH Tree Structures. A well-designed MEDLINE access system should allow the searcher to view all of the subheadings that may be combined with any given MeSH term.[20] The appropriate use of MeSH subheadings can help the searcher create highly specific MEDLINE queries that may improve search precision.

TEXT-BASED VS MeSH-BASED SEARCHES

Perhaps the most compelling reason for the use of MeSH terms when searching MEDLINE is the challenge in choosing how one represents search topics. In addition to using MeSH indexing terms, most MEDLINE retrieval systems also support searching for citations by using one or more words that occur in the citation's title or abstract. This can be a useful searching strategy if, for example, there is no appropriate MeSH term, or if one wishes to modify the scope of a search by combining MeSH terms with title/abstract words. However, a fundamental problem with this "free-text" searching method is that the words used in the title and abstract are part of an uncontrolled vocabulary. This means that no effort has been made to ensure that the language used by the author conforms to any standard or convention. Therefore, a searcher using these free-text representations, rather than MeSH terms, may not find relevant citations because the author and searcher differ in how they represent a concept.

For example, if a searcher performs a MEDLINE search using the word "Hyperlipidemia" and an author has used the narrower term "Hypercholesterolemia," then many relevant citations may be missed because only those articles with the word "Hyperlipidemia" in their title or abstract will be retrieved. However, appropriate use of the MeSH term HYPERLIPIDEMIA (using the MeSH "Explode" feature described later in this article) would find all citations indexed with HYPERLIPIDEMIA, HYPERCHOLESTEROLEMIA, HYPERLIPOPROTEINEMIA, and HYPERTRIGLYCERIDEMIA, irrespective of the words used by individual authors. The lesson here is that the MeSH indexing performed by NLM is a form of intelligent preprocessing that should be taken advantage of whenever possible. Failure to do so is an important reason why MEDLINE searches fail.[27]

Precision and Recall—The Sensitivity and Specificity of Searching

Formal studies of searches using uncontrolled free text, such as occurs in titles and abstracts, suggest that these searches may have a lower recall rate than searches performed using indexing terms such as MeSH. "Recall," defined as the number of relevant citations retrieved by a search divided by the number of relevant citations in the database being searched, is expressed in the following equation as:

$$\text{Recall} = \frac{\text{Number of relevant citations retrieved}}{\text{Number of relevant citations in database}}$$

Using the terminology of decision analysis, recall can be viewed as the sensitivity of the search, in that it measures the ability of the search to retrieve relevant citations from the database.

A study of 975 MEDLINE searches conducted by medical students at Harvard Medical School suggests that MeSH-based searches may be superior to free-text searches. In this unpublished study, title-abstract free-text searches produced significantly lower recall than MeSH-based searches. While 31% of all searches in this series were title-abstract searches, this group comprised 48% of all searches that found no citations. Similar results have been found with databases other than MEDLINE. In 1985, Blair and Maron[28] evaluated the well-known STAIRS automatic text retrieval system as applied to a collection of 40 000 free-text documents (approximately 350 000 pages of text) and found an average recall rate of only 20% (ie, only one in five relevant documents were found). They con-

Table 2.—Medical Subject Headings (MeSH) Publication Types, 1994*

Abstract	Journal Article
Bibliography	Legal Brief
Classical Article	Letter
Clinical Conference	Meeting Report
Clinical Trial	Meta-analysis
Clinical Trial, Phase I	Monograph
Clinical Trial, Phase II	Multicenter Study
Clinical Trial, Phase III	News
Clinical Trial, Phase IV	Overall
Comment	Periodical Index
Congress	Practice Guideline
Consensus Development Conference	Published Erratum
Consensus Development Conference, NIH	Randomized Controlled Trial
Corrected and Republished Article	Retracted Publication
Current Bio-Obit	Retraction of Publication
Dictionary	Review
Directory	Review Literature
Duplicate Publication	Review of Reported Cases
Editorial	Review, Academic
Festschrift	Review, Multicase
Guideline	Review Tutorial
Historical Article	Scientific Integrity Review
Historical Biography	Technical Report
Interview	

*NIH indicates National Institutes of Health.

cluded that to achieve acceptable recall, use of a manual indexing scheme (such as MeSH) is preferable to free-text retrieval. Searches using MeSH can achieve recall rates as high as 90%,[29] although average recall values of approximately 50% are more typical. A number of studies have demonstrated that MEDLINE recall is related to searcher expertise.[30-32] Inversely, not using MeSH or using MeSH inappropriately can result in search failures.[27]

In addition to recall, the searcher is also concerned with "precision," which is defined as the number of relevant citations retrieved divided by the total number of citations retrieved, expressed in equation form as:

$$\text{Precision} = \frac{\text{Number of relevant citations retrieved}}{\text{Total number of citations retrieved}}$$

Using the terminology of decision analysis, precision can be viewed as the specificity of the search, in that it measures the ability of the search to discriminate between relevant and nonrelevant citations.

The precision of free-text searches is usually better than their recall. In the STAIRS study, precision was about 75% vs a recall of approximately 20%. In the Harvard study cited earlier, precision was not measured directly but when asked to assess the relevance of retrieved citations, searchers gave an average "relevancy score" of 66% for MeSH-based searches vs 55% for title-abstract searches.

The relationship of recall to precision is dependent on many variables including the database being searched, the

Table 3.—Medical Subject Headings (MeSH) Check Tags, 1994

Animal	In Vitro
Case Report	Male
Comparative Study	Support, Non-U.S. Gov't
Female	Support, U.S. Gov't, Non-P.H.S.
Human	Support, U.S. Gov't, P.H.S.

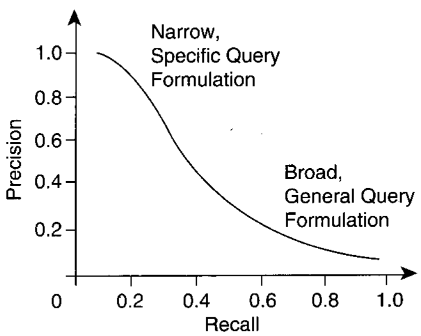

Fig 3.—Average recall-precision graph (adapted from Salton and McGill[33]).

retrieval system, and the searcher's information needs, but Salton and McGill[33] have suggested a composite recall-precision graph that reflects the average performance of a retrieval system for a large number of individual queries (Fig 3).

This graph illustrates that search strategies that are designed to maximize recall will tend to retrieve irrelevant citations and vice versa.[34] One of the skills required of the proficient MEDLINE searcher is effectively balancing precision and recall. As in most exhaustively indexed databases, the use of MeSH indexing terms when searching MEDLINE tends to enhance recall by making it possible to retrieve many of the relevant citations.[34,35] As each important biomedical concept is represented by a single MeSH term, use of that MeSH term when searching MEDLINE should retrieve most of the citations in which the concept is a significant topic. This principle is reflected in the practice of expert MEDLINE searchers who use the MEDLINE Explode feature, described later in this article, to ensure inclusion of all MeSH terms that might be used to index a topic.[34]

MeSH can also be used to improve precision because MeSH indexers are instructed to choose the most specific MeSH term that describes a topic. Therefore, using highly specific MeSH terms to describe a concept in a MEDLINE search query ensures that only citations indexed with that term are retrieved. Again, this principle is reflected in the strategy of expert search-

Table 4.—Medical Subject Headings (MeSH) Topical Subheadings, 1994

Abnormalities	Manpower
Administration & Dosage	Metabolism
Adverse Effects	Methods
Analogs & Derivatives	Microbiology
Analysis	Mortality
Anatomy & Histology	Nursing
Antagonists & Inhibitors	Organization & Administration
Biosynthesis	Parasitology
Blood	Pathogenicity
Blood Supply	Pathology
Cerebrospinal Fluid	Pharmacokinetics
Chemical Synthesis	Pharmacology
Chemically Induced	Physiology
Chemistry	Physiopathology
Classification	Poisoning
Complications	Prevention & Control
Congenital	Psychology
Contraindications	Radiation Effects
Cytology	Radiography
Deficiency	Radionuclide Imaging
Diagnosis	Radiotherapy
Diagnostic Use	Rehabilitation
Diet Therapy	Secondary
Drug Effects	Secretion
Drug Therapy	Standards
Economics	Statistical & Numerical Data
Education	Supply & Distribution
Embryology	Surgery
Enzymology	Therapeutic Use
Epidemiology	Therapy
Ethnology	Toxicity
Etiology	Transmission
Genetics	Transplantation
Growth & Development	Trends
History	Ultrasonography
Immunology	Ultrastructure
Injuries	Urine
Innervation	Utilization
Instrumentation	Veterinary
Isolation & Purification	
Legislation & Jurisprudence	

ers who use the MeSH Tree Structures (described later in this article) to find the most specific MeSH term describing a concept.

The successful application of these searching principles assumes high-quality MeSH indexing. In 1983 Funk et al[25] concluded that "MEDLINE, with its excellent controlled [MeSH] vocabulary, exemplary quality control, and highly trained indexers, probably represents the state of the art in manually indexed data bases."[25] Since then NLM has significantly enhanced MeSH to cover many new concepts in areas such as the acquired immunodeficiency syndrome (AIDS), genetics, immunology, medical informatics,[36] and molecular biology. Over $2 million and 44 full-time equivalent indexers are used each year by NLM to ensure optimal indexing of MEDLINE.[37]

THE MeSH TREE STRUCTURES

The MeSH vocabulary is not simply a list of approximately 17000 concept terms. It is organized into a complex hierarchy called the "MeSH Tree Structures." In this hierarchy the MeSH terms are arranged into a set of branching, treelike structures of increasing specificity. Figure 4 illustrates this organization using a portion of the MeSH Tree dealing with Intestinal Neoplasms.

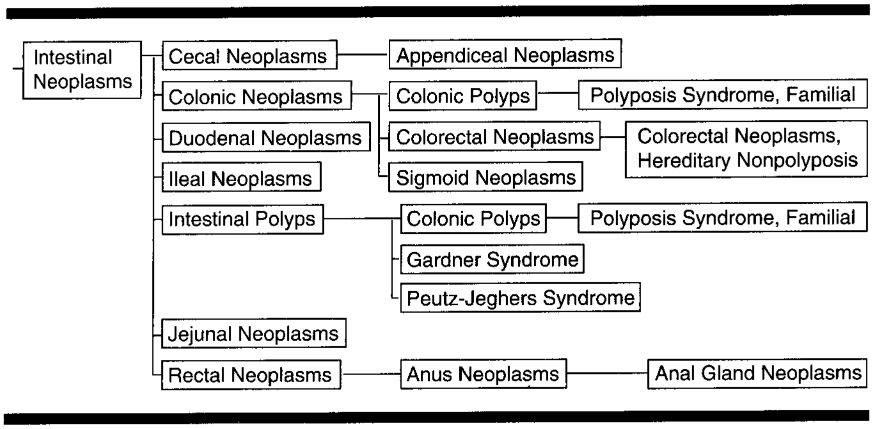

Fig 4.—Sample Medical Subject Headings (MeSH) Tree Structure.

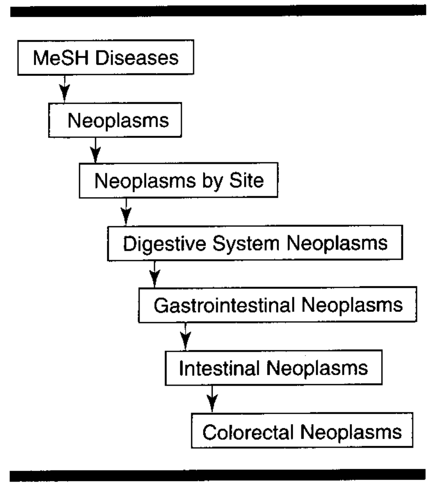

Fig 5.—Path through Medical Subject Headings (MeSH) Tree to COLORECTAL NEOPLASMS.

The MeSH Tree Structures support a number of useful strategies when searching MEDLINE. By traversing the tree to the most specific term representing a concept, the searcher can create very specific search queries. When indexing new MEDLINE citations NLM indexers use the most specific MeSH term available. For example, in the sample citation shown in Fig 1 the specific term COLORECTAL NEOPLASMS is used rather than the more general INTESTINAL NEOPLASMS. Being aware of this indexing practice and using the MeSH Tree to find the most specific term allows the searcher to improve the precision of a MEDLINE search, thus reducing the number of irrelevant citations retrieved.

The MeSH Tree also allows one to broaden the scope of a search and therefore improve recall. For example, to retrieve MEDLINE citations dealing with screening strategies for all intestinal cancers (not just COLORECTAL NEOPLASMS), the searcher can use the MeSH Tree to find the more general term INTESTINAL NEOPLASMS. However, instead of searching with just this term, one would Explode INTESTINAL NEOPLASMS to retrieve all citations indexed with that term as well as citations indexed with any of its more specific descendants arranged beneath it in the MeSH Tree (all MeSH terms contained in Fig 4).

Exploding a term is a useful strategy if a MEDLINE search produces too few citations or if the searcher feels that recall is unacceptable. Indeed many expert searchers would say that inclusive searches ("Explosions") are the preferable strategy in general since their use usually increases the retrieval of relevant citations. This increased recall may be accompanied by a parallel increase in the retrieval of irrelevant citations, as predicted by Salton's average recall-precision graph (Fig 3).

The MeSH Tree Structures provide not only a way to vary the specificity of a search but also a method for finding MeSH terms when only the general concept area is known. For example, one can easily find the more specific term COLORECTAL NEOPLASMS by entering the MeSH Tree at NEOPLASMS and traversing the path as shown in Fig 5.

THE PROBLEM OF LANGUAGE

As the volume and complexity of medical knowledge increase so too does the language used to describe that knowledge. Each specialist field has its own subvocabulary that can serve as a barrier to the nonspecialist. The increasing importance of highly technical fields such as molecular genetics, biotechnology, and medical informatics will surely deepen the language divide between specialist and nonspecialist. To effectively retrieve information from large biomedical databases, the searcher must be able to express a query in the language appropriate to the target domain. Translating from the searcher's own vocabulary to the appropriate domain vocabulary is a fundamental problem in information retrieval.

MeSH is the canonical language of MEDLINE. It is a difficult vocabulary to master. The official printed reference consists of three volumes containing more than 2300 pages of text and weighs approximately 5.5 kg (12.1 lb).[26] Despite extensive cross-referencing and the use of MeSH "entry terms" that link commonly used terms to MeSH terms, the inexperienced or infrequent MEDLINE searcher may still have difficulty finding appropriate MeSH terms.

The fundamental difficulty with any controlled vocabulary such as MeSH is finding the precise term used to represent a concept. Many associated concepts may map to a single canonical MeSH term. For example, HEART FAILURE, CONGESTIVE is the only MeSH term used to represent all types of cardiac failure. How can a MEDLINE searcher find the MeSH terms representing the concepts he or she wishes to search for? A number of approaches to this problem are possible using MeSH. MeSH contains a large set of Entry Terms that are used to map non–MeSH-concept descriptors to appropriate MeSH terms. For example, the MeSH Entry Term WILSON DISEASE invokes the MeSH term HEPATOLENTICULAR DEGENERATION. Most MEDLINE searching systems support the use of Entry Terms and this gives the searcher some freedom in using commonly used biomedical terms even if they are not MeSH terms. Another strategy useful in finding MeSH terms is to search MEDLINE for a known article on a subject (perhaps searching by author or one or more words in the title/abstract fields) and then view the MeSH terms used to index that citation. Searchers can also use the MeSH Tree to find MeSH terms by beginning from a very general category and browsing through the hierarchy until a specific term is identified.

Many MEDLINE access systems provide assistance in choosing MeSH terms but they vary in their scope and ease of use. What is needed is a method for converting the searchers uncontrolled natural language to MeSH. Given the richness and complexity of language, this is not a trivial problem. To take advantage of MeSH as a unique gateway to the biomedical literature, searchers need tools to help them overcome both the complexity of the MeSH thesaurus and the problems implicit in using a highly controlled vocabulary system to create information retrieval queries. A number of computer-based tools have been developed to address this problem.

The NLM's Unified Medical Language System (UMLS) project[38-40] should be of considerable value in reducing the difficulties inherent in mapping standard biomedical terms to MeSH. The UMLS Metathesaurus contains a rich set of links between MeSH Terms and related concepts in classification systems such as the American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*) the American College of Pathologists' *Systematized Nomenclature of Medicine* (*SNOMED*), the American Medical Association's *Current Procedural Terminology* (*CPT*), the *International Classification of Diseases* (*ICD*), the Computer-Stored Ambulatory Record (*COSTAR*), and the *Library of Congress Subject Headings* (*LCSH*). In addition, the UMLS contains semantic information for each concept term, which should be of assistance in the development of smart computer programs that can intelligently assist the nonexpert user in defining and executing queries across a range of biomedical databases.

MicroMeSH,[41-43] a complete microcomputer implementation of the MeSH vocabulary, was developed by the authors at the Laboratory of Computer Science at Massachusetts General Hospital/Harvard Medical School as part of their NLM-sponsored UMLS research. MicroMeSH provides powerful searching, mapping, and browsing tools to assist users in finding appropriate MeSH terms, exploring the MeSH Tree Structures, and using MeSH subheadings.

Coach[44] is a computer program under development at NLM that is designed to help users of the Grateful Med program improve MEDLINE search and retrieval capabilities. Coach assists the searcher in finding appropriate MeSH terms (using UMLS resources) and also provides tools for browsing through the MeSH Tree Structures.

CONCLUSION

The MeSH thesaurus, as the indexing vocabulary of MEDLINE and other important NLM databases, is potentially a powerful tool for improving access to the rapidly expanding biomedical knowledge base. Little attention has previously been given to teaching health care workers about the structure and use of MeSH. In part this has been because MeSH is difficult to master and because until recently most MEDLINE searches were performed by trained library professionals. However, the advent of inexpensive microcomputers and the availability of easy-to-use MEDLINE searching software means that an increasing number of health care workers will be using self-service bibliographic retrieval systems. This article is intended to demystify MeSH and encourage searchers to explore how it can be used to improve bibliographic retrieval.

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