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NATURAL LANGUAGE ACCESS TO CLINICAL DATA BASES

by

Martin N Epstein

Dissertation

Submitted in partial satisfaction of the requirements for the degree of

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by

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## ABSTRACT

## NATURAL LANGUAGE ACCESS TO CLINICAL DATA BASES

This research describes a natural language question answering system, MEDINQUIRY, which allows convenient access by a medical specialist to a clinical data base on patients with malignant melanoma. Such a facility can be used in a "consultant" capacity to directly provide a problem solver with efficient and timely decision support for research studies and patient management. The physician can input requests in English that retrieve specified data for particular patients or for groups of patients satisfying certain characteristics, that specify simple calculations to be performed, and that allow browsing through the data base. MEDINQUIRY can assist an expert in developing hypotheses about relationships that hold among variables, and in relating information in the data base to prognosis and outcome.

The approach followed involves compiling an application language containing both domain specific knowledge about melanoma, and general knowledge about language supporting medical inquiry. A prototype system MEDINQUIRY, was designed and implemented employing the application language to analyze and process English language requests against the clinical data base.

MEDINQUIRY accepts a wide range of English language requests. For each request analyzed, it generates a formal query request that is passed to the data base, and provides a relevant response to the submitted inquiry. The system supports dialogue interactions; the user can follow a line of inquiry to test a particular hypothesis by entering



a sequence of requests. Phrases rather than complete sentences can be used. The interpretation of the phrase is carried out in the context of prior requests. It is possible to define new constructs at the phrase level, and a limited capability exists, using a sequence of stored requests, to respond to meta-questions. It is also possible to process certain classes of time oriented requests and requests that involve negation.

Several issues involved in the design and implementation of the system are discussed. A set of criteria are suggested by which MEDINQUIRY could be evaluated. Based on these criteria, some preliminary results are given on the performance of the prototype system.

This research is also concerned with gaining an understanding of the medical inquiry process, and identifying effective inquiry strategies. A model is proposed which describes how information about malignant melanoma, and medical inquiry processes might be organized to compose requests. The model attempts to represent the processes of hypothesis formation and testing, by using a process and knowledge representation model to provide a framework that can be used in subsequent work on MEDINQUIRY in particular, and medical inquiry in general.

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CONTENTS

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List of Figures . . . . .	ix
<u>1. INTRODUCTION</u> . . . . .	1
1.1 Background and Rationale . . . . .	1
1.2 Objectives . . . . .	3
1.3 Research Approach . . . . .	6
1.4 Scope of Dissertation . . . . .	9
<u>2. LITERATURE REVIEW</u> . . . . .	11
2.1 Access Methods . . . . .	11
2.2 Formal Query Languages . . . . .	12
2.3 Menu Trees or Branching Logic . . . . .	15
2.4 Natural Language Access . . . . .	21
2.5 Recent Work in Problem Solving Strategies and Artificial Intelligence Research . .	26
<u>3. OVERVIEW OF MALIGNANT MELANOMA</u> . . . . .	33
3.1 Epidemiology . . . . .	33
3.2 Diagnosis . . . . .	34
3.3 Histologic Classification . . . . .	35
3.4 Classification Schemes for Staging Melanoma . . . . .	38
3.5 Therapy . . . . .	42
3.6 Prognosis . . . . .	45
<u>4. MEDINQUIRY: SYSTEM STRUCTURE</u> . . . . .	52
4.1 Overview of MEDINQUIRY . . . . .	52
4.2 Data Base: Design Considerations . . . . .	55
4.3 Nature of Medical Information . . . . .	56









7.2	Prognosis . . . . .	173
7.3	Models of Inquiry . . . . .	177
7.3.1	Process Model for Inquiry . . . . .	178
7.3.2	Knowledge Representation Model . . . . .	184
7.4	Comments on Use of Models in MEDINQUIRY . . . . .	193
8.	<u>SUMMARY AND FUTURE WORK</u> . . . . .	196
	<u>REFERENCES</u> . . . . .	204
	<u>REFERENCES ON MALIGNANT MELANOMA</u> . . . . .	211

#### APPENDICES

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<u>A.</u>	<u>DATA FORMS USED IN MEDINQUIRY</u> . . . . .	214
A.1	Clinical Form . . . . .	215
A.2	Initial Therapy Record . . . . .	224
A.3	Pathology Data Form . . . . .	227
A.4	Follow-up Data Form . . . . .	228
<u>B.</u>	<u>CLASSIFICATION SYSTEMS FOR MALIGNANT MELANOMA</u> . . . . .	229
B.1	Staging System For Malignant Melanoma . . . . .	229
B.2	TNM Classification for Malignant Melanoma . . . . .	230
<u>C.</u>	<u>DATA ATTRIBUTES IN PROTOTYPE MELANOMA DATA BASE</u> . . . . .	231
<u>D.</u>	<u>ITEMS IN APPLICATION VOCABULARY AND WORD CLASSES IN</u> <u>GRAMMAR</u> . . . . .	235
<u>E.</u>	<u>EXAMPLES OF CLASSES OF REQUESTS SUPPORTED</u> . . . . .	239
<u>F.</u>	<u>A COMPLETE TRANSCRIPT OF A MEDINQUIRY SESSION</u> . . . . .	250



## List of Figures

1	Overview of MEDINQUIRY . . . . .	53
2	Derivation Sequence for the Specification of Attributes	77
3	Derivation Tree for Query Constraints . . . . .	79
4	Process Model for Inquiry . . . . .	179
5	Knowledge Representation Model . . . . .	185
6	Instantiation of Knowledge Representation Model . . .	189

## Chapter 1

### INTRODUCTION

#### 1.1 Background and Rationale

Data bases in the medical environment have found application in areas such as administrative support, clinical practice, and research studies. As a prerequisite for effective use of data bases, it is necessary to determine the data to be collected, the purposes for which the information in the data base is to be used, and the strategies required to support these purposes. Developing appropriate decision support mechanisms would make these data more easily accessible to problem solvers, especially for those applications which require access to a large store of experiential knowledge. In computer-aided clinical research studies, data bases can support statistical analysis, summarization and tabulation of results, evaluation of alternative therapies, surveillance of compliance with protocols, and the description of the clinical course of a disease. In the area of patient management, data bases can be used in a "consultant" capacity to assist medical decision makers in reviewing prior experience with similar patients. Such a facility is useful for patients with acute as well as chronic disease.

For physicians to examine and effectively use this data, it must be quickly and easily accessible. They must be able to subset the data, according to any classification criteria desired, so they can compare and contrast patients in a flexible manner, identify interesting cases,





match a patient with others in the data base having similar characteristics, tabulate findings, and test hypotheses. Decision support systems providing these capabilities would encourage and support efforts at studying the clinical course of a disease, understanding relationships among variables, assessing prognosis, evaluating therapeutic protocols, and conducting prospective and retrospective studies.

A limitation of current medical data systems is that they are difficult to use, for people who are not familiar with the specialized retrieval operations required, regardless of their simplicity. This is particularly true of physicians or other clinical investigators who are usually unwilling or unable to spend the time required to learn special purpose query languages or conventions. Therefore, an intermediary must act as a translator between the individual who wants to know and the data system that may have the answers. This requirement inhibits intellectual access to the data and prevents the majority of physicians, even those who have collected the data, from having free and informal interaction with their data.

One way of reducing the dependence on an intermediary is to structure the system so that the physician is presented successively with a series of alternatives. Based on the user's selection, the interrogation proceeds along a particular predetermined path. This kind of approach makes it unnecessary for a user to know much about the operation of the system. But, since the system controls the inquiry process, the user is limited in the options that may be initiated and in the order in which they can be considered. This approach has been



characterized as a "menu tree" or "branching logic" model and has found application in many areas of medicine for data acquisition as well as data retrieval. For a strictly hierarchical data base, with a uniform structure and a standard set of operations, such a system may be extremely efficient. However, for working with patient medical records, where the user either wants answers to specific questions concerning patient care, or to pursue a line of inquiry to test a hypothesis, such a system proves to be cumbersome to use.

An alternative approach to the problem of access is the development of a clinical data base system that provides free and informal access through the use of natural language. The computer system developed as part of this research, MEDINQUIRY, is designed to respond to requests posed at a terminal by subject matter experts, in a subset of English, by accessing a data base of patients with malignant melanoma. The system accepts a wide range of natural language requests and, for each analyzed request, generates a formal query request that is passed to the data base, matches the request against the data base, and provides a relevant response to the submitted inquiry. Potentially, it offers significant advantages for the improvement of care in specialty clinics by increasing the availability, in a timely manner, of data that support decision making. The prototype version of this system has been available since January 1978 and is undergoing continual improvement of the conceptual and linguistic coverage and completeness of the system.

## 1.2 Objectives

The overall objective of this research is to develop a clinical



data base system that will allow clinicians, researchers, and other health professionals, personal access to data on specific diseases using queries formulated in English. The longer term objectives are to study the use of the system by physicians, to gain insights into and to model the process of hypothesis formation and testing on the part of experts, and to evaluate the efforts of using the system to aid the physician in patient management and in studying the clinical course of disease more precisely.

This report describes the design and implementation of a prototype natural language question answering facility to provide a direct and convenient interface between an expert and a computerized data base of patients with malignant melanoma, in order to study prognosis, and to support patient management and clinical research. This facility allows convenient access to relatively large amounts of data about patients with malignant melanoma by making it possible to process logically sophisticated queries that entail arranging and rearranging the data in the data base. The goal is to handle that portion of language and knowledge necessary to understand a specific area of medicine.

The specific objectives of this research are:

- 1) to build an application language that contains both domain specific knowledge about melanoma and general knowledge about language that will allow understanding English language requests formulated by clinicians, researchers, and health professionals
- 2) to design and implement a prototype system that will allow clinicians and pathologists to query, in English, a clinical data base on patients with malignant melanoma



- 3) to propose a model that describes how information about melanoma might be organized and to use this model to gain insights into and to support the medical inquiry process

The first objective entails development of formal structures for representing knowledge about malignant melanoma to support medical inquiry and is extendible, in the long run, to other areas of medicine. The second objective is concerned with creating an operational system that uses the application language to analyze and process requests against a data base consisting of patients with malignant melanoma, and providing appropriate responses to these requests. The third objective is concerned with gaining an understanding of the medical inquiry process, and supporting effective inquiry strategies. A model is proposed that describes how information about malignant melanoma, and medical processes in general, might be organized. This model attempts to represent the process of hypothesis formation and testing, using a process and knowledge representation model, to provide a framework that can be used in subsequent work on MEDINQUIRY in particular, and medical inquiry in general. The long term goal (which is beyond the scope of the current research) would be to use the medium of natural language to study the use of the system by experts. An information processing approach would be followed to analyze and evaluate how interactions are performed, to gain insights into the process of hypothesis formation on the part of experts, and to understand the various strategies that may be used in establishing relationships among variables and in studying prognosis and outcome for patients with melanoma.





### 1.3 Research Approach

For a medical expert to make productive use of a computer facility for patient management or clinical research, two requirements are important: (1) there must be a convenient and powerful interface that allows the user to interact directly with the data base; (2) the data available must support the purposes for which the facility is being used.

To meet the first requirement, a language processing package called LIFER (Language Interface Facility with Ellipsis and Recursion), developed at SRI International, is used. LIFER has been developed as a practical system for creating English language interfaces to different kinds of computer software. The selection of the data base for the prototype system was influenced by the University of California, San Francisco's (UCSF) participation in a cooperative group of four institutions which had been collecting data on patients with malignant melanoma. One of the purposes of that collaborative effort was to create a comprehensive data base in machine readable form that would allow study of the clinical course of the disease and the relationship among variables in the data base. A subset of these data, relating to those patients who were seen at UCSF, was selected for inclusion in the data base for the prototype system.

The prototype version of MEDINQUIRY was implemented at SRI International using the LIFER interface package to provide natural language access to a data base of 130 patients with malignant melanoma. The physician can input requests in English that retrieve specified data (on any of 156 attributes in the study) for particular patients or for



groups of patients satisfying certain characteristics, that specify simple calculations to be performed, that allow browsing through the data base, that assist in identifying and studying relationships among patient attributes, and that relate information in the data base to prognosis and outcome.

The approach followed entails compilation of an application language consisting of domain specific knowledge about malignant melanoma that supports inquiry. LIFER interface functions are used to specify patterns, fixed phrases, words in sets, predicates, and pronoun references required to analyze English language requests posed by the user. Functions are written in the INTERLISP programming language to operate with the LIFER parser to construct a formal query request that is passed to the data base, and additional functions are written to respond to the user's request.

A set of grammatical rules, representing the set of potential requests to be processed by the system, were developed based on a comprehensive review of the literature on melanoma, an analysis of the data base, and conversations with experts in melanoma. The classes of questions implemented include the capability to provide information about attributes and their values in the data base, counts of patients with particular attribute value combinations, relations and distributions such as tabulations and tabulated counts, and calculations such as averages and proportions. The system supports dialogue interactions; the user can follow a line of inquiry to test a particular hypothesis by entering a sequence of requests in which one may depend on a preceding one. Phrases rather than complete sentences can be used,

where the meaning of a phrase is interpreted based on an analysis of prior queries. It is possible to define new constructs at both the phrase and sentence level, and a limited capability exists, using a sequence of stored requests, to respond to meta-questions (1). It also is possible to process certain classes of time oriented requests and requests that involve negation. A model is proposed which attempts to describe alternative ways to organize the information used to compose requests about melanoma and to suggest ways for thinking about the process of prognosis.

This research attempts to provide the physician with resources that will allow him or her to enter requests and receive useful information about a disease, in this case, malignant melanoma. By observing the process followed by physicians in posing requests and studying the results of their interactions with MEDINQUIRY, it may be possible to develop criteria for knowledge bases and process models about diseases. The approach is distinctive in that it supports the physician in developing his/her own hypotheses about relations that hold among medical data. It is possible for a physician who uses MEDINQUIRY to introduce into the data base higher order concepts that will help organize the data, but the primary purpose of this research is to make it easy for the physician or medical expert to find out what information is present in a data base and to provide more effective and timely decision support.

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(1) A meta-question is a high order or complex question which contains knowledge about other questions. Thus, a high order question can specify a sequence of simpler questions to be used to respond to the high order question. In MEDINQUIRY, users can more conveniently enter a meta-question, and have it automatically broken down into a set of questions that are answered in sequence. Examples of meta-questions are given in Section 5.3.



#### 1.4 Scope of Dissertation

As this research is of an interdisciplinary nature, in the field somewhat loosely named Medical Information Science, an extended literature review relevant to data access and a review of malignant melanoma is included to provide necessary and useful background information for readers with different backgrounds and perspectives. This material is presented in Chapters 2 and 3.

Chapters 4 and 5 provide a description of the design and use of the prototype MEDINQUIRY system. Chapter 4 presents the components involved in the design of MEDINQUIRY and includes discussions of the considerations in constructing the data base, the nature of the medical information to be studied, the LIFER concept, and the interactive process followed to build an application language interface. Chapter 5 describes the use of MEDINQUIRY, covering the classes of requests currently implemented, ways of extending the responsiveness and acceptability of the system, and provides an extract from a session illustrating the use of MEDINQUIRY to respond to potentially relevant medical inquiries.

Chapter 6 discusses issues in the design, implementation, and use of the system. It describes how temporal relations, negation, and comments are handled in the current release of the system. A discussion is given of the criteria which may be used to evaluate the performance of the system, and a preliminary evaluation is presented of how well the prototype system satisfies these criteria.

Chapter 7 develops an information processing model that attempts to describe how information is organized in support of the medical inquiry

process and presents a framework that represents how questions about melanoma are formulated and posed to the system.

Chapter 8 summarizes the results of the research, describes how the development of MEDINQUIRY is proceeding, and offers several suggestions for further research.

Several appendices are included that provide additional information about MEDINQUIRY. Appendix A contains the forms used to collect data for MEDINQUIRY, while Appendix B presents two of the classification systems used in staging patients with malignant melanoma. Appendix C lists the data attributes in the current data base, while Appendix D lists the vocabulary items and word classes used in the application language. Appendix E provides an extensive set of examples of requests currently supported, and Appendix F gives a complete transcript of a session.

## Chapter 2

### LITERATURE REVIEW

This chapter presents a review of selected literature on methods used to access medical data, and recent work in problem solving strategies and artificial intelligence in medicine that relate to knowledge-based systems and the process of hypothesis formation and testing. This overview provides a framework for viewing related research, and also presents the range of applications using these methods for a variety of purposes.

#### 2.1 Access Methods

Previous efforts to provide an interface between the user and a data base can be characterized as follows: formal query languages, menu trees (or branching logic), and natural language access. Each of these approaches will be described and pointers will be given to the relevant literature describing medical applications that use these approaches. The data that are to be accessed are stored in the data base either in coded form or as textual strings, and access is performed either online or offline as a batch job. Although not covered extensively in this review, these approaches are also used for data acquisition and for interfacing with data base management systems. The special issues involved with the encoding of free text are not considered in this review. See Pratt (1971) for a review of the methods used to encode pathology statements using a categorized nomenclature, and Pacak and Dunham (1979) for a survey of work on coding medical language statements.





## 2.2 Formal Query Languages

Formal query language methods make use of a relatively rigid formal structure. The user of the system must specify both the attributes and values to be matched against the data base and the operations that must be performed on the retrieved data to display the required results. The statements of the query language may consist of explicit or implicit "if, then, else" clauses, or of boolean expressions whose elements are propositions relating attribute and value pairs. The complexity of the languages and their unnaturalness combine to make them difficult to learn. Moreover, to maintain competence, once acquired, it is necessary to use the system frequently. As a result, most occasional users rely on an information specialist who acts as an intermediary to translate their requests into the formal expressions the system can process. This process may introduce misunderstandings of what was requested as well as delays in obtaining the desired responses. Formal query languages have been used effectively in medicine in situations where the number of distinct attribute names in the data base that may be searched is small, or the number of questions that can be asked is limited. Several examples are now given of systems that illustrate the context within which formal query languages are used to support the retrieval of information.

Beaman, Justice and Barnett (1979) have developed and implemented the computer-based medical information system COSTAR (COMputer STOREd Ambulatory Record) that supports the medical, administrative, and financial requirements of an ambulatory group practice. During a patient visit, the data are collected on encounter forms, and then entered into



the data base (see Barnett et al., 1979). A formal query language MQL (Medical Query Language) is used to retrieve patient information from the data base and to respond to unanticipated data analysis requests that are posed of the data base. A query request consists of a series of statements each beginning with a keyword such as, WHEN, LIST, DEFINE, DO, STORE, or RETRIEVE. A sample request is "WHEN SEX = MALE and AGE > 40 LIST NAME, UNIT , PRIMARY MD". A facility is also provided that allows the requestor to formulate queries that express temporal relationships between events in the medical record. In addition, a report generator is available that uses an interactive menu-selection scheme to generate certain predefined listings and/or tabulations.

At Duke University, a computer-based data management system has been developed for acquiring data and estimating prognoses for patients with coronary artery disease (Starmer et al., 1974; Rosati et al., 1975; Starmer and Rosati, 1977). The hope is that actual experience present in the data base can be used to accumulate new knowledge about the "best" strategy to be followed for a given patient. The Duke system produces a "prognostigram" for patients with coronary artery disease, taking into account different modes of therapeutic intervention. The emphasis is on selecting from a large number of patients with coronary artery disease, seen over long periods of time, a subset of patients who, according to specified criteria, match a patient currently under consideration. The clinical experience of these patients with different therapeutic strategies is displayed, and is available for analysis. In addition, the incidence of secondary events is tabulated comparing patients managed medically or surgically on characteristics such as previous



history of myocardial infarction, duration of ischemic heart disease, or prior therapy with beta blockers. Observed variation in outcome among groups of patients with similar characteristics may aid in detecting "missing descriptors" required for accurate predictions. This system uses a formal query language (MIDAS) to search the data base. For example, the request "AGE < 40 and AGE >= 30 and AV02D < 5.5 and (NO = 1 or NO = 2) and Surgery = YES" will search for patients with ages between 30 and 39 with arterio-venous oxygen less than 5.5 vol % who had one or two diseased coronary vessels and who were treated surgically.

Okubo and Lampson (1977) describe access to a data base on surgical pathology, autopsy, nuclear medicine and neuro-radiology data. The data in the data base are coded and stored as synonym class numbers, and a thesaurus is used to define the correspondence between those synonym classes and the query language. An information analyst interacts with the user to help define the questions, which are then input using a formal query language. Platt et al. (1974) also make use of a formal query language to access a data base of surgical pathology and autopsy results. Statements in the language are translated into keywords with appropriate logical connectors, and then used to access the text strings which are stored in the data base.

For more complex requirements, various features have been developed to aid the user in query formulation. Kenton and Scott (1978) present the MEDLINE philosophy for search and retrieval from a large bibliographic file of medical documents. Searching reference data, abstracts, and textwords is accomplished by entering a request using key words with logical connectors. The system thesaurus, Medical Subject



Headings (MESH), aids the user in the selection of appropriate search terms.

The Systematized Nomenclature of Pathology (SNOP) is used in a similar manner in a system developed by Epstein and Harper (1969) for retrieving autopsy, surgical pathology, and cytopathology data. In their data base, the number of attributes is limited and the codes corresponding to the concept to be searched on can be found in SNOP, and used to guide the user in constructing a query request.

In an attempt to augment conventional data analysis to assist in clinical assessment and decision making, Osserman et al. (1978) describe a computer-based system COMTRAC (COMputer based case TRACing) that supports graphical display of results for patients with multiple myeloma. In response to a request entered in a command language, a search is made of the data base and graphical output is provided on either a CRT or as hard copy. An advantage of such displays is that trends can be easily presented and analyzed, and comparison can be made of the efficacy of different therapeutic approaches. Only several pre-selected variables may be used in creating the displays; however, the query language can be used to retrieve information on other attributes in the data base.

### 2.3 Menu Trees or Branching Logic

A second approach that has been applied to data access is the use of menu trees or branching logic. This approach attempts to reduce the dependency on an intermediary by designing a system that prompts the user to enter an acceptable value (for example, a yes/no answer or a



The first part of the course covers the basic concepts of algebra, including the properties of real numbers, the operations of addition, subtraction, multiplication, and division, and the concept of a function. The second part of the course covers the basic concepts of geometry, including the properties of lines, angles, triangles, and quadrilaterals, and the concept of area.

The third part of the course covers the basic concepts of trigonometry, including the properties of sine, cosine, and tangent, and the concept of the unit circle.

The fourth part of the course covers the basic concepts of calculus, including the concept of a limit, the derivative, and the integral.

The fifth part of the course covers the basic concepts of statistics, including the concept of a mean, a median, and a mode, and the concept of a standard deviation.

The sixth part of the course covers the basic concepts of probability, including the concept of a probability distribution, the binomial distribution, and the normal distribution.

recognized text string), or to choose (possibly using a light pen or other similar device) from several options. Each selection results in the generation of subsequent sets of alternatives until the request has been completely formulated. Profiles for different classes of questions can be created and stored and subsequently used to collect the parameters required to produce the desired response (for example, to search the data base and create appropriate tabular forms for output, or to apply appropriate statistical routines). This type of organization makes it unnecessary for a user to know much about the structure of the system or to learn a formal language. However, since the system controls the inquiry process, the user is limited in the operations that may be initiated and the order in which the options may be considered. For users with a considerable amount of experience, who know exactly how to ask for what they want, this procedure may appear to be tedious. In addition, it may be necessary to create new logic trees (that is, new profiles) for each new class of request.

This approach has been applied in many areas of medicine for data acquisition as well as data retrieval. In fact, the appeal of this method for retrieval derives in large part from the availability of the methodology developed for data acquisition. Furthermore, in many medical applications the retrieval application has followed and built on the data acquisition methodology. Often, predefined batch programs are used to produce well specified tabular outputs, and only a limited general purpose retrieval facility is available.

In the area of data acquisition, the Technicon Hospital Information System (Barrett et al., 1975; Hodge, 1977; Sneider et al., 1979) is an



example in which branching logic has been applied in an actual hospital environment and is an integral part of a total hospital information system, which has been demonstrated to be cost-effective. The Technicon system serves as a data communication interface monitoring the transmission of data between nursing stations, the clinical laboratory, hospital admissions, and other units of the hospital. A limited facility exists for the display of data for a particular patient while in the hospital, although all reports generated by the system are inserted in the patient chart. A more ambitious retrieval system for archival data, using branching logic methods, is currently under development at the National Institutes of Health (Lewis and Macks, 1977).

Greenes et al. (1970) describe a prototype computer-based medical record system that uses a tree structured organization to acquire progress notes on patients with hypertension. For research retrieval the physician interacts with the system, in a mode similar to that used for data acquisition, to find all records in the data base that meet the specified constraints.

Zuckerman and Stenn (1977) have developed a general purpose end user report generator for use with the COSTAR system to retrieve outpatient data. The report generator uses command prompts such as: Select, to specify groups of patients or visits; List, to define attributes to be displayed; and Tab, to indicate cross tabulations that assist the user in specifying the organization of the report.

A relatively complex system that uses a branching logic approach for retrieval is the ARAMIS system at Stanford (Fries, 1972, 1976; McShane et al., 1979) for studying patients with rheumatic diseases. In



this system, patient data from several medical centers have been collected and stored in data bases using the Time Oriented Databank System (TOD) as a framework for organization. The computer databank contains precise clinical information that would allow a systematic approach to such issues as determining prognosis, and evaluating outcome with different treatments. It is possible to compare an individual patient with patients most similar in the data base, and to determine "best" predictor variables using statistical methods such as, multiple logistic regression, nearest neighbor methods, and life-table analysis. Retrieval is accomplished through use of predefined protocols that interrogate the user for the necessary information to complete a request for a particular statistical computation, a specified summary report, or other displays. The Time Oriented Data Base system is currently being extended to other application areas in medicine such as a National Stroke Data Base and a cancer data base.

The CLINFO system (Groner, et al., 1977; Palley, et al., 1977), which has been implemented on a minicomputer, uses some of the same methodology as the ARAMIS system. However, it deals with smaller data bases and provides computer "worksheets" that allow the user to establish a personal format for his own data, and then to browse through these data. Data and results may be displayed in tables, plots, or histograms. The worksheets also can be manipulated to request that particular statistical computations or retrieval operations be performed. The retrieval operations use the "Subset" option to identify and establish subgroups of patients, based on specified criteria; and the "Retrieve" option to enable moving selected items into worksheets



for study. The CLINFO system is now available commercially through Bolt Beranek and Newman (see Bolt Beranek and Newman, 1979).

Feinstein et al. (1972) use menu trees to construct queries for a data base of patients with lung cancer. This system collects, from the user, a set of parameters describing a patient with lung cancer, and then attempts to assess how patients in the data base, with similar characteristics, have done in the past. The user of the system can modify the definition of "similar" to include as large a group of patients as may be required to compare with the patient under consideration. Reviewing the prior experience of those patients with similar characteristics might assist the physician in deciding how to treat the patient under consideration.

Hall et al. (1979) describe a general purpose clinical data base system called MARI (Medical Aggregate Record Inquiry) that provides for exploratory and aggregate analysis of information in a general patient data base. Retrieval is accomplished using a modified menu-tree approach in which the user is prompted in a stepwise manner, by a displayed menu-tree, to compose a request. The menu-tree allows the user to specify commands by entering either the first letter of the displayed option or, when appropriate, a keyword (or code) associated with items in the data base. MARI completes the commands and provides additional information to create a complete English query. The following general capabilities are supported: (1) retrieval of information on a particular patient; (2) retrieval of one or more attributes across a group of patient records; and (3) analysis of relations between and among variables in a selected subset of patients. The authors have created a





facility that also enables the study of the physician's decision making process in the hope that MARI can assist with this process.

Miller and Strong (1978) and King et al. (1980) describe a generalized data base management system, MEDUS/A, to manage data collected in the clinical care process. Both a formal query language (MEDIQ) and a branching logic facility (Interactive Query System) are provided for the user. Those classes of requests that are used often are stored as query profiles. Fox (1978) also describes a data management system ACIS (A Clinical Information System) that uses a data definition language and a schema to accept descriptions of the data base and generate PL/1 programs to construct the data base. Retrieval is done using menu-trees which prompt the user in creating a boolean request to be matched against the data base. SNOMED (Systematized Nomenclature of Medicine) is used to both encode information in the data base and to specify items to be retrieved.

Safran et al. (1976) have as their primary objective the application of decision theoretic methods to assist in formulating diagnostic plans for patients with Hodgkin's disease. The data base consists of patient cases collected at Stanford University and from reports in the literature. Searching of their data base is accomplished by an interactive program that asks a series of questions to construct a retrieval request. The results of a search of the data base is a "prognostigram", with either a calculation of survival or disease free interval for patients who match the criteria in the request.

Schoolman and Bernstein (1978) and Bernstein et al. (1980) describe the use of branching logic to retrieve information from a "computerized



textbook" on viral hepatitis. The knowledge base of the system, which is created and updated by medical experts, contains a concise summary of what is known about viral hepatitis as described in the medical literature. The user browses through the table of contents displayed on a terminal and selects, on the basis of header statements, the associated paragraphs that seem likely to contain information of interest. These paragraphs can then be displayed and adjacent paragraphs can be accessed easily. It is necessary to return to the table of contents for subsequent requests. Current plans involve construction of similar knowledge-based systems for human genetics and peptic ulcer disease. An extensive research and development effort is planned to create a computer based system for the acquisition and representation of this knowledge, and for access to these knowledge-based systems.

The branching logic approach also has been used extensively in computer assisted instruction (CAI), where it has proved especially useful in supporting dialogue interaction between a person who is learning about a particular subject area and an instructional program for that area. An overview of the many CAI programs in medicine is given in Kamp (1975). Deland (1979) contains a collection of papers reviewing work in the area of computer-assisted instruction that have attained wide acceptability in several institutions. It is pointed out that to be used, and thus useful, these systems must meet the criteria of user acceptance, cost effectiveness, and goal fulfillment.

#### 2.4 Natural Language Access

The third and most recent approach to providing access to data is



through queries expressed in natural language. The underlying technology is an outgrowth of a long history of research in computational linguistics (see Walker (1973) and Damerau (1976) for detailed surveys of this work), but it is only recently that practical natural language interfaces have become available for such an application. The motivation for providing natural language access to a data base is to reduce the requirements for special training on the part of the user. The objective is to make it possible for a specialist in a particular subject area, without special computer experience, to engage in the kind of dialogue with the system, about the information contained in the data base, as he might with a person. The natural language interface will allow users to formulate requests that more closely resemble the thought process of the user than would be possible with other methods for data access. The language constructs used need not be explicitly specified or anticipated in the initial design of the system. Moreover, the user is in direct control of what he wants to do at any given time.

Several such systems, outside of the medical areas, are currently undergoing extensive experimental tests in real environments. Of special interest are the efforts of Hendrix et al. (1978), Codd (1978), Waltz (1978), Harris (1979), Woods (1978), Petrick (in press), and Martin (1978).

In medicine, several projects that address the issue of natural language access are underway. The prototype MEDINQUIRY system, described in this research, perhaps provides the most comprehensive capabilities for English language access to a medical data base, but other groups are also working along similar lines.



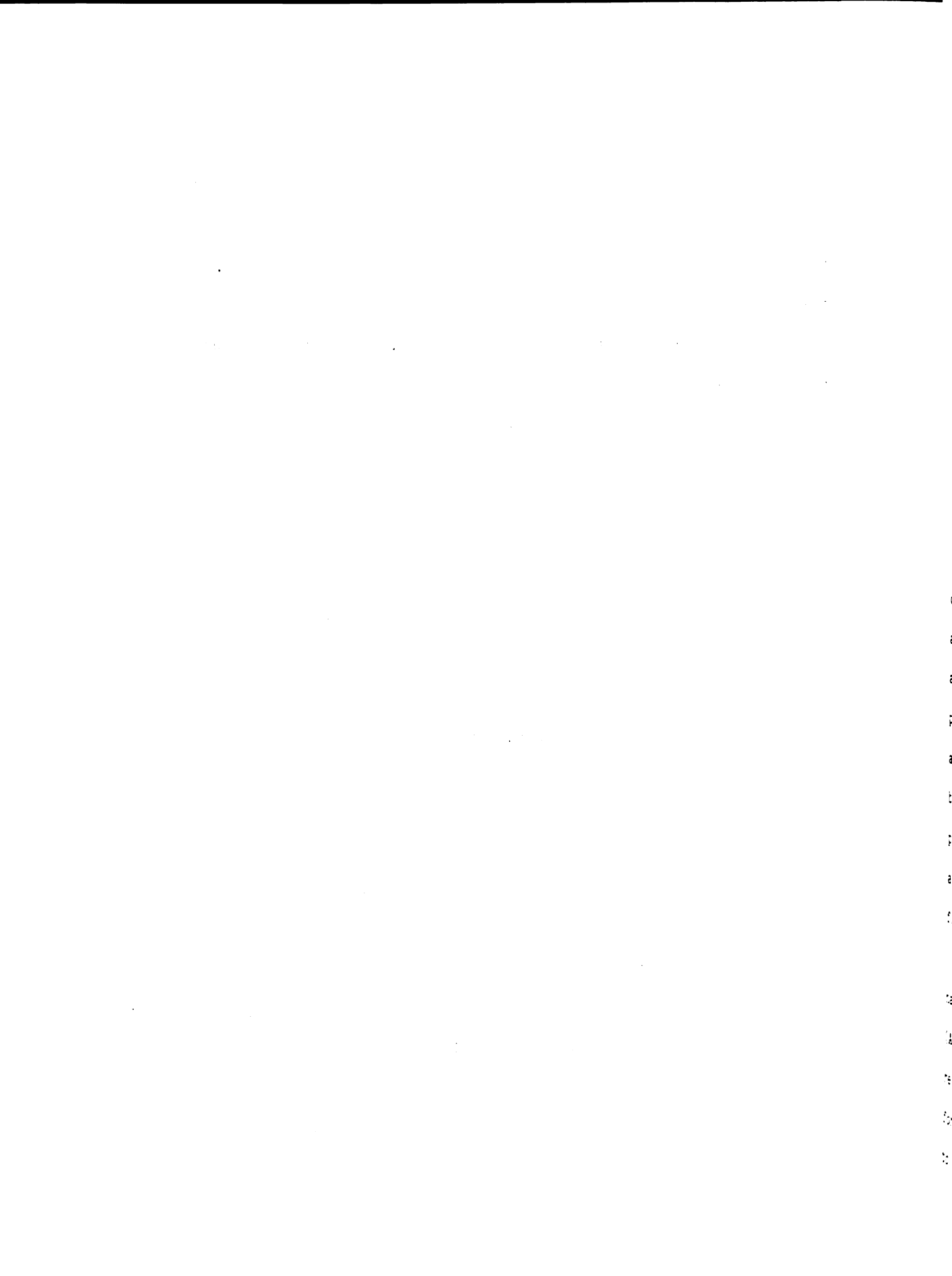
Scott et al. (1977) in their work on MYCIN, a consultation system for antimicrobial therapy, have developed a language facility for interpreting simple English questions without contending with some of the more complex issues in natural language processing. It was introduced specifically to allow physicians to ask for explanations of particular actions that MYCIN has taken. The authors explicitly recognize the importance of such a capability for obtaining user acceptance of the overall system.

A long term effort has been underway at the New York University Linguistic String Project (Grishman and Hirschman, 1978; Sager et al., 1978) to develop methods for both encoding natural language data in a tabular form, and then retrieving the formatted data using questions formulated in English. Currently, this group is working on the encoding and retrieval of radiology reports and pediatric discharge summaries. They use a complex syntactic analysis procedure in both encoding and retrieval operations. They note, however, that the question answering component is still quite rudimentary.

Wong et al. (1978) have started work on a prototype system that would support natural language inquiry for pathology data.

Woodyard (1979) describes MEDQUEL (MEDical QUery Language), a prototype system that supports English language inquiry of a clinical data base of patients with renal disease. The INGRESS data base management system, running under the UNIX operating system, is used for the management and retrieval of clinical records. The limited natural language facility allows the decision maker to directly formulate simple requests or requests that can be fully specified. In the prototype





system, a small vocabulary and a small number of rules are used. The natural language request is analyzed and processed as follows: lexical analysis of the request to identify relevant words, parsing of the query using an augmented finite state machine, construction of a formal query request, and execution against the data base. To enable more sophisticated analyses within MEDQUEL to support decision making, Copland, Hamel, and Bourne (1979) are developing a system for exploratory data analysis. The system operates in "exploratory" mode to guide an unsophisticated user through the process of selecting suitable data analysis strategies. The prototype system supports various statistical analyses and the processing of certain temporal data.

Corley and Underwood (1979) discuss the design and implementation of a system for access to a data base of patients seen at a HMO. The approach used couples a limited English language capability, which allows the recognition and processing of noun phrases, with a menu-tree prompting strategy. The menu-tree is used to select the question class and the limited English language is used to specify the constraints to be included in the request. The access module described is part of a prototype medical record data base management system that also includes a coding scheme used to semantically encode the source data to facilitate retrieval.

Fox (1979) uses an augmented transition network to provide a natural language front end to a data base management system called ACIS (A Clinical Information System). There appear to be a limited number of requests that can be parsed and mapped into appropriate ACIS commands for access to the data base. The author also is exploring an interface to ACIS using the Robot natural language processor (see Harris, 1978).



To provide more convenient and flexible access to bibliographic data bases and knowledge bases, Doszkocs et al. (1980) are developing CITE (Current Information Transfer in English) which uses an English-like query language for retrieval of information. Requests are formulated in English, a search is performed on a document or textual data base using the key words in the request, a weighting algorithm ranks the retrieved information which is then displayed in order of decreasing weights. Requests are not analyzed by syntactic or semantic analyses; however, the approach provides a way to ask questions without the constraints of a complex query language, or the need for an intermediary to formulate the request and participate in the query process.

The use of limited natural language in medical student education is illustrated by the CASE (Computer Aided Simulation of Clinical Experience) system (see Harless et al., 1973a). A student assumes the role of a practicing physician and interacts with CASE without being restricted in the language used in the dialogue. The procedures applied to understand and respond to free English statements involve: identifying key concepts, searching for qualifiers or modifiers to focus on specific meaning, and using a contextual search to request clarification when necessary. These strategies provide a practical approach to conducting dialogues in medical education where the statements processed are relatively uncomplicated and focused, and the domain to be understood is relatively limited in scope. A generating system, Genesys (see Harless et al., 1973b), allows construction of cases representing a wide variety of patients with different disease manifestations.

## 2.5 Recent Work in Problem Solving Strategies and Artificial Intelligence Research

It is appropriate in this review to briefly consider the relevance of work in problem solving strategies, and artificial intelligence research as applied to medicine, even though it does not directly address the problem of data access. Epstein and Kaplan (1977) provide a useful perspective that will help clarify the relationship between these two areas in their examination of criteria for clinical decision making. They derive these criteria from the way that physician's decisions depend directly on knowledge bases and process models, formalizations of which contribute to a major part of the related work within problem solving strategies and artificial intelligence. Process model criteria deal with functional blocks of data acquisition, data analysis (which includes hypothesis selection and testing), and plan formulation with associated feedback between functional blocks. Knowledge representation criteria include items such as relations, strength of relations, levels of information, and diagnostic and therapeutic procedures.

Both process models and knowledge bases are used in studying the problem solving strategies employed by physicians. Researchers have used the paradigms of information processing, clinical judgment, and decision analysis in the hope that such paradigms can provide a conceptual framework for analyzing the problem solving process and assist in developing models of these processes. In addition, understanding the strategies used can aid in creating programs that better support the problem solving needs of experts.

An information processing approach has been followed by both



psychologists and clinicians in trying to understand the conceptual strategies and structures used by the problem solver. It is described here in greater detail than the other paradigms since this technique is especially relevant to the research described in this paper. The information processing approach to problem solving is based on understanding the process which takes place between the initial state (input) and the final state (the desired goal), and to record the sequence of steps followed in the process. Kleinmuntz (1970), concerned with understanding the process of hypothesis selection, studies the sequences of hypotheses employed by neurologists in acquiring data to make decisions. To determine the heuristic principles used, he applies the usual information processing procedure of observing the subjects (in this case, physicians) "thinking aloud". The output of this analysis are binary trees, which model the processes of a single neurologist and the composite strategies that a group of neurologists apply in making a diagnosis. Wortman (1972) also studies computer-aided diagnosis as a problem of simulating clinical reasoning, and incorporates into a computer program structures that demonstrate "understanding" of the reasoning process in the domain of neurology. His model attempts to predict the performance of the problem solver. He hypothesizes that physician search strategy first involves a hierarchical search of the proposed memory organization; if blocked in determining the diagnosis, a sequential search of other alternatives in the model is performed (see Wortman and Kleinmuntz, 1972).

Elstein et al. (1978) conduct a detailed study of the reasoning process of experienced internists as they engage in diagnostic problem





solving. They analyze the verbalized problem solving behavior of clinicians using simulated clinical cases, and control the sequence and amount of data presented in an attempt to determine which variables play an important role. The process model used is composed of four general steps: (1) cue acquisition: data are collected from history, physical exam, or laboratory results, (2) hypothesis generation: data collected are used to formulate alternative hypotheses relevant to the potential problem, (3) cue interpretation: data are interpreted using the hypotheses under consideration, (4) hypothesis evaluation: evidence collected is used to confirm or refute the diagnostic hypotheses generated. These steps are repeated until the problem is solved. Some of their findings suggest that the chief complaint establishes a small set of working hypotheses. Only a small number of hypotheses are considered at one time, hypotheses are generated early in the patient workup when only a small amount of data has been collected, and both general and specific hypotheses become more focused as additional information is gathered and interpreted.

A similar project is being conducted by Kassirer and Gorry (1978) who analyze protocols of the problem solving behavior of six clinicians, taking the history of present illness in a simulated patient, to arrive at a diagnosis. Their conclusions are similar, in many ways, to those of Elstein. Their observations include:

- 1) when only small amounts of data are available, a sharp focus in problem solving behavior occurs with rapid generation of hypotheses;
- 2) the initial hypothesis is important in providing a context for the remainder of the problem analysis;

- 3) physicians continue to search for complications that require immediate care, even after the diagnosis is determined;
- 4) the diagnostic process differed among experts depending on their primary area of expertise;
- 5) numerous strategies are used to explore, confirm, or reject hypotheses.

Studies of clinical judgment usually take the form of reflections on how experienced clinicians develop problem solving strategies. This paradigm has been used in teaching students and other medical professionals to reason in a logical and rational way and thus, attempts to describe the processes used from the point of view of the expert clinician. See Feinstein (1967), Wulff (1976), and Cutler (1979) for their perceptions of what clinical judgment is about. A conference held at UCLA in 1977 (see Engelhardt et al., 1979) includes a collection of papers that present various perspectives on the subject of clinical judgment.

The decision analysis paradigm provides a quantitative method for making diagnostic and therapeutic judgments. It provides a methodology for describing complex problems in a direct way. These are the steps followed: the problem is structured as a decision tree taking into account the possible actions (tests, treatments) that may be taken by the decision maker and the various states (alternatives) that the patient might be in. Analysis of the decision tree involves estimation of the probability (likelihood) of each possible state, and the values (or utilities) of each possible outcome. Based on this information, overall utilities are calculated to suggest the optimal path that might

be followed. Sensitivity analysis should be performed to determine how the model responds to changes in various parameters. Discussions on the use of decision theoretic techniques may be found in Pauker and Kassirer (1978), Schwartz (1979), Weinstein and Fineberg (1980), and Bunker et al. (1977).

Recent developments in artificial intelligence are providing procedures that may provide new capabilities for physicians, particularly in support of judgments they make during diagnosis and therapy. For example, programs like MYCIN (Shortliffe, 1976; Davis, 1977) and INTERNIST (Pople et al., 1975; Pople, 1977) are developed by formalizing and incorporating into a knowledge base, sets of rules that are believed to underlie the behavior of physicians in making judgments about, respectively, antimicrobial therapy and differential diagnosis in internal medicine. A different strategy is followed in CASNET (Weiss et al., 1978), which incorporates a representation of the pathophysiological processes that take place in glaucoma. Szolovits and Pauker (1978), in reviewing these three systems as well as their own Present Illness Program (Pauker et al., 1976), conclude that although they demonstrate expert-like behavior, none is yet capable of the reasoning that an expert possesses. The methods used in these applications include semantic networks, production rules, and Bayesian procedures to collect data and compile evidence to support a particular diagnostic or therapeutic decision.

The practical use and acceptability of expert, knowledge-based, consultant systems would be greatly enhanced by the availability of flexible and convenient user interfaces. Several prototype systems use



natural language as an interface to expert consultation systems for the acquisition of rules to construct a knowledge base, and for directly collecting data required for a consultation. Bonnet (1978) describes a prototype system, BAOBAB, which uses a semantic grammar to support natural language rule acquisition for MYCIN, directly from the expert. The user enters the proposed rules in English, the system interprets the statements, and asks the user to verify the correctness of the rule; if acceptable, the rule is added to the MYCIN knowledge base as a production rule. To support natural language acquisition of data for MYCIN, Bonnet (1979) uses a semantic grammar to analyze medical statements as they are input by experts. Knowledge is broken into schemas that model different types of structured text expected as input. For each statement typed by the expert, a paraphrase of what is understood is presented; when input is incompletely understood, additional questions are asked to clarify what was intended. Ciesielski (1978) also is developing a natural language front-end for the CASNET/Glaucoma consultation system. The system accepts a language description of a case, and converts those descriptions into coded input for use by the consultant system.

A promising approach for providing enhanced decision support for researchers, involves the application of artificial intelligence techniques to patient data bases to provide clinically meaningful interpretation of information in data bases. Programs such as those being developed by the RX project, attempt to develop heuristic procedures that assist an investigator to intelligently formulate hypotheses for statistical tested against an ARAMIS data base (see Blum

and Wiederhold, 1977; Blum, 1979). Given a hypothesis to be tested, criteria are generated by RX for selection of relevant patient records. A suitable user interface, possibly natural language, to specify the statistical procedures to be performed, would provide an even more powerful problem solving capability.

Although the information processing and artificial intelligence approaches described are concerned with the diagnostic problem solving process, similar methods may be fruitful in modeling and understanding how experts formulate and verify hypotheses in question answering dialogues. The inclusion of a knowledge base and process model in question answering systems would provide the decision maker with more flexible and intelligent access to information present in data bases or knowledge bases and thus, augment their ability to use this information in problem solving.



## Chapter 3

OVERVIEW OF MALIGNANT MELANOMA

This section reviews some of the relevant literature and describes some of the current knowledge about malignant melanoma. The purpose is to provide some background for the reader who may be unfamiliar with the disease. It is intended to identify medically important areas of inquiry, and thus suggest queries that might be formulated and tested using the melanoma data base. It may also clarify the motivation for the linguistic and conceptual coverage that needs to be developed to understand requests about melanoma.

3.1 Epidemiology

Malignant melanoma is a lethal, though uncommon, cancer of man which arises from neoplastic changes in pigment cells. Most of these occur on the skin, often in a pre-existing mole or lesion. They are most frequently seen in individuals with blue eyes, red hair, poor tolerance to sunlight, or who develop sunburn on short exposure. Incidence of the disease in the United States is approximately six per hundred thousand individuals or 10,000 new cases of malignant melanoma per year, with approximately four thousand deaths from it occurring each year (see Young et al., 1978) (1). The incidence of melanoma varies by geographic area; the San Francisco Bay Area has reported an overall incidence of ten to eleven per hundred thousand individuals, while Metropolitan

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(1) The references on malignant melanoma are included in a separate section beginning on Page 211.



Detroit has an overall incidence of four per hundred thousand individuals. Exposure to sunlight may play a role in the development of melanomas (see Elwood et al., 1975). Convincing epidemiologic data have been compiled that implicate sunlight as a cause of basal and squamous cell carcinomas. Some evidence that malignant melanomas are caused by sun exposure is based on epidemiologic studies showing that light skinned Caucasians, exposed to large amounts of solar radiation, have a higher incidence of melanoma (see Davis, 1976). Although relatively uncommon, it occurs mainly between the ages of thirty to fifty years, an age group ordinarily relatively free of malignant disease.

### 3.2 Diagnosis

Primary malignant melanoma of the skin is ordinarily easy to detect by clinical examination. These primary malignant melanomas, even 3-4 mm. in size, can usually be recognized by certain simple criteria. Variegation of color, irregular borders, and irregularities in surface pattern configuration are characteristic features. Color change signs of malignant melanoma that are of diagnostic significance include shades of red, white, or blue, or these colors with brown or black. Other characteristics important for the recognition of melanomas include: change in size, change in pigmentation, change in shape, bleeding or ulceration of the lesion, and irritation occurring with increased frequency. Some studies indicate that primary cutaneous melanoma may exist in a silent, intra-epidermal, preinvasive form for several years. Early detection of melanomas provides the best hope for long term cure. A biopsy, preferably an excisional biopsy, should be performed on



suspicious lesions. References to an overview of diagnosis of melanoma may be found in Mihm et al. (1973) who present a color atlas detailing the clinical signs of malignant melanoma to aid in early diagnosis, and in Clark et al. (1974) and Sober et al. (1979) who describe criteria in making the diagnosis of melanoma.

### 3.3 Histologic Classification

Management of individuals with malignant melanoma and assessment of prognosis are based, in large measure, on histologic classification of primary cutaneous malignant melanoma by type, level, and thickness of tumor. Clark et al. (1969, 1975), and McGovern (1970) developed the classification of human malignant melanoma by type of melanoma and level of invasion.

In order of increasing lethality of disease, the common types of melanoma are lentigo maligna melanoma (LMM), superficial spreading melanoma (SSM), and nodular melanoma (NM). The terms radial (or lateral) and vertical growth phases can be used to describe and understand the developmental biology of the types of melanoma. Lentigo maligna melanoma is related to chronic sunlight overexposure and is usually seen in older patients. It is uncommon and constitutes about five percent of melanomas. It develops within Hutchinson's melanotic freckle and grows radially with much later development of a vertical growth phase. Melanoma of the superficial spreading type (with radial growth phase of the radial spreading type) is the most common, constituting about seventy percent of melanomas. These lesions may take years to develop and consist of a radial growth phase (or horizontal



growth phase) with a later vertical growth phase as the development of the lesion progresses. Melanoma of the nodular type, the most lethal form of melanoma, begins with a vertical growth phase (or a minimal radial growth phase), and is usually deeply invasive when first detected. Prognosis is directly related to tumor thickness at time of diagnosis; thickness at time of diagnosis is related to ease of recognition; ease of recognition is related to clinical size; and clinical size is related to radial growth phase. Good prognosis is associated with melanomas which have only a radial growth phase, with poorer prognosis once the vertical growth phase begins.

Two other forms of malignant melanoma, much less common than the three described above, are briefly noted. Acral lentiginous melanoma (ALM) is a specific type of melanoma limited to the palms, soles, and subungual sites (e.g., beneath the nails of thumb and toes). ALM are those volar and subungual melanomas that are not classified as SSM or NM. The clinical features of ALM are similar to those of LMM, and like LMM and SSM, they also develop through a radial and subsequent vertical growth phase. ALM is distinguished from SSM and LMM through study of the histologic features of the radial growth phase of these three forms of melanoma. A fifth type of melanoma, mucosal lentiginous melanoma (MLM), occurs in the mouth, nasal cavity, sinuses, vagina, and anus and may be more prevalent in blacks and orientals than whites. They are often not diagnosed until the vertical growth phase has begun. The histologic picture is similar to LMM, but the biologic behavior is more similar to SSM. Eventually, ALM and MLM may come to be regarded as similar neoplasms and be classified as a single type of melanoma.



Invasiveness in each of these types is further subdivided into levels I, II, III, IV, and V. The level of invasion is defined as follows:

- Level I: above the basement membrane of the epidermis, called in-situ melanoma with tumor confined to epidermis. These lesions are called "atypical melanocytic hyperplasia" and are not considered malignant lesions.
- Level II: tumor invading the papillary dermal layer but not extending into the reticular layer.
- Level III: tumor filling and expanding the papillary layer but not invading the reticular layer.
- Level IV: tumor penetrating the reticular dermal layer.
- Level V: tumor invading the subcutaneous fat.

This classification, by type and level, serves as one guide to prognosis, and may be a reflection of certain basic biologic phenomena occurring in primary melanoma. Likelihood for survival of individuals with malignant melanoma decreases with increase in level of invasion. Outcome is worse for patients with primaries without an intra-epidermal component, that is, nodular melanomas. This is likely due to their being detected later, and therefore they are more deeply invasive. It is probably the case that SSM and NM behave in a like manner given the same level of invasion.

A third way of classifying melanoma is to measure the depth of invasion (see Breslow 1970, 1975). The use of depth of invasion correlates well with the Clark-McGovern levels in spite of skin thickness differences between individuals and different areas on the skin. This method is easier to measure than level, and the results are more easily reproducible. It has been recently suggested as a better





method for predicting prognosis and outcome for patients with melanoma (see Breslow et al., 1978 and Eldh et al., 1978). Studies by Breslow (1975), Holmes et al. (1976), and Wanebo et al. (1975) indicate that primary malignant melanomas of the skin can be grouped histologically as low risk, intermediate risk, or high risk. To a large degree this grouping is based on tumor thickness. Primaries less than .76 mm. in thickness are considered low risk; those between .76 and 1.25 mm. are considered intermediate risk; and those greater than 1.25 mm. in thickness are considered high risk. A recent paper by Gromet et al. (1978) suggests that thin primaries showing the phenomenon of tumor regression, are to be assigned a higher risk than that assigned by thickness alone.

#### 3.4 Classification Schemes for Staging Melanoma

Classification schemes can be used to provide a clinical or histologic description of the patient's state, to aid in selecting treatment, to assist in determining prognosis for the individual patient, to aid in communicating more precisely about patients with cancer, to make possible meaningful comparisons of outcome reported from different sources, and to assist in therapy evaluation.

The following general staging system has been proposed for malignant melanoma.

Stage I - represents local disease without metastatic spread

Stage II - represents tumor confined to the regional lymph nodes

Stage III - represents disseminated spread of disease beyond regional nodes



Each of these stages can be extended to include substages to more accurately describe disease extent. Appendix B presents the pathological staging scheme, with substages, used in this study to stage individuals with malignant melanoma.

Staging is an integral part of the disease model for melanoma. Depending on the evidence available at a patient encounter, a stage may be assigned based on clinical or histological information. Use of the above staging scheme for patients with malignant melanoma, when coupled with other attributes such as type, level and tumor thickness, explicitly identifies and names the current state of the patient. The extent of a patient's cancer may be estimated at various times, beginning with the initial examination and treatment, through subsequent follow up encounters. Multiple classifications may be assigned as the state of the patient changes over time. Staging can be used, together with other characteristics of the cancer and the patient, in determining optimal therapy and in estimating prognosis.

The TNM classification scheme (see Manual for Staging of Cancer, 1977) is also widely used in cancer studies. The TNM classification is made up of 3 categories T, N, and M.

- T - describes increasing sizes and involvement of the primary tumor
- N - describes the presence or absence of metastases to regional lymph nodes
- M - describes the presence or absence of distant metastases

Items in the categories T, N, and M are grouped, according to optimal therapy and prognosis, into appropriate combinations to create a small number of identifiable states of disease. A modified version of



the TNM classification scheme is presented in Appendix B, which makes it somewhat more compatible with the staging system in Appendix B.

The proposed TNM classification augments the staging system described above to include data on tumor thickness and level of invasion, providing additional specificity and incorporating important risk data into the classification scheme. Tumor thickness is categorized as less than .76 mm., .76 to 1.5 mm., 1.51 to 3.0 mm., and greater than 3.0 mm., while levels are recorded as 2 through 5. In addition, an R category is included to indicate the presence of residual tumor on postsurgical treatment, and a G category is included to indicate tumor grade.

Such a system allows the definition of disease states based on initial severity of disease as well as current disease extent, and separates patients into subgroups based on risk associated with the primary. For example, T3 N1 M0 describes level 4 and/or tumor thickness between 1.51 and 3.0 mm. with presence of regional lymph node involvement of the regional draining nodes, and no known distant metastases.

The staging and TNM classifications are different ways of organizing information about patients with malignant melanoma. The TNM system incorporates more detailed information as part of the classification, but is more complex and this has limited its acceptance in practice. Although correspondences exist between the TNM classification and the staging scheme described above, these schemes are only partially compatible. In the example above, T3 N1 M0 can correspond to either Stage IIA, IIB, or IIC depending on the clinical status of the



nodes. Furthermore, the staging system does not include information on the tumor thickness or level of invasion, while the TNM system does not contain information on the clinical status of lymph nodes prior to lymph node dissection or distinguish between local recurrence within the surgical scar and satellitosis within 5 cm. of the primary.

In the Manual for Staging of Cancer, another staging system is defined which differs from the one described above. In developing a correspondence between the TNM system and the staging system in the manual, melanomas invasive to level 4 or 5 with no additional evidence of disease are included in Stage II rather than Stage I.

Therefore, to be able to accommodate multiple ways of viewing data that satisfy the requirements of a particular study, it is necessary both to map between classification schemes and to be able to develop new classification modalities from the existing data. Computer-based management systems can assist in providing more consistent schemes for staging and classifying information and provide ways to map information into the required classification system, providing the basic data have been collected and are in the computer-based system.

Cox et al. (1979) discuss the need to classify cancer patients in greater detail than is available in current classification methods. They suggest collecting nonanatomic clinical factors as well as surgical, histologic, biochemical, and immunologic observations, and that these data be included in developing an appropriate classification system for patients with a particular type of cancer. These data include information under the headings biological characteristics of the tumor, host resistance, host-tumor interaction, and the effect of treatment vs.

effect on the host. The issues that deal with developing and using an appropriate classification system for medical inquiry is discussed in Chapter 7.

### 3.5 Therapy

Currently, initial treatment commonly used in the U.S. for individuals with malignant melanoma is surgical and involves treatment of the primary melanoma and possibly the regional lymph nodes. In most cases, surgical therapy consists of wide excision of the primary, with 3 to 5 cm. borders about the primary in all directions, to and including the deep fascia. Different studies have suggested 2, 4 or up to 6 cm. borders in all directions, but this depends on such factors as site of the primary, tumor thickness, and level of invasion. A skin graft is usually required for closure.

Melanoma usually metastasizes through lymph channels to regional lymph nodes, although routes through the blood and vascular system are sometimes followed. There is little question that it is desirable to perform a therapeutic lymph node dissection of clinically positive regional lymph nodes. However, there is some disagreement over what course should be followed with clinically negative nodes. The hypothesis that prophylactic regional lymph node dissections have therapeutic rather than prognostic value has not been definitively resolved. To demonstrate this, it is necessary to identify those characteristics that provide improved outcome in selected patients with clinically negative nodes who have had elective dissections.

In considering the issue of regional lymph node procedures, it is





necessary to consider the therapeutic and prognostic objectives that are to be achieved. Would patients with microscopically positive nodes have improved outcome; would the presence of metastases make these patients candidates for adjuvant chemotherapy or immunotherapy; or, would knowledge of the histologic status of the regional lymph nodes only provide a better estimate of prognosis for a particular patient?

An Australian study by Davis (1976) indicates that there is little advantage in elective lymph node dissection. Similar survival rates are obtained with a therapeutic lymph node dissection when necessary. Holmes et al. (1976) use risk associated with the primary to determine whether to perform a lymph node dissection. They conclude that patients with levels IV and V disease should have elective lymph node dissections. Wanebo et al. (1975) indicate that patients with wide excision and lymph node dissection have a better prognosis than patients with wide excision alone. However, in this retrospective study, the number of patients receiving wide excision alone was small. Cohen et al. (1977) suggest that the value of prophylactic lymph node procedures may be to identify patients with poor prognosis as candidates for adjuvant treatment protocols, rather than to identify patients who might benefit from elective lymph node procedures. They also conclude that the most important factor for predicting prognosis is the number of nodes found to be histologically positive.

In an ongoing prospective randomized study, Veronesi et al. (1978) suggest that elective lymph node dissections for patients with malignant melanoma of the extremities does not improve outcome and is therefore, not recommended. They recommend that patients be followed closely at 3



month intervals and that therapeutic dissections be performed as needed. The importance of continuous and accurate follow up is stressed.

Kapelanski et al. (1979) do not find data in their study to support the hypothesis that either elective lymph node procedures or therapeutic lymph node procedures increase survival. They point out that regional node dissections do not control the spread of disease. Microstaging by level does correlate well with survival; however, when used to predict therapy, it appeared to fail and does not correlate well with the presence or absence of nodal metastases.

To date, treatment of malignant melanoma by chemotherapy, radiotherapy or immunotherapy has not been generally successful, and prognosis is best improved through early detection and wide surgical excision during the early stages of the disease before deep invasion occurs. Immunotherapy protocols have used BCG, Levamisole and Transfer Factor as adjuvant therapy. Spitler and Sagebiel (1980) report on a randomized double-blind trial of levamisole versus placebo as adjuvant therapy for surgical treatment of melanoma. They conclude that there is no benefit derived for patients treated with levamisole, as compared to placebo, as adjuvant therapy for malignant melanoma. Other trials are still underway and to date, only limited success has been reported. A review of work with BCG immunotherapy is described in Eilber et al. (1974). A general review of the use of immunotherapy for melanoma may be found in Gutterman et al. (1975). A review of the current status of immunotherapy trials may be found in Terry (1980).

Chemotherapy for patients with Stage III disease has had little beneficial effect. Somewhat better results have been achieved with



adjuvant chemotherapy and/or immunotherapy for individuals with high risk disease who are in Stage I or II, such as patients with positive lymph nodes or a primary located on the trunk. Dacarbazine (DTIC) is the most extensively used chemotherapeutic agent for metastatic melanoma and has produced some beneficial results for patients with metastatic skin lesions or lymph node involvement, while poor results have been obtained for those individuals with visceral spread. See Comis (1976) and Clark (1979) for a review of the experience with chemotherapeutic agents in the treatment of melanoma.

### 3.6 Prognosis

Prognosis of patients with melanoma has been described as a function of such parameters as pathological type, level of invasion, tumor thickness, ulceration or bleeding or itching of the primary, regression of the primary, mitotic rate, angiogenesis, clinical and histological status of lymph nodes, location of the primary as well as age and sex. There is no evidence that superficial spreading melanomas and nodular melanomas with the same level of invasion and tumor thickness have different prognoses. Malignant melanoma occurs more frequently in women than men by a 3:2 ratio, but the prognosis is better for women. Women have lesions on exposed sites more often than men, and it has been suggested that concern for their appearances might result in earlier visits to physicians, so earlier diagnoses could account for their better prognosis. Outcomes are better for melanomas of the extremities than for those of the head and neck, and are worst for lesions of the trunk.



Since treatment of melanoma, other than early surgical excision, has not been especially successful, many studies have focused on identifying reliable prognostic variables that might indicate subsets of patients that would benefit from currently available therapeutic modalities or from experimental protocols. Several of these studies are now briefly reviewed to identify the indicators that have been used.

Schmoeckel and Braun-Falco (1976) propose a prognostic index defined as the product of tumor thickness and the number of mitoses per square millimeter. Using this measure, they were able to predict metastatic disease with a 14 percent rate of false negatives and positives. However, they measure tumor thickness using a different method from the one proposed by Breslow, thereby making comparison and reproducibility of these results difficult.

McGovern et al. (1979) study the prognostic significance of histologic type, mitotic activity, and regression of the primary. They conclude that these histologic parameters derive their significance from their close correlation with tumor thickness. In particular, the histologic features ssm, low mitotic activity, or partial regression were predominant in thin lesions, while the histologic features nm, many mitoses, or no regression were predominant in thick lesions which have a poorer prognosis. Thus, tumor thickness should be considered the most important prognostic indicator.

Mackie et al. (1972) suggest a prognostic score sheet in which attributes considered important in predicting prognosis are given weights. A composite weight is calculated for each patient, and a cutoff point is defined separating low risk, intermediate risk, and high risk





patients. Predictions for high risk and low risk patients were 80 % accurate, while the prognostic score for the intermediate risk group did not accurately predict outcome. The attributes included in this study were sex, site, size of lesion, duration of symptoms, nodal involvement, presence of disseminated disease, mitotic rate, ulceration of the primary, and lymphatic invasion.

Everall and Dowd (1977) provide a list of factors that may have prognostic significance in melanoma. Included are factors such as age, sex, duration of symptoms, size, type, level, thickness, site, lymphocytic infiltration, lymphatic involvement, mitotic rate, cell type, ulceration or bleeding of the primary, presence of satellites, and presence of metastatic disease. Combining these factors to define risk categories could prove useful in predicting prognosis.

Kapelanski et al. (1979) suggest microstaging based on depth of penetration, defining their categories as papillary (level 2 and thin level 3), reticular (thick level 3 and level 4), and subcutaneous (level 5) as being better prognostic indicators of survival. This grouping may also assist in more accurately defining outcome for thin and thick level 3 melanomas.

Breslow et al. (1978) use a multiple logistic model to examine the effect on outcome of the variables tumor thickness, level of invasion, sex and age for 248 cases of melanoma of the limbs. They conclude that increases in both tumor thickness and level of invasion are strongly related to decrease in survival, but that tumor thickness is a more accurate predictor of prognosis than level of invasion. The presence of histologic lymph node involvement increases with both level of invasion and measured thickness of the primary lesion.



Eldh et al. (1978) use multivariate analysis methods to retrospectively study 223 patients with stage I malignant melanoma who were followed for at least five years. They report that age, site of the primary, tumor thickness, diameter of the primary, level of invasion, ulceration of the primary, and mitotic activity are significant factors affecting 5 year survival; while sex, type of melanoma, degree of lymphocytic infiltration, and vascular involvement do not correlate with decreased survival. They emphasize that determination of tumor thickness was of greatest value as a prognostic indicator.

Polk and Linn (1971) argue for the use of multivariate analysis methods to analyze the issues concerned with lymph node dissections. They claim that it is necessary to consider multiple factors to arrive at useful indicators for elective lymphadenectomies. Correlating tumor thickness, level, mitotic rate, or site of primary individually, with histologic status of lymph nodes and/or outcome, may result in a loss of information. However, studying relationships among the parameters may help to explain the variability among patients and yield better prediction as to which patients might benefit from an elective lymph node procedure.

A recent study by Balch et al. (1979) attempts to follow the suggestion of Polk and Linn. Balch et al. develop a multifactorial analysis using Cox's regression model to determine the best prognostic variables for patients with stage 1 melanoma. In their retrospective study, they identify the histologic variables tumor thickness and ulceration (i), and the clinical variables initial surgical therapy and

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(i) See Balch et al. (1980) for a discussion of the prognostic significance of ulceration of the primary



site of the primary to be the most useful prognostic indicators. Tumor thickness was the most important variable in predicting survival. Concerning the issue of the efficacy of elective lymph node dissections, the authors claim their multivariate analysis supports the hypothesis that patients with tumor thickness between 1.51 and 3.99 mm. who had a wide local excision and an elective lymph node dissection had a much better survival rate than those individuals with only a wide local excision. ELND showed no benefit in the extremely favorable (tumor thickness less than .76 mm.) or in the extremely unfavorable (tumor thickness greater than 4 mm.) patient. However, in the study, the number of patients in each of the groups is small. No indication is given of the results of the ELND, or whether the two groups with or without ELND were comparable with respect to initial risk or site of the primary. The study does provide a good start and it might be beneficial to prospectively explore other range functions for tumor thickness to determine which provide optimal predictive capability of outcome.

An appropriately designed and organized classification scheme is necessary to aid in the many facets of data analysis. The TNM system previously described is organized to allow inclusion of additional predictor variables that may also aid in developing a better prognostic index. It should be possible to extend this classification or develop alternate schemes to better name disease states based on observations and findings that have potential prognostic significance (see also Cox et al. 1979). What is desirable is to determine those prognostic indicators that will accurately identify individual patients who will have recurrence, rather than groups of patients that, overall, have a



high risk for recurrence. This would allow selecting appropriate patients for entry into therapeutic protocols.

In addition to the reports noted above, there is a rather large, and at times conflicting, literature on malignant melanoma that study the relationships among attributes, as well as studying prognostic indicators for survival or recurrence. To illustrate the large number of reviews that have been reported, several significant studies are briefly noted. Wanebo et al. (1975) studied melanoma of the extremities; Ames et al. (1976) performed a retrospective study of 357 patients with stage 1 melanoma of the head or neck; and Sugarbaker et al. (1976) describe a retrospective study of 418 patients with stage 1 melanoma of the trunk and suggest methods for predicting lymph node involvement in these patients. Knutson et al. (1971) present a rather comprehensive retrospective study of 230 patients with cutaneous melanoma. They studied the clinical course of the disease including recurrence rates and survival, as well as relationships between site, sex, and metastatic spread.

Two recent books provide extensive reviews of malignant melanoma. Kopf et al. (1979) present a comprehensive review of malignant melanoma covering epidemiology, diagnosis, therapy, prognosis, and staging. Clark et al. (1977) review the developmental biology of primary malignant melanomas, the immunobiology of melanoma, and the use of melanoma as a model to trace the sequence of events that may affect the ability of melanoma to metastasize.

A data base of the kind provided in this study would allow systematic exploration of many of the hypotheses implicit or explicit in





the discussion above. The following are some of the important issues that might be considered in studying melanoma with the aid of a clinical data base of patients with malignant melanoma.

- 1) What characteristics of the primary serve as a guide to prognosis and therapy? Are microstage methods of level and/or thickness the best indicators of prognosis, or do other parameters such as mitotic rate, vascular or lymphatic invasion, presence of ulceration of the primary, or regression of the primary afford similar or better utility in determining prognosis and therapy?
- 2) What are the relationships among histologic parameters? Are there strong or weak relationships between such parameters as mitotic rate, level of invasion, tumor thickness, and regression of the primary?
- 3) How can disease states be defined so that they reflect the clinical course of the disease and usefully discriminate subgroups of patients?
- 4) Do regional lymph node procedures (RLNP) significantly affect the clinical course of the disease?

In the chapters that follow, some of these questions are studied with the aid of the current data base of patients with malignant melanoma. Chapter 7 describes a process and knowledge representation model that might be useful in providing a framework to support medical inquiry and to aid in defining appropriate problem solving strategies.



## Chapter 4

### MEDINQUIRY: SYSTEM STRUCTURE

This chapter describes the components involved in the design of MEDINQUIRY. Included is a discussion of the considerations in constructing the data base, the nature of the medical information to be studied, the LIFER concept, and the interactive process followed to build an application language interface. An extract of the application language is provided illustrating both how the interface is built and how it can be enhanced in response to the inquiry needs of users.

#### 4.1 Overview of MEDINQUIRY

Figure 1 provides a functional description of the system components and the information flow between them. In the figure, directed double dashed lines '==>' denote the logical flow of information between the user, the natural language processor, the data base access module, the data base, and the response generator; directed dashed lines '<---' denote feedback between components; while dashed lines '---' denote knowledge that supports a particular component.

The user initiates an English language request at the terminal. The natural language processor attempts to analyze the request using knowledge specific to melanoma and general knowledge about language contained in the interface builder defined application language. For requests that are successfully analyzed, MEDINQUIRY presents to the user a paraphrase of the request. This paraphrase ensures that the request has been understood correctly by the system, and is in accordance with



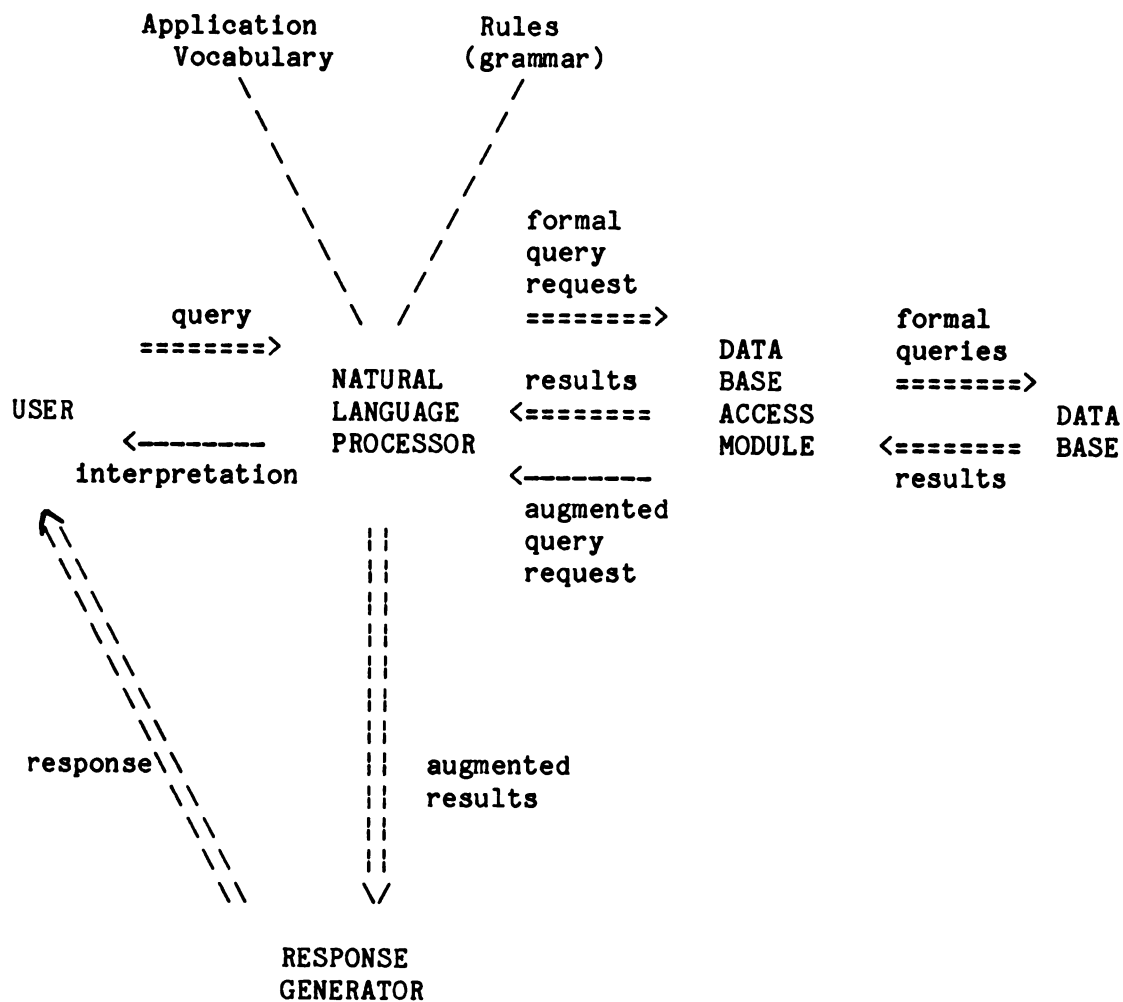


Figure 1. Overview of MEDINQUIRY

the user's intent. For requests that cannot be analyzed, an attempt is made to indicate where the request is blocked.

The natural language processor consists of an augmented transition network parser, and a set of INTERLISP functions written by the system builder. These functions are applied in the process of analyzing the user's query to construct a logical formal query request which is passed to the data base access module. The data base is interrogated and the patient data satisfying the query constraints are returned to the natural language processor. Depending on the operations to be performed on the retrieved patient data, the relevant display and processing functions are called to produce the required output. The response generator then reorganizes the data into a suitable form which responds to the user's original request.

In instances where multiple formal query requests are generated and multiple accesses to the data base are required to respond to the request, one or more augmented query requests may be returned to the language processor during the course of parsing the request. The system's understanding of the request may appear in several segments which, when taken together, provide MEDINQUIRY's understanding of the entire request.

The remainder of this chapter details the structure of each component and the procedures followed to respond to English language requests about melanoma.





#### 4.2 Data Base: Design Considerations

The melanoma data base for the prototype system contains information about 156 attributes for 130 patients. The starting point in creating the data base was data collected at UCSF (University of California, San Francisco) as part of the Melanoma Clinical Cooperative Group (MCCG) from 1972, when the first patient entered the study, through December 1976 when all patient data to be included in the prototype system were assembled. These data include personal data, patient background, patient physical examination, history of the primary lesion, physical examination of the primary, family history of skin disorders, pathology data, lymph node procedures, and follow up results. The original MCCG forms contained nearly 350 attributes, but for a variety of reasons many of these items were considered inappropriate for inclusion in the data base.

The criteria used to eliminate items from the original cooperative study were: (1) information missing for an attribute in a high percentage of cases; (2) information consistently recorded incorrectly; (3) attributes considered irrelevant for inclusion in the computer data base on the basis of discussions with melanoma experts; (4) attributes with the same values in greater than 95 per cent of the patients. For purposes of privacy and security, data relating to patient name, physician information, and addresses were not entered. Despite this selection of items, the melanoma data base was still found to be incomplete and to contain numerous errors, particularly in the pathology data and follow up results. This was due, in part, to UCSF's role as a referral clinic and not seeing many patients with the primary intact or



on a routine and continuing follow up basis. An extensive effort, by the author, was required to re-extract the pathology and follow up data elements from the primary records, to edit the attributes and values, and then to create the data base. In the future, to use these data effectively, a review of all pathology slides and follow up results, in conjunction with follow up visits, would probably ensure more precise and complete information in the data base. This would certainly be the case given the new insights now available on what should be examined for patients with melanoma. To ensure that minimal criteria for completeness and accuracy were met for the remaining data, selected medical records were re-checked and corrections made to the data base where necessary.

Appendix A contains the forms used to collect the data in the prototype MEDINQUIRY system, while Appendix C lists the attributes included in the data base.

#### 4.3 Nature of Medical Information

In order to design and implement MEDINQUIRY to support the objectives of this research, it is necessary to consider the nature of the medical information to be processed. This entails understanding the rationale underlying the data acquisition process, and requires insight by the system's builder of the concepts relevant to melanoma that must be handled. The properties of the attributes (variables or items) in the data base influence how an application language is defined, and what processes must be understood and supported to respond to English language requests. Thus, the system's builder must be aware of such issues as: sources from which the data are derived, issues dealing with



the reliability of data, criteria which are used to determine how the data are categorized, and scales of measurement used for the data. This section presents a brief overview of these issues and their relevance to the design and implementation of MEDINQUIRY.

The sources of data in the current study include:

- 1) Demographic data (or personal data) such as age and sex
- 2) Background data that include family history of disease, history of skin diseases, environmental factors such as sun exposure, and history of the primary lesion
- 3) Symptoms that are considered subjective like trauma to the site of the primary, or objective symptoms such as bleeding of the primary
- 4) Physical signs observed in the course of the physician examination of the patient and the primary lesion such as size of the primary, surface characteristics of the primary, color of the primary, presence of satellites, or clinical status of regional lymph nodes
- 5) Diagnostic and therapeutic procedures performed such as type of biopsy, type of lymph node procedure, or type of definitive treatment
- 6) Paraclinical findings include histologic findings such as type of melanoma, tumor thickness, level of invasion of the primary, or histologic information concerning lymph node procedures
- 7) Longitudinal data derived from follow up visits such as status, therapy performed at this visit, or therapy since previous encounter

- 8) Inferences such as stage of disease, or risk associated with the primary based on attributes such as level of invasion and tumor thickness

Data collected from these sources vary in their reliability. The patient may not recall how many months the primary bled prior to the time a definitive diagnosis of malignant melanoma was made, or the interviewer may not have phrased a question in comprehensible terms or may have failed to record the response correctly or completely. There are also problems associated with intra- and inter-individual variation in assigning a value to a finding. Paraclinical findings tend to be more accurate than clinical observations; inferentially based attributes are subject to judgmental interpretation.

Scales of measurement differ for attributes depending on how the forms designers thought of it, and the process required to reach consensus on what data should be collected and how these data should be categorized. This also involves determining the operational criteria used to select data for inclusion in a study. These issues have been discussed extensively in books on clinical judgment such as the ones by Feinstein (1967) and Wulff (1976). Attributes may be assigned to certain categories, and are recorded in nominal, ordinal, existential, or interval scales. The attributes in the melanoma data base are described in terms of these scales of measurement.

- 1) A nominal scale consists of qualitative observations in a set of named categories. These items cannot be ranked. The following requirements must be satisfied for categories associated with a



nominal attribute: (1) each category must be well defined; (2) no observation for an item at a given point in time may be a member of more than one category; (3) all possible observations for an attribute are assigned to a category.

In the melanoma data base attributes that are expressed in a nominal scale include: sex, menstrual status, colors of suspicious lesion when first noted, size of lesion when first noted, examiner's opinion of how melanoma arose, eye color, hair color, type of initial biopsy procedure, site of primary, type of melanoma, cell type, type of lymph node procedure, site of lymph node procedure, therapy suggested, and status. Examples of values assigned to attributes on a nominal scale are: "male" and "female" for SEX; "associated with mole", "Hutchinson's melanotic freckle", "de novo", and "cannot determine" for EXAMINER'S OPINION OF HOW MELANOMA AROSE; "blue", "green", "light brown", "dark brown", or "black" for EYE COLOR; "head", "neck", "front", "foot", "thigh", "back", "arm", "hand", and "calf" for SITE OF PRIMARY; "nevroid small", "nevroid large", "pagetoid", "spindle", "pleomorphic", and "mixed" for CELL TYPE; and "no evidence of disease", "possible recurrence", "definite clinical recurrence", "histologic recurrence" (1), or "dead" for STATUS.

- 2) An ordinal scale is used to rank semi-quantitative data and is subdivided into ranked values. The interval between any two adjacent values is not measurably equal. The categories (or

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 (1) In this report, the shorthand form "histologic recurrence" is taken to be synonymous with phrases such as, "histologically confirmed recurrence", "pathologically proven recurrence", or "demonstrated histologic recurrence".



values) for ordinal items are established arbitrarily, and are ranked in either increasing or decreasing order. An ordinal scale may include values like "none", "mild", "moderate", and "severe" or "few", "moderate", and "many". Examples of items recorded on an ordinal scale include: SUNBURN with assigned categories "rarely in sun", "practically none", "some redness only", "moderate burn", and "painful burn"; PATIENT SUN EXPOSURE and LESION SUN EXPOSURE with categories "practically none", "little", "moderate", and "much"; histologic attributes LEVEL OF INVASION with values "II", "III", "IV", and "V"; MITOTIC ACTIVITY with values "few", "moderate", and "many"; LYMPHOCYTES and MACROPHAGES with categories "few", "moderate", "many", and "incomplete"; PLASMA CELLS with categories "absent", "moderate", and "prominent". An ordinal scale may also be used to rank inferentially derived attributes such as risk associated with the primary, and clinical or pathologic stage of disease. Risk associated with the primary may be derived from observations such as level of invasion, mitotic activity, and tumor thickness with categories such as "high risk primary", "intermediate risk primary", "low risk primary", and "unclassified". CURRENT STAGE may have the assigned categories "I", "II", or "III" with additional derived subcategories to specify the current disease state.

- 3) In an existential (or dichotomous) scale, the values on an ordinal scale are compressed into categories such as "present" and "absent", or "yes" and "no". An existential scale may be

transformed into an ordinal scale by expanding the categories into a ranking of the likelihood of the event. For example, the existential scale categories "present" or "absent" can be transformed into the ordinal scale categories "definitely present", "probably present", "uncertain", "probably absent", and "definitely absent". Examples of items expressed on an existential scale are: FATHER WITH MELANOMA, MOTHER WITH MELANOMA, PRESENCE OF FRECKLES, EXISTENCE OF A PRE-EXISTENT LESION, BLEEDING OF THE PRIMARY, AND ULCERATION OF THE PRIMARY with values "yes" or "no"; HISTOLOGICALLY PROVEN REGRESSION OF THE PRIMARY, AND HISTOLOGICALLY NOTED PREEXISTING LESION with values "present" or "absent". Time dependent relationships between two states (or points in time) also may be expressed on a time dependent existential scale. For example, LESION SIZE CHANGE and ELEVATION SIZE CHANGE SINCE TIME OF FIRST APPEARANCE may be recorded in the categories "increase", "no change", and "decrease".

- 4) An interval (dimensional or metric) scale is used to record quantitative data that are either continuous or discrete. The interval between each potential value on the scale is measurably equal. For example, age at diagnosis, size of lesion, tumor thickness, months since lesion size change was first noted, months since bleeding of the primary was first noted, number of positive nodes found on lymph node dissection, and months since initial therapy, are expressed in a dimensional scale. An interval scale may be considered a ratio scale. For example, a



primary with a tumor thickness of 3 mm. is twice as thick as a tumor with a thickness of 1.5 mm. The attributes NUMBER OF MOLES and NUMBER OF FRECKLES are expressed on a discrete interval scale. The values assigned to these items are "none", "1 to 25", "26 to 100", "more than 100", and "none".

In theory, attributes may be expressed in several different scales which depend on the consensus reached by experts in the forms design process. For example, MITOTIC RATE can be expressed in an ordinal scale with categories such as "few", "moderate", and "many", an existential scale as "present" and "absent", or an interval scale as the mitotic rate per square mm.

In the melanoma data base, attributes may be characterized as being single-valued, multiple-valued, or composed of repeating groups. A single-valued attribute has only one value assigned to it. For example, AGE and SEX have only one value. Multiple-valued items may have more than one value assigned to them. For example, both "blue" and "black" may be assigned to COLORS OF SUSPICIOUS LESION WHEN FIRST NOTED; CELL TYPES ON HISTOLOGIC EXAMINATION may be "nevoid large" and "nevoid small"; and THERAPY SUGGESTED AT A FOLLOW UP VISIT may be "immunotherapy", "chemotherapy", and "lymph node biopsy". Repeating groups consist of one or more observations that are assigned repeatedly at multiple points in time. For example, follow up information would be collected at each follow up visit and include items such as date of visit, status, therapy at visit, and stage of disease. The types of attributes influence how the data are to be acquired, stored in the data base, and the data base access methods to be employed in retrieving and processing the information.



The nature of the elements in the data base influences how the application language is compiled. Certain attributes contain language ambiguities that need to be understood by MEDINQUIRY. Resolving these ambiguities depends on the source of the data, the context in which a question is asked, and the scale of measurement used to record the results. For example, entries concerning the size of the primary appear in several places. Under history of the primary lesion, the attribute "size (largest diameter) when first noted" is recorded using an ordinal scale with values "pinhead", "pencil eraser", "dime", "nickel", "quarter", "half dollar", "larger than half dollar"; also, under history of the primary, the item "lesion size change" is recorded on a time dependent existential scale of "increase", "no change", and "decrease"; upon physical exam of the intact primary, the values are recorded using an interval scale with measured dimensions of the size of the primary lesion. On histologic examination, the measurements of excision specimen, excisional biopsy, and definitive re-excision are expressed on an interval scale. Information concerning the existence of a pre-existing lesion is present in several places on the data acquisition forms. On history of the primary lesion, the attribute "pre-existent lesion" may be entered on an existential scale "yes" and "no"; later, under the same source, the item "in the examiner's opinion, after careful questioning about a pre-existing lesion, its nature and duration", is recorded on a nominal scale with values "in association with a mole", "from a Hutchinson's melanotic freckle", "de novo", "cannot determine", and "unknown". On the pathology form, the item "presence of pre-existing nevus" is recorded on an existential scale as "present" or "absent".



Thus, the source of data, the reliability of sources, as well as the linguistic characteristics of the values assigned to attributes in data acquisition, directly impact the way in which requests posed by the user are processed. These variations, as well as the arbitrariness in the assignment of categories to attributes, must be included in the knowledge that MEDINQUIRY has about melanoma. The relationship of these issues to the process of hypothesis formation and testing is discussed in Chapter 7.

#### 4.4 Data Base Storage and Access

It is necessary to have available a file management system to store, update, and retrieve information about patients with melanoma. The data base access module, FILEDATA (1), serves this role; it processes data entered and stores them as a collection of tables that may be viewed as a relational data base. At present, the data are stored in three tables; PATIENT TABLE, LYMPH NODE TABLE, and FOLLOW UP TABLE. The rows in each table correspond to an entry for a patient, while the columns correspond to the attributes present in a particular table. Each row in a table is stored as an INTERLISP property list (see Teitelman, 1978) in the form of attribute-value pairs.

For example, the data describing a follow up encounter for patient S-72-001, represented by the list (ID S-72-001 DATE-OF-FOLLOW-UP-VISIT 720108 STATUS NED THERAPY-SUGGESTED NONE STAGE IA MONTHS-SINCE-INITIAL-THERAPY 10), is interpreted as follows: For the patient with the attribute ID having the value S-72-001, the status at the follow up

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(1) The FILEDATA access module for the prototype version of MEDINQUIRY was originally written by J. Slocum.



visit on 1/8/72 is recorded as no evidence of disease, no therapy was suggested at this follow up visit, the patient is classified as Stage 1A, and 10 months have elapsed since the definitive diagnosis of malignant melanoma was made.

Since more than one instance of a lymph node procedure, or a follow up encounter may exist per patient (repeating groups), more than one row may exist per patient in these tables. At present, there were 69 lymph node procedures performed for 60 patients who had lymph node procedures, and 674 follow up encounters for the 130 patients in the data base.

The FILEDATA program provides the basic retrieval functions for extracting the requested information from the data base. A formal query request passed to the data base access module is of the form:

```
FILEDATA <formal-query-request>
```

where a <formal-query-request> is of the form (attribute-1 value-1 attribute-2 value-2 ... attribute-n value-n), and includes query constraints, and specifies the attributes and values to be retrieved if the constraints are satisfied.

After accessing the data base, the results of patients matched are returned to the natural language processor as lists of attribute-value pairs.

For example, to retrieve patients from the data base with tumor thickness between 1.25 and 1.5 mm., the FILEDATA program is called as follows:

```
FILEDATA '(ID ? (AND (NUMBERP *) (LEQ * 1.5) (GEQ * 1.25))).
```

The '?' denotes a value to be retrieved, with an associated attribute, if the row matches the query constraints. The '\*' indicates

that the value from the data base for this attribute is substituted in the query expression, which is then evaluated.

In the above example, the INTERLISP expression '(NUMBERP #)' ensures that comparisons against the data base are performed only on numeric values for tumor thickness. In '(LEQ # 1.5)', the value in the data base for tumor thickness is substituted for '#', and a comparison is made to determine if tumor thickness is less than or equal to 1.5 mm.; while '(GEQ # 1.25)' is used to check if the value for tumor thickness is greater than or equal to 1.25 mm. If all of these constraints for tumor thickness are satisfied, this row is accepted; the attribute-value from the data base is appended to the retrieved row, and the next row of the table is tested. The final result is returned as a list of the form ((ID S-72-001) (ID S-73-008) ... ) or NIL, if no patient records satisfy the query constraints.

As noted previously, more than one row may be returned per patient if either follow up or lymph node information is retrieved.

For example, in response to a request for a listing of the status and time interval since initial therapy for patients with level 5 melanoma with many mitoses, the call FILEDATA '(ID ? STATUS ? MONTHS-SINCE-INITIAL-THERAPY ? LEVEL 5 MITOTIC-RATE MANY)' might return a list such as:

```
((ID S-72-001 STATUS NED MONTHS-SINCE-INITIAL-THERAPY 2) (ID S-72-001
STATUS POSSIBLE-RECURRENCE MONTHS-SINCE-INITIAL-THERAPY 4) (ID S-72-001
STATUS HISTOLOGIC-RECURRENCE MONTHS-SINCE-INITIAL-THERAPY 5) (ID S-72-
001 STATUS NED MONTHS-SINCE-INITIAL-THERAPY 7))
```

The request, "List the tumor thickness for patients with level 5 and many mitoses who demonstrated histologic recurrence", would generate

the call (FILEDATA '(ID ? TUMOR-THICKNESS ? MITOTIC-ACTIVITY MANY STATUS (FMEMB \* (HISTOLOGIC-RECURRENCE DEAD))) and return a response list such as ((ID S-72-008 THICKNESS 1.5) (ID S-72-008 THICKNESS 1.5)), since there is more than one instance of histologic recurrence for this patient.

As these examples illustrate, the response generator must be aware of the different types of results that may be returned during access to several tables, and operate on the information in a suitable manner to produce the desired results.

The following table summarizes the available options for attributes and values in a formal query request. The attribute-value pair lists generated, using these options, are concatenated during the parsing process to form the formal query request. To determine whether to accept a row, all tests for a given row are ANDed; failure for any one test causes the entire row to be rejected.

Option	Attribute-i	Value-i	Explanation
1	litatom	?	Retrieves values associated with attribute-i if row accepted  (e.g., TUMOR-THICKNESS ?)
2	litatom	list	Tests for a match with value in data base substituting appropriate values for '*' in the value list  (e.g., TUMOR-THICKNESS (AND (NUMBERP *) (GEQ * 1.5))
3	litatom	not a list	Compares value-i with corresponding value in data base for this attribute  (e.g., MITOTIC-ACTIVITY MANY)



4            list                    list            Applies function in value-i to values  
    associated with list attribute-i in  
    data base

(e.g., (FATHER-MELANOMA MOTHER-MELANOMA) (LAMBDA (F M)  
    (OR (CAR \*) (CADR \*))))

#### 4.5   Creating an Application Language

The three sections which follow describe the procedures involved in creating the application language. The first section introduces the overall LIFER concept, and the second describes the basic philosophy underlying the creation of the application language. The third section describes the form of the rules used to create the application language and presents several detailed examples of how these rules are used to analyze and respond to English language inquiries.

##### 4.5.1   The LIFER Concept

LIFER was developed to provide a framework for building practical English language interfaces to other computer software. It is composed of two basic parts: a set of interactive language functions and a parser. The language interface builder uses the language interface functions provided by LIFER to define an application language, a subset of English, that contains sufficient conceptual and linguistic knowledge about malignant melanoma to interact effectively with the data base. The parser is a top down left to right parser based on the augmented transition network (ATN) system of Woods (1970). It uses the knowledge about melanoma contained in the application language to analyze input requests. LIFER, itself, does not contain a built in application

vocabulary or grammatical rules; this domain specific knowledge is specified by the interface builder.

The LIFER functions permit specification of patterns, fixed phrases, terms associated with word classes, anaphoric references for pronouns, and predicates. Other LIFER facilities include an automatic facility for handling elliptical constructs (incomplete sentences), and a paraphrase mechanism to extend the language interface by allowing definition of new constructs at the phrase and sentence level. Several additional features, such as a spelling corrector and an interactive editor for modifying rules, are derived from LIFER's implementation in INTERLISP, an interactive list processing programming language, designed for working with complex non-numeric data. A manual describing the LIFER facility is available (see Hendrix, 1977).

#### 4.5.2 Creating an Application Language: An Overview

Before formally describing the LIFER interface functions and their use, it is valuable to present an overview of the methodology underlying the creation of such an interface.

To respond to queries about the melanoma data base, it is necessary to define, compile, and store an application language with the following types of information:

- 1) An application vocabulary of words and phrases containing all vocabulary items used in query requests. It lists all terms that may be assigned to a category. Thus, the entries WHAT, LIST, SHOW ME, DISPLAY, and RETRIEVE belong to the category <LIST>; ARE, IS, WAS, WERE are assigned to <AUXB>; AGE, TUMOR THICKNESS,



THICKNESS, LEVEL, LEVEL OF INVASION, and DEPTH OF INVASION are specified as <NUMERIC-ATTRIBUTE>, while SITE, LOCATION, and SEX are designated as <LITERAL-ATTRIBUTE>; PATIENTS, PTS, CASES, and INDIVIDUALS are members of the category <PRE-PATIENTS>; SSM, NM, SUPERFICIAL SPREADING MELANOMA, and NODULAR MELANOMA are assigned to <TYPE>; ARM, HAND, UPPER EXTREMITY to <SITE>; LEVEL 5, and LEVEL V INVASION to <LEVEL\*>; 5, 4, V, and IV to <LEVEL>. The naming of the categories contain semantic information that reflects how terms assigned to each category are used in the application language. Currently, the application vocabulary contains nearly 900 words, excluding abbreviations and numbers, in 233 semantic categories.

- 2) A grammar containing rules that establish meaningful relations among vocabulary items. Substantial amounts of semantic as well as syntactic information are included in these rules. Rules consist of two parts: a pattern to be recognized and an associated response expression indicating what action should be taken. For example, "(<SHOW> <ATTRIBUTEALL> <OF-FOR> <PATIENTS>) ; (F0046)" is a top level rule in which the categories to the left of the semi colon form the pattern, and (F0046) is the response expression. The category <LIST> that belongs to the more general category <SHOW> is used to interpret a variety of English questions that ask for some kind of tabular output display as a response. As indicated above, <NUMERIC-ATTRIBUTE> refers to attributes whose values are represented numerically, while <LITERAL-ATTRIBUTE> identifies attributes that are literal names.



Both <LITERAL-ATTRIBUTE> and <NUMERIC-ATTRIBUTE> belong to the more general category <ATTRIBUTEALL>. The category <OF-FOR> establishes a prepositional link that relates <ATTRIBUTEALL> to the category <PATIENTS> which, itself, contains "subgrammar" rules specifying the allowable constructs among <PRE-PATIENTS>, <TYPE>, <LEVEL>, <LEVEL\*>, and <SITE>. This top level rule would be invoked in the analysis of queries such as "Display the age, sex, site of primary, and tumor thickness for patients with ssm level 5 of the upper extremities." Matching the pattern portion of the above rule with the English language request would create the following query pattern to be passed to the response function (F0046):

```
(AGE ? SEX ? SITE ? THICKNESS ? TYPE SSM LEVEL 5
  SITE (FMEMB * '(HAND ARM)))
```

Note that this list corresponds to the arguments in the data base access module described in Section 4.4, where FILEDATA is actually called from the interface builder defined function (F0046).

- 3) Special functions developed to evaluate particular classes of requests by performing specified operations on the data base, and then formatting the output to provide an appropriate response. In this example, the response expression (F0046) is a function that calls the data base access module which matches the query request against the contents of the data base, identifies the patient data satisfying the query constraints, and returns a list of patient data first to the natural language processor and then to the response generator which displays the results in an appropriate format.

As an example of the use of MEDINQUIRY, the user enters the request "Display the age, sex, site of primary, and tumor thickness for patients with ssm level 5 of the upper extremities."

MEDINQUIRY responds as follows:

ANALYZED [indicates that the request has been parsed]

MEDINQUIRY has interpreted your request as follows:

List the AGE (AT DIAGNOSIS) and SEX and SITE OF PRIMARY and TUMOR THICKNESS (MM.) for people with DEFINITIVE PATHOLOGICAL TYPE equal SSM and DEFINITIVE PATHOLOGICAL LEVEL equal 5 and SITE OF PRIMARY equal to a member of the set (HAND ARM).

[MEDINQUIRY's interpretation of the request]

ID	AGE (AT DIAGNOSIS)	SEX	SITE OF PRIMARY	TUMOR THICKNESS (MM.)
S-74-061	39	MALE	ARM	4.50

[the formal query request is passed to the data base access module which returns the accepted data, and the response generator operates on these data to provide an appropriate response to the request]

#### 4.5.3 Creating an Application Language: Language Functions

To illustrate how the application language is created interactively, the examples presented informally in the previous section are defined using LIFER's interface functions.

Each rule entered by the interface builder can be viewed as a production rule of the form;

<symbol> ==> pattern ; response expression

When the pattern is recognized, the response expression is invoked. A pattern consists of a sequence of categories and/or terms in the application language separated by blanks. The response expression generated, upon recognition of the pattern, may be part of the original pattern or an INTERLISP expression or function that performs designated operations on the pattern and returns an answer to the question or a value bound to <symbol>. The response expression or "augmentation" is used to create the formal query language request. If the pattern completely accounts for all the items in the input statement, the rule is called a top level pattern; the response expression is evaluated and the result returned to the user. In those instances where the rule is not a top level pattern, it is called a "subgrammar" rule; the value of the evaluated response expression is bound to the meta-symbol <symbol> and additional rules in the application language are applied until either the input is parsed or the parsing attempt fails.

The following examples use LIFER's interface functions to compile rules about melanoma. For convenience, meta-symbols are enclosed in angle brackets. This convention is useful to distinguish between meta-symbols such as <LEVEL> and the word token "level" that appears in the application vocabulary.

1. Pattern Define (PD) rules for top level patterns are written as:

```
PD[(pattern) response-expression <LTG>]
```

The last argument, <LTG> (for Lifer Top Grammar), may be omitted.

As previously noted, the top level pattern required to recognize the input request, "Display the age, sex, site of primary, and tumor thickness for patients with ssm level 5 of the upper extremities.", is written as "<SHOW> <ATTRIBUTEALL> <OF-FOR> <PATIENTS>".



This top level pattern is entered as:

```
PD[(<SHOW> <ATTRIBUTEALL> <OF-FOR> <PATIENTS>) (F0046)].
```

where **<SHOW>** matches "Display the"

**<ATTRIBUTEALL>** matches "age, sex, site of primary, and  
tumor thickness"

**<OF-FOR>** matches "for"

**<PATIENTS>** matches "patients with ssm level 5 of the upper  
extremities"

F0046 is the response expression invoked to return an answer

This rule may be rewritten in the reference language as:

```
<LTG> ==> (<SHOW> <ATTRIBUTEALL> <OF-FOR> <PATIENTS>) ; (F0046)
```

Both **<ATTRIBUTEALL>** and **<PATIENTS>** use a variety of subgrammar rules to match the sentence fragments associated with these symbols. Before the subgrammar patterns are defined, the phrases and words in the application vocabulary that use fixed phrases and words are specified by the functions Fixed Phrase (FP) and Make Set (MS).

2. Fixed Phrases (FP) define phrases that match a meta-symbol and are of the form:

```
FP[(pattern) response expression <symbol>]
```

The response expression is bound to the meta-symbol **<symbol>**.

The following are examples of definitions of fixed phrases:

```
FP[(TUMOR THICKNESS) THICKNESS <NUMERIC-ATTRIBUTE>]  
FP[(LEVEL OF INVASION) LEVEL <NUMERIC-ATTRIBUTE>]  
FP[(DEPTH OF INVASION) (LEVEL THICKNESS) <NUMERIC-ATTRIBUTE>]  
FP[(SUPERFICIAL SPREADING MELANOMA) SSM <TYPE>]  
FP[(NODULAR MELANOMA) NM <TYPE>]  
FP[(SHOW ME) LIST <LIST>]
```

Thus, when the phrase "tumor thickness" is recognized, the response expression "thickness" is bound to the symbol **<NUMERIC-ATTRIBUTE>** which is the attribute name in the data base for tumor thickness. For the phrase "depth of invasion", the response is the list (LEVEL THICKNESS)

which identifies two data base attributes, level and tumor thickness, and is associated with the symbol <NUMERIC-ATTRIBUTE>. Similarly, for the phrase "superficial spreading melanoma", ssm is bound to the symbol <TYPE>. Here ssm is the value in the data base for a type of melanoma, superficial spreading melanoma. These expressions are further augmented during the remainder of the parsing process.

3. Make Set (MS) specifies a set of words to be associated with a <symbol> and are of the form:

MS[<symbol> (list of words with optional bindings)]

Thus, either the word itself or a response associated with the word is bound to <symbol>.

The following illustrate the definition of words associated with sets:

```
MS[<LIST> (LIST WHAT DISPLAY RETRIEVE]
MS[<NUMERIC-ATTRIBUTE> (LEVEL AGE THICKNESS]
MS[<LITERAL-ATTRIBUTE> (SITE SEX (LOCATION . SITE)]
MS[<TYPE> (SSM NM]
MS[<EXTREMITY> (EXTREMITIES (SITE (FMEMB * '(HAND ARM THIGH CALF FOOT
                                     KNEE]
MS[<LEVEL> ((V . 5) (IV . 4)]
MS[<SITE> ((ARM SITE ARM) (HAND SITE HAND]
MS[<PRE-PATIENTS> (CASES INDIVIDUALS PATIENTS PTS]
MS[<WITH> (WITH]
MS[<OF-FOR> (FOR OF]
```

In these rules, each item is related to a data base attribute or to an existing attribute-value in the data base. Thus, the words "level", "age", and "thickness", which are data base attributes, are bound to <NUMERIC-ATTRIBUTE>; the attributes "site", and "sex" to <LITERAL-ATTRIBUTE>; "location" is associated with the data base attribute "site" and assigned to <LITERAL-ATTRIBUTE>. The words "ssm" and "nm" are assigned to <TYPE>; the word "extremities" is associated with

<EXTREMITY> having as a response expression (SITE (FMEMB \* '(HAND ARM THIGH FOOT KNEE))) which is part of the query request to be tested against the data base. For the symbol <LEVEL>, V is bound to 5, IV is bound to 4; while for <SITE>, arm is associated with the list (SITE ARM), and "hand" is associated with the list (SITE HAND) which are attribute-value pairs in the data base. The words "list", "what", "display", and "retrieve" are assigned to <LIST> and specify, in part, the type of output required to respond to a request, while "of" and "for" are prepositions associated with <OF-FOR>, and "with" is associated with <WITH>. The words "cases", "individuals", "patients", and "pts" are bound to <PRE-PATIENTS> indicating that patients is the unit being considered in the query constraint.

4. Subgrammar rules for the patterns <ATTRIBUTEALL> and <PATIENTS> are also defined as productions. Subgrammar rules may be written in either of the following ways:

PD[(pattern) response-expression <symbol>]

or

PD[ <symbol> (pattern) response-expression]

In subsequent discussions, the first alternative is used.

Thus, for the above example, the subgrammar for <ATTRIBUTEALL> is written as follows:

- (a) PD[(<LITERAL-ATTRIBUTE> <MELANOMA>) <LITERAL-ATTRIBUTE> <ATTRIBUTE>]
- (b) PD[(<LITERAL-ATTRIBUTE>) <LITERAL-ATTRIBUTE> <ATTRIBUTE>]
- (c) PD[(<NUMERIC-ATTRIBUTE> <MELANOMA>) <NUMERIC-ATTRIBUTE> <ATTRIBUTE>]
- (d) PD[(<NUMERIC-ATTRIBUTE>) <NUMERIC-ATTRIBUTE> <ATTRIBUTE>]
- (e) PD[(<ATTRIBUTE> AND <ATTRIBUTEALL>) (FO018) <ATTRIBUTEALL>]
- (f) PD[(<ATTRIBUTE> <ATTRIBUTEALL>) (FO018) <ATTRIBUTEALL>]
- (g) PD[(<ATTRIBUTE>) (CREATE.LIST <ATTRIBUTE>) <ATTRIBUTEALL>]

```

<ATTRIBUTEALL> . (AGE SEX SITE THICKNESS)           | rule (f)
  <ATTRIBUTE> . AGE                                   |
    <NUMERIC-ATTRIBUTE> . AGE                         |
      AGE                                             |
  <ATTRIBUTEALL> . (SEX SITE THICKNESS)             |
    <ATTRIBUTE> . SEX                                 |
      <LITERAL-ATTRIBUTE> . SEX                      |
        SEX                                           |
  <ATTRIBUTEALL> . (SITE THICKNESS)                 |
    <ATTRIBUTE> . SITE                               | rule
      <LITERAL-ATTRIBUTE> . SITE                     | (a) | rule (e)
        SITE                                           |
  <MELANOMA> . NIL                                   |
    <OF-FOR> . OF                                     |
      OF                                               |
    <MELANOMA1> . PRIMARY                            |
      PRIMARY                                          |
  AND                                                 |
  <ATTRIBUTEALL> . (THICKNESS)                       | rule
    <ATTRIBUTE> . THICKNESS                           | (g) | rule (d)
      <NUMERIC-ATTRIBUTE> . THICKNESS                 |
        TUMOR                                         |
        THICKNESS                                     |

```

Figure 2. Derivation Sequence for the Specification of Attributes

In (a)-(d), patterns are defined that allow recognition of literal and numeric attributes, and response expression values are associated with the symbol <ATTRIBUTE>. The rules (e) thru (g) allow sequences of literal and numeric attributes to be assigned to the symbol <ATTRIBUTEALL>. The symbol <MELANOMA> matches such strings as "melanoma", "lesion", "primary" or "of the melanoma" so that phrases like "tumor thickness of lesion" and "site of the primary" can be recognized. In rules (a)-(d), the response expressions bind values to the next higher level, while in rules (e)-(f) the specified INTERLISP



expressions are evaluated. CREATE.LIST is a user defined function that creates a list; F0018, a function that combines lists, is defined by

```
(LAMBDA ()
  (APPEND (CREATE.LIST <ATTRIBUTE>)
    <ATTRIBUTEALL>))
```

where APPEND is an INTERLISP function that combines lists to form larger lists.

These grammar rules as well as the fixed phrase, and make set definitions above, can be used to analyze the sentence fragment "age, sex, site of primary, and tumor thickness". This is shown in the derivation structure in Figure 2 where the list of attributes (AGE SEX SITE THICKNESS) is derived during analysis of the sentence fragment and bound to the category <ATTRIBUTEALL>.

The bindings for each <symbol> at different levels of the tree are generated by applying the rules defined above. Several of the subgrammar rules used in this analysis are indicated to the right of the derivation. Applying these rules creates the desired top most binding for <ATTRIBUTEALL>.

The subgrammar rules for <PATIENTS> which define the constraints that apply to the above request (see Page 73) are as follows:

- (h) PD[(**<PATIENT1>** **<WITH>** **<CONSTRAINT>**) (APPEND **<PATIENT1>** **<CONSTRAINT>**) **<PATIENTS>**]
- (i) PD(**<PRE-PATIENTS>**) (F0033) **<PATIENT1>**]
- (j) PD[(**<NOUN-HIST>** **<WITH>** **<CONSTRAINT>**) (F0030) **<CONSTRAINT>**]
- (k) PD[(**<NOUN-HIST>**) **<NOUN-HIST>** **<CONSTRAINT>**]
- (l) PD[(**<TYPE\*>** **<LEVEL\*>**) (APPEND **<TYPE\*>** **<LEVEL\*>**) **<NOUN-HIST>**]
- (m) PD[(**<TYPE>**) F0037 **<TYPE\*>**]
- (n) PD[(**<LEVEL <LEVEL>**) F0020 **<LEVEL\*>**]
- (o) PD[(**<SITE>**) **<SITE>** **<NOUN-HIST>**]
- (p) PD[(**<DET>** **<SITE>**) **<SITE>** **<SITE>**]
- (q) PD[(**UPPER <EXTREMITY>**) '[**SITE (FMEMB \* '(HAND ARM] <SITE>**]

Grammar rule (h) establishes the relationship between individuals

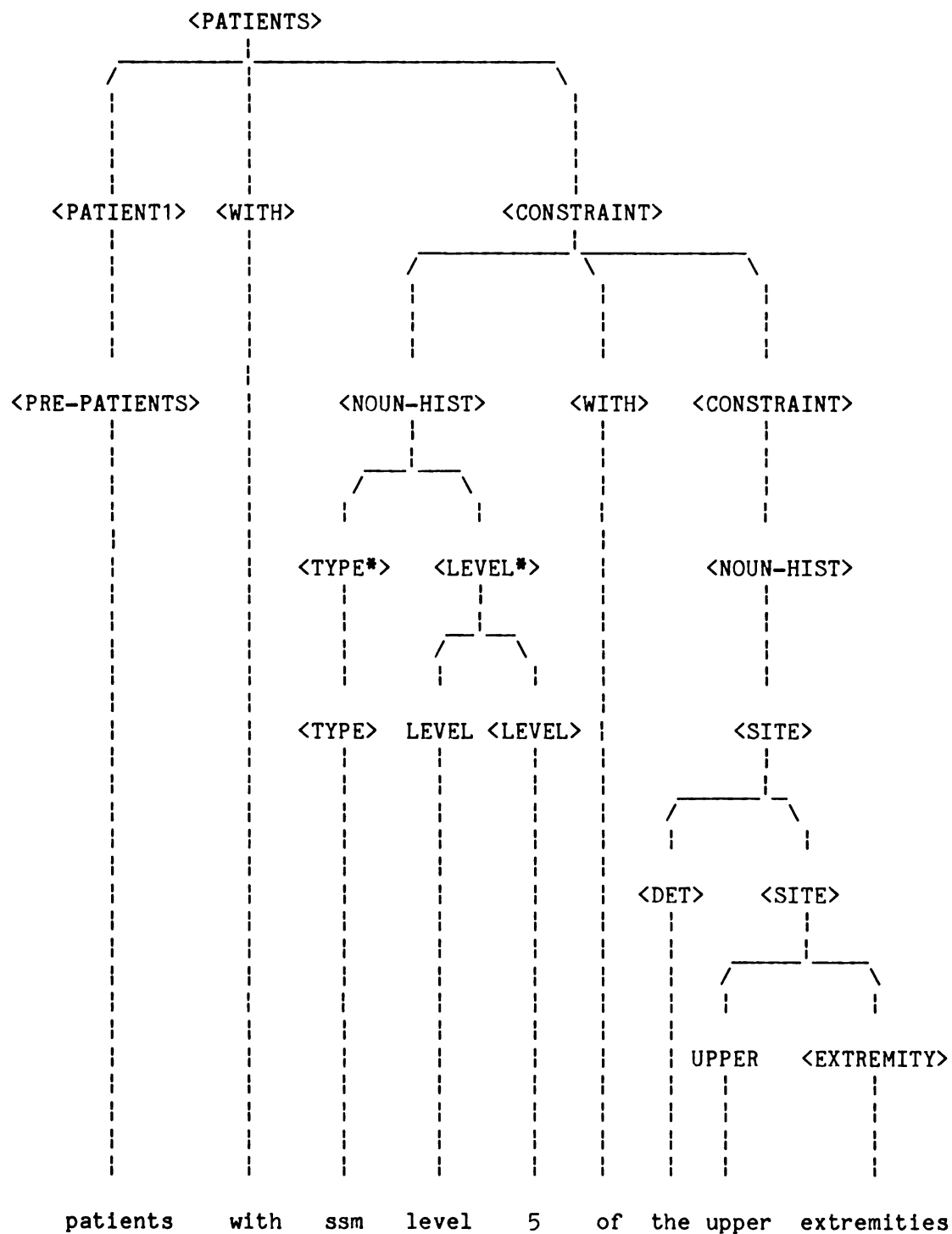


Figure 3. Derivation Tree for Query Constraints

and constraints to be matched against the data base; rule (i) specifies words that refer to individuals; items (j) - (k) define the category <NOUN-HIST> as consisting of phrase constraints that belong to the category <CONSTRAINT>; items (l) - (q) specify the admissible phrases that are associated with <NOUN-HIST>.

Figure 3 shows the derivation of query constraints for the sentence fragment "patients with ssm level 5 of the upper extremities".

From this analysis, the constraint list associated with <PATIENTS> would be (TYPE SSM LEVEL 5 SITE (FMEMB \* '(ARM HAND))).

The operation to be performed on the results from the data base is defined by the following grammar rule:

```
PD[(<LIST> <DET>) 'LIST <SHOW>]
```

which recognizes the string "Display the".

The argument list passed to the data base access module is:

```
(ID ? AGE ? SEX ? SITE ? THICKNESS ? TYPE SSM LEVEL 5 SITE (FMEMB *
                                     '(ARM HAND)))
```

Note in this formal query request that the attribute list (AGE SEX SITE THICKNESS) is augmented by ?'s to retrieve the values from the data base for these attributes when the constraints (TYPE SSM LEVEL 5 SITE (FMEMB \* '(ARM HAND))) are satisfied. The list (ID ?) is appended to the request to also retrieve the patient ID from the data base for each record that is accepted.

Thus, the initial request "Display the age, sex, site of primary, and tumor thickness for patients with ssm level 5 of the upper extremities." is made up of the following parts:

- 1) a list of constraints which are to be matched against the data base (see Figure 3)

- 2) a list of attributes whose values will be returned as a list of attribute value pairs for each patient satisfying the constraints (see Figure 2)
- 3) an operator (included in the expression F0046) that designates the calculations to be performed and the format of the output to be provided

See Page 72 for the analysis generated by MEDINQUIRY in response to this request. The reader also may wish to glance at the overview on creating an application language which presents a more intuitive approach to this analysis (see Page 69).

Two additional functions that may be specified in creating the application language allow the definition of predicates and references to pronouns.

5. Make Predicate (MP) which is of the form MP [<symbol> predicate] allows an input string to be assigned to <symbol> only if it satisfies the predicate.

For example, MP[<LEVEL> (LEVELP]

where LEVELP is defined by

```
(LAMBDA (N) (AND (NUMBERP *)
                 (LEQ N 5)
                 (GEQ N 2])
```

will check that the value for level of invasion is a number in the range 2 to 5 inclusive. Values outside that range will not be accepted under the meta-symbol <LEVEL>. Predicates are especially useful to check for

numbers, so that all numbers associated with <symbol> do not have to be explicitly stated in the application language.

6. Make Pronoun (MPN) provides a capability to perform limited pronoun reference by referring to antecedent classes in the current or prior request. Given a specification of the form MPN[<symbol> (list of pronouns or pronouns bound to symbols)], a backwards search is made of the current sentence for another instance of <symbol> which, if found, has its value bound to <symbol>. If no reference to this symbol is found in the current sentence, the previous sentence also is searched. A value for a given pronoun also may be specified as an augment to the pronoun (that is, another meta-symbol) whose value is associated with <symbol> in the MPN definition. In the example MPN[<PATIENT-MOD> ((THESE . <PATIENTS>)], when the pronoun "these" is identified in a request under the category <PATIENT-MOD>, the current request as well as the previous one are scanned for the symbol <PATIENTS> and if found, the value for <PATIENTS> is bound to <PATIENT-MOD>. If the symbol <PATIENTS> is not found, the match for "these" fails under the category <PATIENT-MOD>.

When analyzing an inquiry, the order of evaluation of items under a given symbol in the application language is fixed phrases; sets and pronouns; predicates; and grammar rules. In cases where possible ambiguities exist in the grammar, the proper ordering of the rules is important for the "correct" parse to be generated first. It is the responsibility of the interface builder to order the rules to meet this requirement. It is possible to determine all legal parses for a request and to display these to the user. However, at this time, it is probably

not appropriate for a naive user to study all the parse trees generated to determine which one was desired.

LIFER is designed so the application language need not be completely specified in advance of any parsing. Instead, it actually is more productive to test input requests in parallel by extending the language definition; the immediate feedback reduces the time required to construct an appropriate interface. Thus, the set of rules described in this section can be used to construct and test part of the language definition which can be enhanced in a stepwise manner.

The following table describes the scope of the application vocabulary and grammar rules in current use:

Words (vocabulary items) :	868
Categories :	233
Words in sets :	781 (created by MS)
Fixed phrases :	357 (created by FP)
Grammatical patterns :	760 (created by PD)
Pronoun references :	9 (created by MPN)
Predicates:	11 (created by MP)
INTERLISP functions:	156

Appendix D contains a list of the words and categories in the current release of the MEDINQUIRY system. (i)

#### 4.6 Rules and Application Vocabulary

What follows is an extract of a small segment of the MEDINQUIRY application language which illustrates some of the types of information that need to be defined and stored to respond to queries. Also included,

---

(i) These figures are current as of September, 1979. However, with continued use, and construction of two 500 patient data bases with somewhat different attributes, the application vocabulary and the grammar rules are being extended and changed.



are those rules given in the previous section. For ease of understanding, the rules are presented in the reference language and associated with each <symbol> are some of the grammar rules (created by PD), sets (created by MS), fixed phrases (created by FP), and predicates (created by MP). Comments are provided in brackets to explain certain features of the application language. In conclusion, several examples are provided that use this application language.

SYMBOL: <ATTRIBUTE>

GRAMMAR

=> (<LITERAL-ATTRIBUTE> <MELANOMA>) ; <LITERAL-ATTRIBUTE>

=> (<LITERAL-ATTRIBUTE>) ; <LITERAL-ATTRIBUTE>

=> (<NUMERIC-ATTRIBUTE> <MELANOMA>) ; <NUMERIC-ATTRIBUTE>

=> (<NUMERIC-ATTRIBUTE>) ; <NUMERIC-ATTRIBUTE>

SYMBOL: <ATTRIBUTEALL> [defines set of attributes whose values are to be retrieved from the data base]

GRAMMAR

=> (<ATTRIBUTE> AND <ATTRIBUTEALL>) ; (FO018)

=> (<ATTRIBUTE> <ATTRIBUTEALL>) ; (FO018)

=> (<ATTRIBUTE>) ; (CREATE.LIST <ATTRIBUTE>)

SYMBOL: <AUXB>

SET

ARE  
HAS  
IS  
WAS  
WERE

SYMBOL: <CONSTRAINT> [defines the general classes of constraints to be matched against the data base]

GRAMMAR

=> (<NOUN-HIST> <WITH> <CONSTRAINT>) ; F0030

=> (<NOUN-HIST> <CONSTRAINT>) ; F0030





=> (<NOUN-HIST>) ; <NOUN-HIST>

=> (<NOUN-FUP> <CONSTRAINT>) ; (APPEND <NOUN-FUP> <CONSTRAINT>)

. [**<NOUN-FUP>** specifies phrases related  
 . to follow up information]  
 .

SYMBOL: <EXTREMITY>

SET

EXTREMITIES ; (SITE (FMEMB \* (QUOTE (HAND ARM THIGH CALF FOOT  
 KNEE))))  
 EXTREMITY ; (SITE (FMEMB \* (QUOTE (HAND ARM THIGH CALF FOOT KNEE))))  
 LIMB ; (SITE (FMEMB \* (QUOTE (HAND ARM THIGH CALF FOOT KNEE))))  
 LIMBS ; (SITE (FMEMB \* (QUOTE (HAND ARM THIGH CALF FOOT KNEE))))

SYMBOL: <LEVEL\*>

GRAMMAR

=> (<LEVEL>) ; F0020  
 => (LEVEL <LEVEL>) ; F0020  
 => (LEVEL <LEVEL> INVASION) ; F0020  
 => (LEVEL <LEVEL> OR <LEVELN>) ; F0031

SYMBOL: <LEVEL>

GRAMMAR

=> (<NS>) ; <NS> [handles instances where level is not specified,  
 indeterminate, not available, unassigned,  
 unknown, or undetermined.]

SET

II ; 2  
 III ; 3  
 IV ; 4  
 UNCLASSIFIED  
 V ; 5

PREDICATE

LEVELP

SYMBOL: <LIST> [specifies in part the operation to be performed on retrieved data]

FIXED-PHRASES

(SHOW ME) ; LIST  
(GIVE ME) ; LIST

SET

CALCULATE  
CITE  
COMPUTE  
DETERMINE  
DISPLAY  
FIND  
GIVE  
LIST  
OUTPUT  
PRINT  
RETRIEVE  
SELECT  
SHOW  
WHAT

SYMBOL: <LITERAL-ATTRIBUTE>

FIXED-PHRASES

(CELLULAR HOST RESPONSE) ; (LYMPHOCYTES MACROPHAGES PLASMA.CELLS)

SET

SEX  
SITE  
LOCATION  
MITOTIC RATE  
TYPE

SYMBOL: <NOUN-HIST> [constraints associated with histopathology data]

GRAMMAR

=> (<TYPE\*> <LEVEL\*>) ; (APPEND <TYPE\*> <LEVEL\*>)

=> (<TYPE\*>) ; <TYPE\*>

=> (<LEVEL\*>) ; <LEVEL\*>

=> (<SITE>) ; <SITE>



=> (<HISTOLOGY> <CONFIRM> <PATH-NAME>) ; <HISTOLOGY>

[<HISTOLOGY> includes phrases that relate histologic attributes with their values such as many mitoses and high mitotic rate; <PATH-NAME> includes terms such as: histologic, histogenic, histology, pathologic, and anatomic]

=> (<HISTOLOGY> <PATH-NAME> <CONFIRM>) ; <HISTOLOGY>

=> (<HISTOLOGY>) ; <HISTOLOGY>

SYMBOL: <NUMERIC-ATTRIBUTE> [specifies dimensional attributes]

#### GRAMMAR

=> (<MELANOMA1> <NUMERIC-ATTRIBUTE>) ; <NUMERIC-ATTRIBUTE>

=> (<PATH-NAME> LEVEL) ; (QUOTE LEVEL)

=> (THICKNESS <MELANOMA>) ; (QUOTE THICKNESS)

#### FIXED-PHRASES

(TUMOR THICKNESS) ; THICKNESS

(DEPTH OF TUMOR) ; THICKNESS

(DEPTH OF INVASION) ; (THICKNESS LEVEL)

(DEPTH OF INVOLVEMENT) ; (THICKNESS LEVEL)

(LEVEL OF INVASION) ; LEVEL

(OVERALL TUMOR THICKNESS) ; THICKNESS

(DEGREE OF INVASION) ; LEVEL

(VERTICAL TUMOR THICKNESS) ; THICKNESS

(LEVEL OF INFILTRATION) ; LEVEL

(AGE AT DIAGNOSIS) ; AGE

(VERTICAL THICKNESS) ; THICKNESS

#### SET

AGE

DEPTH ; THICKNESS

LEVEL ; LEVEL

THICKNESS

SYMBOL: <NUMERIC-ATTRIBUTES> [creates lists of numeric attributes]

GRAMMAR

=> (<NUMERIC-ATTRIBUTE>) ; (CREATE.LIST <NUMERIC-ATTRIBUTE>)

=> (<NUMERIC-ATTRIBUTE> <NUMERIC-ATTRIBUTES>) ; F0032

=> (<NUMERIC-ATTRIBUTE> AND <NUMERIC-ATTRIBUTES>) ; F0032

SYMBOL: <NUMERIC-OPERATOR> [specifies calculations to be performed on retrieved data]

SET

AVERAGE ; MEAN  
 GREATEST ; MAXIMUM  
 HIGHEST ; MAXIMUM  
 LEAST ; MINIMUM  
 LOWEST ; MINIMUM  
 MAXIMUM  
 MEAN  
 MEDIAN  
 MINIMUM  
 OLDEST ; MAXIMUM  
 YOUNGEST ; MINIMUM

SYMBOL: <NUMERIC-OPERATORS> [creates lists of numeric operators]

GRAMMAR

=> (<DET> <NUMERIC-OPERATORS>) ; <NUMERIC-OPERATORS>

=> (<NUMERIC-OPERATOR>) ; (LIST <NUMERIC-OPERATOR>)

=> (<NUMERIC-OPERATOR> AND <NUMERIC-OPERATORS>) ; F0050

=> (<NUMERIC-OPERATOR> <NUMERIC-OPERATORS>) ; F0050

=> (<OF-FOR> <DET> <NUMERIC-OPERATORS>) ; <NUMERIC-OPERATORS>

SYMBOL: <OF-FOR>

SET

OF  
 FOR

SYMBOL: <PATIENT1>

GRAMMAR

=> (<PRE-PATIENTS>) ; F0033

=> (<OF-FOR> <PATIENT1>) ; <PATIENT1>



=> (<OF-FOR> <QUANT> <PATIENT1>) ; <PATIENT1>

SYMBOL: <PATIENTS> [highest level constraint that relates individuals with constraints]

GRAMMAR

=> (<PATIENT1> <WITH> <CONSTRAINT>) ; (APPEND <PATIENT1>  
<CONSTRAINT>)

=> (<WITH> <CONSTRAINT>) ; <CONSTRAINT>

SYMBOL: <PRE-PATIENTS>

SET

CASES  
INDIVIDUALS  
PATIENTS  
PTS  
PEOPLE  
PERSONS

SYMBOL: <SELECT-TABULATE> [specifies items admissible as tabulated results]

GRAMMAR

=> (<BY> <ATTRIBUTEALL>) ; <ATTRIBUTEALL>

=> (<TABULATED> <BY> <ATTRIBUTEALL>) ; <ATTRIBUTEALL>

SYMBOL: <SHOW> [defines, in part, the class of question being asked]

GRAMMAR

=> (<LIST> <AUXB> <DET>) ; (QUOTE LIST)

=> (<LIST> <AUXB>) ; (QUOTE LIST)

=> (<LIST> <DET>) ; (QUOTE LIST)

=> (<LIST>) ; (QUOTE LIST)

SYMBOL: <SITE> [specifies semantic class for site of primary]

GRAMMAR

=> (<DET> <SITE>) ; <SITE>

=> (<EXTREMITY>) ; <EXTREMITY>

=> (LOWER <EXTREMITY>) ; [QUOTE (SITE (FMEMB \* (QUOTE (FOOT THIGH





CALF KNEE)]

=> (UPPER <EXTREMITY>) ; [QUOTE (SITE (FMEMB \* (QUOTE (HAND ARM]

FIXED-PHRASES

(HEAD OR NECK) ; [SITE (FMEMB \* (QUOTE (HEAD NECK]

(HEAD AND NECK REGION) ; [SITE (FMEMB \* (QUOTE (HEAD NECK]

(EXPOSED SITES) ; [SITE (FMEMB \* (QUOTE (ARM HAND HEAD NECK]

SET

ARM ; (SITE ARM)

BACK ; (SITE BACK)

CALF ; (SITE CALF)

FOOT ; (SITE FOOT)

FRONT ; (SITE FRONT)

HAND ; (SITE HAND)

HEAD ; (SITE HEAD)

KNEE ; (SITE KNEE)

LEG ; (SITE (FMEMB \* (QUOTE (LEG CALF))))

NECK ; (SITE NECK)

SHOULDER ; (SITE SHOULDER)

THIGH ; (SITE THIGH)

TRUNK ; (SITE (FMEMB \* (QUOTE (FRONT BACK))))

SYMBOL: <TABULATED>

SET

ARRANGED

DISPLAYED

GROUPED

LISTED

ORDERED

ORGANIZED

OUTPUT

PRINTED

STRATIFIED

TABULATED

SYMBOL: <TYPE\*> [completes possible phrases for type of melanoma]

GRAMMAR

=> (<TYPE>) ; F0037

=> (<TYPE> TYPE) ; F0037

SYMBOL: <TYPE> [semantic class that identifies type of melanoma]

FIXED-PHRASES

(SUPERFICIAL SPREADING MELANOMA) ; SSM

(SUPERFICIAL SPREADING MALIGNANT MELANOMA) ; SSM

(MELANOMA OF THE SUPERFICIAL SPREADING TYPE) ; SSM

(MELANOMA OF THE NODULAR TYPE) ; NM

(LENTIGO MALIGNANT MELANOMA) ; LMM

(LENTIGO MALIGNA MELANOMA) ; LMM

SET

LMM

NAVAIL

NM

SSM

UNCLASSIFIED

UNDETERMINED

SYMBOL: <WITH>

GRAMMAR

=> (<HAVE> <WITH>) ; (QUOTE WITH)

=> (<HAVE>) ; (QUOTE WITH)

SET

OF

WITH

Several examples are now given, using the above application language, to analyze query requests as submitted by a user of the system. The top level rule defined to process the request, "What is the minimum, maximum, and average tumor thickness for patients with melanoma of the extremities ordered by level of invasion?" is

```
<LTG> ==> (<SHOW> <NUMERIC-OPERATORS> <NUMERIC-ATTRIBUTES> <PATIENTS>
           <SELECT-TABULATE>); (TABULATE-NUMERIC <NUMERIC-OPERATORS>
           <NUMERIC-ATTRIBUTES> <SELECT-TABULATE>)
```



The pattern to the right of the semi-colon is the response expression invoked when the top level pattern to the left of the semi-colon is matched during the parsing process. The symbol <SHOW> matches "What is the"; <NUMERIC-OPERATORS> matches "minimum, maximum, and average"; <NUMERIC-ATTRIBUTES> matches "tumor thickness"; <OF-FOR> matches "for"; <PATIENTS> matches "patients with melanoma of the extremities"; and <SELECT-TABULATE> matches "ordered by level of invasion". The function TABULATE-NUMERIC with the designated arguments, calls the appropriate functions to perform retrieval from the data base and to display the results in the required tabular form.

Several additional examples of requests that may be entered using this top level rule and the application language above are: "Calculate the average age for pts. with nm of the arm organized by sex", "Compute the mean tumor thickness for individuals with level 5 melanoma of the trunk arranged by mitotic rate.", or "Find the minimum and maximum vertical thickness of the primary for people having melanoma of the back ordered by level of invasion".

Variations in the language for formulating inquiries, using the same response function, can be handled through the definition of additional top level patterns. For example, the top level pattern

```
<LTG> ==> (<SELECT-TABULATE> <SHOW> <NUMERIC-OPERATORS>
            <NUMERIC-ATTRIBUTES> <OF-FOR> <PATIENTS>); (TABULATE-NUMERIC
            <NUMERIC-OPERATORS> <NUMERIC-ATTRIBUTES> <SELECT-TABULATE>]
```

can be used to interpret the requests, "Stratified by level, determine the average tumor thickness for pts with many mitoses who had melanoma of the lower extremities.", or "Organized by level, calculate the average tumor thickness for patients with malignant melanoma of the trunk".



The top level rule

```
<LTG> ==> (<OF-FOR> <PATIENTS> <SHOW> <NUMERIC-OPERATORS>
           <NUMERIC-ATTRIBUTES> <SELECT-ATTRIBUTES>) ; (TABULATE-NUMERIC
           <NUMERIC-OPERATORS> <NUMERIC-ATTRIBUTES> <SELECT-TABULATE>)
```

can be used to respond to requests such as: "for pts with level 5 melanoma, find the maximum and minimum tumor thickness and age at diagnosis arranged by sex.", or "for people with melanoma located on the extremities, what was their average age ordered by sex?".

Counts of the number of patients satisfying certain constraints can be recognized by first assigning the terms "count" and "how many" to the category <HOW-MANY> using MS and FP respectively, and writing an INTERLISP function that performs counts. Then the top level rule

```
<LTG> ==> (<HOW-MANY> <PATIENTS>) ; (COUNTPTS (IDFILEDATA <PATIENTS>))
```

will respond to requests such as, "How many people had level 5 melanoma of the trunk?", and "Count individuals with level 5 superficial spreading melanoma".

One of the functions, COUNT.CALC, called from COUNTPTS that performs the counting is defined as follows:

```
(COUNT.CALC
 [LAMBDA (PTS)
  (PROG ((NUMB 0))
    [MAPC PTS (FUNCTION (LAMBDA (X)
      (COND
        ((GETP (CADR X)
          (QUOTE IDD)))
        ((PUT (CADR X)
          (QUOTE IDD)
          T)
          (SETQ NUMB (ADD1 NUMB)]
    [MAPC PTS (FUNCTION (LAMBDA (X)
      (REMPROP (CADR X)
        (QUOTE IDD)]
    (RETURN NUMB])
```

Tabulated counts can be defined by the rule

```
<LTG> ==> (<HOW-MANY> <PATIENTS> <SELECT-TABULATE>) ; F0040
```

that responds to inquiries like: "how many people with ssm 5 ordered by tumor thickness?", "How many pts with level 4 arranged wrt site of the primary?", and "Count the pts with melanoma of the trunk stratified by location of primary, level of invasion, and mitotic rate.".

Many other requests can be formulated based on the application language defined above, and the language can be augmented to respond to additional classes of requests. A description of the facilities available in the present release of the system is presented in the next chapter.



## Chapter 5

### MEDINQUIRY: SYSTEM USE

This chapter describes the classes of requests currently implemented, presents ways of enhancing the acceptability of the system, illustrates the use of pronoun references and meta-questions to augment the basic query facility, and concludes with an annotated transcript of an extract of a MEDINQUIRY session.

#### 5.1 Classes of Requests

The classes of requests were derived from a comprehensive review of the literature on melanoma (see Chapter 3), from analysis of the data elements and values in the melanoma data base, and from conversations with experts in melanoma. Requests in each of the classes may be either simple, or complex requests that include conjunction between several items. The overall structure of the application language supports a wide range of requests that are transformed into the following general components: constraints to be matched against the data base; selected attributes which are to be retrieved from the data base; specified attributes which are used to tabulate the results; and operations which are to be performed to produce a response.

The classes of requests implemented in the current version of MEDINQUIRY are summarized, with examples, as follows:

1. Information about the contents and characteristics of the data base:  
the system can respond to requests about the attributes associated with

an information class in the data base, the values of attributes in the data base, the definition of selected attribute-value pairs in the data base, or general questions about the composition of the data base. This capability is especially useful for users who may be experts in melanoma, but may not be familiar with the actual data attributes in this data base or how these data were recorded in the study.

For example:

How many patients in the study?

Count the number of follow up visits.

List the classes of attributes in the melanoma study.

What items are associated with follow-up results?

Display the values in the study for mitotic rate.

How was regression of the primary recorded in the database?

Show me the spread of collected values for thickness of the primary.

How is few mitoses defined?

Define Stage IF.

2. Information about a particular patient: MEDINQUIRY can retrieve and display one or more data elements on a particular patient, or provide a listing of all data in an attribute class on a particular patient.

For example:

List the pathology results for patient S-72-002.

Display the tumor thickness and mitotic rate for pt. S-72-003.

What data is available for S-72-004?

Describe the clinical course of the disease for pt S-72-003.

Show the changes in the primary lesion for pt. S-74-061.

3. Counts: the data base is searched and the number of patients (or instances) satisfying a particular combination of attribute-values is displayed.

For example:

How many cases were characterized by an increase in the size of the lesion for 6 months prior to initial therapy?

Count the number of individuals who had lymph node procedures.

What is the total number of lymph node procedures performed?

Count the number of individuals with melanoma of the superficial spreading type who had many mitoses, thick primaries, and histologically confirmed recurrence within 2 years after diagnosis.

In how many pts was level 4 or level 5 disease observed?

How many people with no histologic recurrence within year 1?

4. Relations and distributions: the relation between specified attributes subject to constraints in the request is determined and several output displays are provided. The types of displays supported include tabulated counts, tabulated groupings, and outputs organized by specific items in the data base.

For example:

Stratify pts with ssm of the upper extremities by depth of involvement of the primary.

List the site of the primary, site of lymph node procedures, and the number of positive nodes found for individuals who had ssm, elective lymph node procedures, and tumor thickness greater than 1.5 mm.

Which patients with high risk primaries had pathologically confirmed recurrence in year one?

How many patients with level 4 or 5 melanoma organized by tumor thickness?

Count the number of pts with recurrence grouped by tumor thickness?

Count the individuals with ssm and order them by mitotic rate and tumor thickness.

How many pts in the data base stratified by type, mitotic activity, and regression of the primary?

What is the distribution of patients with regression of the primary arranged by tumor thickness and level of invasion?

For individuals with level 4 or 5 melanoma with no evidence of disease within 24 months, display the age, tumor thickness, mitotic rate, and change in the primary organized by tumor thickness.

Display the surface characteristics of the primary in patients with ssm of the upper extremities who had tumor thickness greater than 3 mm.

5. Calculations: computations are performed on selected subsets of data and the results are displayed. Calculations that may be performed include simple proportions, percentages, averages, medians, maxima, and minima.

For example:

What is the minimum, maximum, mean and median tumor thickness and age for pts with melanoma of the extremities arranged by level of invasion?

Calculate the proportion of individuals with ssm and thickness greater than 3 mm. who had histologically demonstrated recurrence within 24 months of initial therapy.

What percentage of patients had the primary in a preexisting mole?

Compute the average and median tumor thickness for patients with histologically positive nodes.

Determine the mean and median thickness of the melanomas for individuals with no histologically involved lymph nodes.

6. Yes-no questions: the response indicates the presence or absence of items in the data base with the specified constraints by providing a count of the number of individuals or elements satisfying the specified constraints.

For example:

Did any pts with ssm of the trunk have the following: regression of the primary, few mitoses, and pathologically demonstrated recurrence



in the first year of follow up?

7. Information about the grammar and application vocabulary: the response provides information about the context of use of words in the grammar, as well as a description of information in a given word class, in the grammar. This capability can assist the user in determining where and how a particular word is used in the grammar, and can aid the user in determining why a given request will not parse.

For example:

How is regression used?

Explain <hist-att-1>.

In what way is <literal-attribute> referred to?

Where is ulceration used?

The classes of requests described above constitute a basic set of request types. Requests may also be input as sequences of questions that depend on prior requests to support dialogue interactions using pronoun references, elliptical constructions, or paraphrase definitions. These facilities are described in the next two sections. Additional examples of requests that are currently supported are given in Appendix E. Users who plan to use the system are encouraged to browse through this list to gain perspective about the language constructs that can presently be used in formulating requests.

## 5.2 System Enhancements to Assist the User

This section describes additional facilities that make the man-machine interface more responsive and reliable and therefore,



potentially more usable and acceptable for the expert. These facilities include system interpretation of all requests that require access to the data base, a spelling corrector, an automated facility for processing elliptical inputs (incomplete sentences), and a paraphrase mechanism to extend the language interface by defining new constructs at the phrase or sentence level (i).

The following examples were extracted from an actual session and illustrate several of these features. The data base response to these requests has been omitted for clarity of presentation. Item 5 illustrates the spelling correction feature where transpositions of letters, as well as other detectable misspellings, are corrected and the request analyzed. In item 6, typing the sentence fragment "2 years" matches a similar context in the previous request and a substitution is made. Request 6 is an example of the ellipsis add-on capability. The system first tries to parse the request "ordered by tumor thickness" and when this fails, an attempt is made to find a grammatical rule in the application language that allows adding the request onto the end of the prior request. The user is asked whether the substitution is appropriate; if the response is in the affirmative, MEDINQUIRY proceeds to analyze the request.

```
5_how mnay individuald had histologic recurrence within 1 year?
    MANY <-spelling
    spelling-> INDIVIDUAL
```

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS equal to a member of the set

-----

(i) Extensions at the sentence level that make use of meta-questions are described in the next section.



(HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY less than 13.

6\_2 years

Trying Ellipsis: HOW MANY INDIVIDUAL HAD HISTOLOGIC RECURRENCE WITHIN 2 YEARS

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY less than 25.

7\_ordered by tumor thickness.

Trying Ellipsis: Do you mean HOW MANY INDIVIDUAL HAD HISTOLOGIC RECURRENCE WITHIN 2 YEARS ORDERED BY TUMOR THICKNESS ? yes

ANALYZED

MEDINQUIRY has interpreted your request as follows:

How many individuals with STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY less than 25 organized with respect to TUMOR THICKNESS (MM.).

Requests 8-17 (see below) illustrate how the system deals with requests that are blocked, that is, do not parse within the framework of the existing rules. In item 8, MEDINQUIRY does not recognize "1" as being acceptable following level; possible alternative word classes or words that may be used at this point are presented. The user may ask the system to explain what the word class <level> may contain. Request 9 indicates that there is no level 1 disease acceptable in the grammar, and in fact, there are no patients with level 1 in the data base. The predicate LEVELP only accepts values for level in the range 2 through 5 (see Page 81, where LEVELP is defined). It seems reasonable to block these types of requests at parse time, rather than to access the data



base and receive the answer that there are no patients satisfying the request. Similarly, in request 10, "as well as" does not seem to be an acceptable phrase in the current MEDINQUIRY application language. However, using the paraphrase facility that allows the definition of new phrases, it may be added to the application language (see item 11). The original request can then be submitted and will parse properly (see item 12). Now, whenever the string "as well as" appears in a query, the word "and" is substituted prior to analysis of the query. (i)

Request 13 is inappropriate and asks the system to calculate the average sex. Note that the names of word classes and words that may appear are suggestive of their meaning and use in the application language. That is, items under <NUMERIC-ATTRIBUTES> should belong to the class of numeric attributes such as, age or tumor thickness; <NUMERIC-OPERATORS> might be operators such as minimum and maximum; while AND could be used as a language connector between average and median. Similarly, in request 14, the reference to recurrence as a tabulated attribute is ambiguous. A more appropriate item to tabulate on would be attributes such as time to recurrence or type of recurrence.

Requests 15 through 17 illustrate the procedure followed in attempting to determine how to complete a request when the system has analyzed all the words in the request, but expects additional words to follow.

---

(i) This involves use of the LIFER preprocessor facility that scans the substitutions that have been specified as preprocessor options. Punctuation also is processed in a similar manner.



8\_count the number of pts with level 1 invasion

The word "1" is not in the MEDINQUIRY vocabulary.

Acceptable alternatives are the following words or word classes (in angle brackets):

<LEVEL>, <MELANOMA>, <NUM-COMP>, <OF-FOR>, BETWEEN, OF

9\_explain <level>

ANALYZED

"<LEVEL>" may be any sequence of words following one of the patterns:  
<LEVEL> => <NS>

"<LEVEL>" may be any sequence of words following one of the patterns:  
(NOT AVAILABLE)

"<LEVEL>" may be any member of the set (II III IV NAVAIL UNCLASSIFIED  
UNKNOWN V )

"<LEVEL>" may be any word or symbol satisfying the predicate LEVELP

10\_display the age as well as sex for pts with ssm 5 ordered by tumor  
thickness.

MEDINQUIRY does not expect "AS" to follow  
"DISPLAY THE AGE"

Options for next word or word class are:

<ATTRIBUTEALL>, <ATTRIBUTES>, <NUM-COMP>, <NUMERIC-ATTRIBUTES>,  
<NUMERIC-OPERATORS>, <OF-FOR>, AND, AT, BETWEEN

11\_let "as well as" equal "and".

ANALYZED

AND

12\_display the age as well as sex for pts with ssm 5 ordered by  
thickness.

(DISPLAY THE AGE AND SEX FOR PTS WITH SSM 5 ORDERED BY THICKNESS)

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Stratified by TUMOR THICKNESS (MM.) display the AGE (AT DIAGNOSIS) and  
SEX for people with DEFINITIVE PATHOLOGICAL TYPE equal SSM and  
DEFINITIVE PATHOLOGICAL LEVEL equal 5.



13\_What is the average sex for people with ssm 5?

MEDINQUIRY does not expect "SEX" to follow  
"WHAT IS THE AVERAGE"

Options for next word or word class are:  
<NUMERIC-ATTRIBUTES>, <NUMERIC-OPERATORS>, AND, SUNTAN, TAN

14\_how many pts with ssm ordered by recurrence and site of primary?

MEDINQUIRY does not expect "RECURRENCE" to follow  
"HOW MANY PTS WITH SSM ORDERED BY"

Options for next word or word class are:  
<ATTRIBUTEALL>

15\_how many patients had lesion sun exposure?

MEDINQUIRY has analyzed the entire request, but it expected more words  
to follow. Acceptable alternatives are the following words or word  
classes:  
<ATT-COMP>

To determine what words are in a class type EXPLAIN <WORD-CLASS>.

16\_ Explain <ATT-COMP>

ANALYZED

"<ATT-COMP>" may be any sequence of words following one of the patterns:  
(WAS EQUAL)

"<ATT-COMP>" may be any member of the set  
(= EQUAL IS WAS WERE).

17\_how many pts had lesion sun exposure equal much?

ANALYZED

[Other paraphrases of this request such as "how  
many pts had much lesion sun exposure?" also  
would be processed.]

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with LESION SUN EXPOSURE equal MUCH.

The number of patients satisfying your requests is 31.





### 5.3 Dialogue Interactions

MEDINQUIRY supports dialogue interactions through a limited facility to use pronouns to reference prior requests, through the use of ellipsis and ellipsis add-on capabilities, and through the use of the LIFER macro-paraphrase facility to define meta-questions.

The following sequence of requests illustrate the recognition of pronoun reference. In these requests, the pronouns "them", "these", "those", and "they" reference the appropriate subsets of patients identified in the previous request.

How many patients with ssm?  
 How many of them had level 5 disease?  
 List the age, sex, and tumor thickness for these people.  
 How many of those cases demonstrated histologic recurrence within  
 24 months?  
 Who are they?

The following sequence of requests illustrate the use of the ellipsis add-on and ellipsis facilities coupled with pronoun references to carry on a dialogue interaction. The elliptical processing interprets the sentence fragments that are input in the context of information in the previous request.

Count pts. with level 4 or 5 melanoma who had histologic recurrence.

ordered by sex.

[interpreted as: Count pts. with level 4 or 5 melanoma who had histologic recurrence ordered by sex.]

ordered by tumor thickness

[interpreted as: Count pts. with level 4 or 5 melanoma who had histologic recurrence ordered by tumor thickness.]

level 2 or 3

[interpreted as: Count pts. with level 2 or 3 melanoma who had histologic recurrence ordered by tumor thickness.]

Order these patients by mitotic rate and tumor thickness.



Note that in each of these sequences of questions the basic set of questions supported by MEDINQUIRY can be used to designate a subset of the data base upon which subsequent requests can be based. Additional examples of dialogue interactions are given in Appendix E.

In the request below, the capability to define meta-questions is shown. A meta-question is specified through the use of the paraphrase facility to define a pattern that can be used to extend the language interface to respond to a sequence of requests.

24\_let "determine recurrence rates for patients with level 5 disease" equal "how many patients with level 5 disease were followed in year 1? What proportion of them had histologic recurrence in the first year? how many of them had ned in year 1? what percentage of them were seen in year 2 and had histologic recurrence in the second year?"

ANALYZED

HOW MANY PATIENTS WITH LEVEL 5 DISEASE WERE FOLLOWED IN YEAR 1

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 5.

WHAT PROPORTION OF THEM HAD HISTOLOGIC RECURRENCE IN THE FIRST YEAR

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 5 had STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

HOW MANY OF THEM HAD NED IN YEAR 1

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS not equal to a member of the set (POSSIBLE.RECURRENCE DEFINITE.RECURRENCE HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 5.

WHAT PERCENTAGE OF THEM WERE SEEN IN YEAR 2 AND HAD HISTOLOGIC RECURRENCE IN THE SECOND YEAR

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with MONTHS SINCE INITIAL THERAPY greater than or equal to 13 and less than or equal to 24.

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 5 had STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 13 and less than or equal to 24.

LIFER.TOP.GRAMMAR => DETERMINE <RECURRENCE> RATES FOR <PATIENT1>  
<CONSTRAINT>

MEDINQUIRY analyzes each of the four requests that comprise the meta-question without accessing the data base. This ensures that each of the requests can be parsed by the system. A new pattern "Determine <recurrence> rates for <patient1> <constraint>" is added to the top level of the grammar. Thus, any request entered that matches this

pattern will invoke the entire meta-question and respond in turn to each of the four questions that make up the meta-question. In particular, this meta-question can be used to determine the recurrence rates in each of the first two years of follow-up for patients satisfying the constraints specified by the subgrammar pattern '<constraint>'.

The original meta-question can now be answered as well as other questions following similar patterns. This is illustrated by the examples below.

25\_determine recurrence rates for pts with level 5 disease.

ANALYZED

-- Macro expansion --

HOW MANY PTS WITH LEVEL 5 DISEASE WERE FOLLOWED IN YEAR 1

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 5 and ID equal to a member of the set (S-72-014 S-73-013 S-73-039 S-73-040 S-74-055 S-74-061 S-74-066 S-74-087 S-75-004 S-75-025 S-75-026 S-75-033 S-75-034 S-75-039 S-76-003 S-76-022).

The number of patients satisfying your request is 16.

WHAT PROPORTION OF THEM HAD HISTOLOGIC RECURRENCE IN THE FIRST YEAR

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 5 and ID equal to a member of the set (S-72-014 S-73-013 S-73-039 S-73-040 S-74-055 S-74-061 S-74-066 S-74-087 S-75-004 S-75-025 S-75-026 S-75-033



S-75-034 S-75-039 S-76-003 S-76-022) had STATUS equal to a member of the set HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

16 case(s) were accepted  
 10 case(s) satisfied the specified constraints  
 0 case(s) were rejected due to missing or unspecified values.  
 PROPORTION IS 0.62

HOW MANY OF THEM HAD NED IN YEAR 1

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS not equal to a member of the set (POSSIBLE.RECURRENCE DEFINITE.RECURRENCE HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 5 and ID equal to a member of the set (S-73-040 S-74-087 S-75-034 S-75-039).

The number of patients satisfying your request is 4.

WHAT PERCENTAGE OF THEM WERE SEEN IN YEAR 2 AND HAD HISTOLOGIC RECURRENCE IN THE SECOND YEAR

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with MONTHS SINCE INITIAL THERAPY greater than or equal to 13 and less than or equal to 24.

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 5 and ID equal to a member of the set (S-73-040 S-74-087 S-75-034) had STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 13 and less than or equal to 24.

3 case(s) were accepted  
1 case(s) satisfied the specified constraints  
0 case(s) were rejected due to missing or unspecified values.  
PERCENTAGE IS 33.33

The above results indicate that of 16 patients with level 5 disease who were followed in year one, approximately 2/3's of them had histologic recurrence in the first year. For those with no evidence of disease in year 1, 1/3 of them had histologic recurrence in year 2. Thus, although the sample size is small, the results tend to support the hypothesis that individuals with level 5 melanomas have a very poor prognosis.

Note that the patient ID numbers, which are included in the system interpretation of the requests, specify those patients being considered in each request. This is an optional feature and if desired, may be omitted by setting the appropriate flag. Also note, that one patient, S-75-039, had no evidence of disease in year 1 but was not followed in year 2.

It is also possible to use the paraphrase feature of LIFER to specify additional constraints at the phrase level that can be substituted in the meta-question. For example, a concept "hrp2" can be specified that describes a potential high risk primary as follows:

26\_define "hrp2" similar to "many mitoses and tumor thickness > 1.5 mm."

ANALYZED

MANY MITOSES AND TUMOR THICKNESS > 1.50 MM

Whenever MEDINQUIRY finds HRP2 in a request, it will be replaced by  
MANY MITOSES AND TUMOR THICKNESS > 1.50 MM.



Once defined, the concept "hrp2" can be used with the previously defined meta-question to determine whether the aggregate of high mitotic activity and tumor thickness greater than 1.5 mm. is a good indicator of prognosis (see question 24 on Page 106). For example,

27\_determine recurrence rates for people with hrp2

(DETERMINE RECURRENCE RATES FOR PEOPLE WITH MANY MITOSES AND TUMOR THICKNESS > 1.50 MM)

ANALYZED

-- Macro expansion --

HOW MANY PEOPLE WITH MANY MITOSES AND TUMOR THICKNESS > 1.50 MM WERE FOLLOWED IN YEAR 1

[output omitted]

The results of this request showed that over 2/3 (10 of 15) of the patients with "hrp2" had histologic recurrence in the first year of follow up, with only five patients having no evidence of disease in the first year of follow up. Two of these patients were not seen in year 2 and three patients had no histologic recurrence in year 2. From these results, it is reasonable to infer that the concept "hrp2" is a useful prognostic indicator. It also may be worthwhile to test if the parameters mitotic activity alone or tumor thickness alone are as good indicants of prognosis. That is, is there a strong correlation between tumor thickness and mitotic activity in assessing prognosis?

Other possible requests that can be answered using the same defined meta-pattern include:

Determine the recurrence rates for individuals having level 2 disease with histologically demonstrated regression.

Determine the recurrence rates for pts with regression of the primary.

Determine the recurrence rates for people who had many mitoses and were older than 40 yrs.

#### 5.4 Extracts from a Sample Transcript

This section contains a transcript of some interactions with MEDINQUIRY. The system prompts with a number followed by an underscore; each query is entered as indicated. When the request has been processed and understood by MEDINQUIRY, the system responds with the word "ANALYZED"; for each request that requires access to the data base, a paraphrase of the system's understanding of the request is given. This verifies, for the user, that the request has been properly understood. The data base is then accessed to retrieve the required information, and an appropriate answer is returned.

The examples presented indicate some of the kinds of responses that are currently provided. The transcript also illustrates the process of inquiry itself, in particular, the way that successive queries can build directly on preceding ones to support a dialog required to formulate and test hypotheses of interest. Note that in these examples, punctuation as well as abbreviations are handled. A commentary of some of the salient features of these examples follow the transcript.

1\_ how many patients are there in the melanoma data base?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with melanoma.

The number of patients satisfying your request is 130.

2\_list the classes of attributes in the study.

ANALYZED

PERSONAL DATA  
 FAMILY HISTORY OF DISEASE  
 PATIENT BACKGROUND  
 PATIENT PHYSICAL EXAMINATION  
 HISTORY OF PRIMARY  
 PHYSICAL EXAMINATION OF PRIMARY  
 PATHOLOGY DATA  
 LYMPH NODE PROCEDURES  
 FOLLOW UP DATA

3\_what is the average, median, minimum, and maximum age at diagnosis for individuals in the db arranged by sex?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What is the MEAN and MEDIAN and MINIMUM and MAXIMUM AGE (AT DIAGNOSIS) for people with melanoma organized with respect to SEX.

-----  
 SEX = FEMALE

AGE (AT DIAGNOSIS)  
 56 items accepted.  
 Average is 41.93

Median value is: 39.50

Minimum is: 17

Maximum is: 82

-----  
 SEX = MALE

AGE (AT DIAGNOSIS)  
 73 items accepted.  
 The following items were rejected in the averaging process: NIL  
 Average is 42.48

Median value is: 41

Minimum is: 18

Maximum is: 77

4\_ordered by level of invasion!

Trying Ellipsis: WHAT IS THE AVERAGE MEDIAN MINIMUM AND MAXIMUM AGE AT DIAGNOSIS FOR INDIVIDUALS IN THE DB ORDERED BY LEVEL OF INVASION

MEDINQUIRY has interpreted your request as follows:

What is the MEAN and MEDIAN and MINIMUM and MAXIMUM AGE (AT DIAGNOSIS) for people with DEFINITIVE PATHOLOGICAL TYPE equal to a member of the set (SSM NM LMM UNDETERMINED UNCLASSIFIED) organized with respect to DEFINITIVE PATHOLOGICAL LEVEL.

-----  
DEFINITIVE PATHOLOGICAL LEVEL = 2

AGE (AT DIAGNOSIS)

41 items accepted.

Average is 39.39

Median value is: 39

Minimum is: 17

Maximum is: 82

-----  
DEFINITIVE PATHOLOGICAL LEVEL = 3

AGE (AT DIAGNOSIS)

32 items accepted.

The following items were rejected in the averaging process: NIL

Average is 38.03

Median value is: 38.00

Minimum is: 19

Maximum is: 57

-----  
DEFINITIVE PATHOLOGICAL LEVEL = 4

AGE (AT DIAGNOSIS)

35 items accepted.

Average is 45.29

Median value is: 43

Minimum is: 20

Maximum is: 77

-----  
DEFINITIVE PATHOLOGICAL LEVEL = 5

AGE (AT DIAGNOSIS)  
17 items accepted.  
Average is 51.59

Median value is: 55

Minimum is: 18

Maximum is: 81

-----  
DEFINITIVE PATHOLOGICAL LEVEL = NAVAIL

AGE (AT DIAGNOSIS)  
1 items accepted.  
Average is 69.00

-----  
DEFINITIVE PATHOLOGICAL LEVEL = NS

AGE (AT DIAGNOSIS)  
1 items accepted.  
Average is 24.00

-----  
DEFINITIVE PATHOLOGICAL LEVEL = UNCLASSIFIED

AGE (AT DIAGNOSIS)  
2 items accepted.  
Average is 31.00

Median value is: 31.00

Minimum is: 26

Maximum is: 36

5\_what is the distribution of pts. in the data base ordered by site of the primary and sex?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

How many individuals with melanoma organized with respect to SITE OF PRIMARY and SEX.



SITE OF PRIMARY = ARM  
SEX = FEMALE  
Number of items in this category = 11

SITE OF PRIMARY = ARM  
SEX = MALE  
Number of items in this category = 13

SITE OF PRIMARY = BACK  
SEX = FEMALE  
Number of items in this category = 8

SITE OF PRIMARY = BACK  
SEX = MALE  
Number of items in this category = 26

SITE OF PRIMARY = CALF  
SEX = FEMALE  
Number of items in this category = 11

SITE OF PRIMARY = CALF  
SEX = MALE  
Number of items in this category = 2

SITE OF PRIMARY = FOOT  
SEX = FEMALE  
Number of items in this category = 2

SITE OF PRIMARY = FOOT  
SEX = MALE  
Number of items in this category = 4

SITE OF PRIMARY = FRONT  
SEX = FEMALE  
Number of items in this category = 5

SITE OF PRIMARY = FRONT  
SEX = MALE  
Number of items in this category = 10

SITE OF PRIMARY = HAND  
SEX = MALE  
Number of items in this category = 2

SITE OF PRIMARY = HEAD  
SEX = FEMALE  
Number of items in this category = 8

SITE OF PRIMARY = HEAD  
SEX = MALE  
Number of items in this category = 12

SITE OF PRIMARY = KNEE  
SEX = FEMALE

Number of items in this category = 1

SITE OF PRIMARY = NECK

SEX = FEMALE

Number of items in this category = 2

SITE OF PRIMARY = NECK

SEX = MALE

Number of items in this category = 2

SITE OF PRIMARY = THIGH

SEX = FEMALE

Number of items in this category = 8

SITE OF PRIMARY = THIGH

SEX = MALE

Number of items in this category = 3

6\_what fraction of pts. with level 2 disease had a change in color of the primary?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 2 had CHANGE IN COLOR OF LESION equal YES.

39 case(s) were accepted

26 case(s) satisfied the specified constraints

2 case(s) were rejected due to missing or unspecified values.

PROPORTION IS 0.67

7\_calculate the percentage of individuals with level 2 having a change in the size of the lesion prior to diagnosis.

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with DEFINITIVE PATHOLOGICAL LEVEL equal 2 had CHANGE IN SIZE OF LESION equal to a member of the set (YES INCREASE DECREASE).

39 case(s) were accepted

31 case(s) satisfied the specified constraints

2 case(s) were rejected due to missing or unspecified values.

PERCENTAGE IS 79.49



8\_how many pts. had level 4 or 5 disease, stratified by presence of ulceration and bleeding of the primary?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

How many individuals with DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (4 5) organized with respect to ULCERATION and BLEEDING OF LESION.

ULCERATION = NIL  
BLEEDING OF LESION = NIL  
Number of items in this category = 1

ULCERATION = NO  
BLEEDING OF LESION = NO  
Number of items in this category = 23

ULCERATION = NO  
BLEEDING OF LESION = YES  
Number of items in this category = 8

ULCERATION = YES  
BLEEDING OF LESION = NO  
Number of items in this category = 2

ULCERATION = YES  
BLEEDING OF LESION = YES  
Number of items in this category = 18

9\_what percent of cases with tumor thickness greater than 1.5 mm. were at risk in the first year and had histologic recurrence in year 1?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with TUMOR THICKNESS (MM.) greater than 1.50 had STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

35 case(s) were accepted



17 case(s) satisfied the specified constraints  
 1 case(s) were rejected due to missing or unspecified values.  
 PERCENTAGE IS 48.57

10\_how many people with lnp ordered by level?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

How many individuals with LNP TYPE equal to a member of the set  
 (ELND TLND BIOPSY) organized with respect to DEFINITIVE PATHOLOGICAL  
 LEVEL.

DEFINITIVE PATHOLOGICAL LEVEL = 2  
 Number of items in this category = 7

DEFINITIVE PATHOLOGICAL LEVEL = 3  
 Number of items in this category = 16

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 Number of items in this category = 20

DEFINITIVE PATHOLOGICAL LEVEL = 5  
 Number of items in this category = 15

DEFINITIVE PATHOLOGICAL LEVEL = NS  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = UNCLASSIFIED  
 Number of items in this category = 1

11\_histologically positive nodes.

Trying Ellipsis:

HOW MANY PEOPLE WITH HISTOLOGICALLY POSITIVE NODES ORDERED BY LEVEL

MEDINQUIRY has interpreted your request as follows:

How many individuals with NUMBER OF LYMPH NODES POSITIVE greater than 0  
 organized with respect to DEFINITIVE PATHOLOGICAL LEVEL.

DEFINITIVE PATHOLOGICAL LEVEL = 2  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 3  
 Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = 4

Number of items in this category = 11

DEFINITIVE PATHOLOGICAL LEVEL = 5  
Number of items in this category = 8

DEFINITIVE PATHOLOGICAL LEVEL = NS  
Number of items in this category = 1

12\_what are the pathology attributes?

ANALYZED

SURGICAL PATH NUMBER  
DEFINITIVE PATHOLOGICAL TYPE  
DEFINITIVE PATHOLOGICAL LEVEL  
SITE OF PRIMARY  
TUMOR THICKNESS (MM.)  
MITOSES  
CELL TYPE  
RISK FACTOR  
CLONISM  
REGRESSION  
NUMBER OF LYMPHOCYTES  
NUMBER OF MACROPHAGES  
ANGIOGENESIS  
PLASMA CELLS  
NEVUS

13\_follow up results

Trying Ellipsis: WHAT ARE THE FOLLOW UP RESULTS

FOLLOW UP DATES  
MONTHS SINCE INITIAL THERAPY  
STATUS  
PRIOR THERAPY  
THERAPY SUGGESTED  
PATHOLOGIC STAGE

14\_what are the acceptable values for status?

ANALYZED

STATUS = NED, HISTOLOGIC RECURRENCE, DEFINITE RECURRENCE, DEAD,  
POSSIBLE RECURRENCE, NIL, OTHER

15\_how many pts with level 4 or 5 disease were followed in year one?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (4 5).

The number of patients satisfying your request is 47.

16 how many of them had no evidence of disease within the first year?  
ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS not equal to a member of the set (HISTOLOGIC.RECURRENCE POSSIBLE.RECURRENCE DEAD DEFINITE.RECURRENCE) and MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (4 5).

The number of patients satisfying your request is 21.

17 ordered by tumor thickness.

Trying Ellipsis: Do you mean HOW MANY OF THEM HAD NO EVIDENCE OF DISEASE WITHIN THE FIRST YEAR ORDERED BY TUMOR THICKNESS ? yes

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS not equal to a member of the set (HISTOLOGIC.RECURRENCE POSSIBLE.RECURRENCE DEAD DEFINITE.RECURRENCE) and MONTHS SINCE INITIAL THERAPY greater than or equal to 0 and less than or equal to 12.

MEDINQUIRY has interpreted your request as follows:

How many individuals with DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (4 5) organized with respect to TUMOR THICKNESS (MM.).

TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
 Number of items in this category = 2

TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)  
 Number of items in this category = 2

TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
 Number of items in this category = 10

TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
 Number of items in this category = 1

TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
 Number of items in this category = 6

18\_list those individuals who were seen in the second year and had histologic recurrence in the 2nd year.

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with MONTHS SINCE INITIAL THERAPY greater than or equal to 13 and less than or equal to 24.

MEDINQUIRY has interpreted your request as follows:

List the ID for people with DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (4 5) and STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 13 and less than or equal to 24 and ID equal to a member of the set (S-72-004 S-73-022 S-73-027 S-73-040 S-74-048 S-74-059 S-74-077 S-74-087 S-75-008 S-75-016 S-75-017 S-75-019 S-75-032 S-75-034 S-75-041).

ID = S-72-004, S-73-040

19\_list the tumor thickness, level of invasion and mitotic rate for these pts.

ANALYZED

MEDINQUIRY has interpreted your request as follows:

List the TUMOR THICKNESS (MM.) and DEFINITIVE PATHOLOGICAL LEVEL and MITOSES for people with DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (4 5) and STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) and MONTHS SINCE INITIAL THERAPY greater than or equal to 13 and less than or equal to 24 and ID equal to a member of the set (S-72-004 S-73-022 S-73-027 S-73-040 S-74-048 S-74-059 S-74-077 S-74-087 S-75-008 S-75-016

S-75-017 S-75-019 S-75-032 S-75-034 S-75-041).

ID	TUMOR THICKNESS (MM.)	DEFINITIVE PATHOLOGICAL LEVEL	MITOSES
S-72-004	2.20	4	MODERATE
S-73-040	12	5	NIL

### 5.5 Commentary

Items 1 and 2 illustrate queries that elicit general information about the data base.

Requests 3-5 are concerned with the epidemiology of melanoma. Item 3 studies the relationship between the incidence of melanoma, and sex and age at diagnosis. The processing of elliptical constructs is shown in question 4, where the request is analyzed by matching the pattern "ordered by level of invasion" to a similar context in the previous request. This question enables the study of differences in age distribution in patients with melanoma based on level of invasion of the primary. Item 5 explores the relationship between site of the primary and sex. It supports the hypothesis that women have a higher incidence of melanoma on the lower extremities, while males have a higher incidence of primary melanomas on the trunk.

Requests 6-8 investigate the utility of several reported warning signs of melanoma, and correlate several observed clinical characteristics with the histologic parameter level of invasion. From the data in the current data base, it appears that the early warning signs of change in color of the primary as well as change in size of the lesion occur in a very high proportion of patients with thin melanomas,





while the presence of ulceration and bleeding of the primary were noted in a majority of patients with more deeply invasive lesions.

Question 9 illustrates the use of time dependent information in formulating a request about the recurrence rate in the first year for patients with thick primaries. Close to half the patients with tumor thickness greater than 1.5 mm. had histologic recurrence in the first year following initial therapy.

Requests 10 and 11 indicate the yield of histologically positive lymph nodes by level of invasion. It is found that a much greater percentage of patients with level 4 or 5 disease have histologically positive nodes on lymph node dissection than do patients with level 2 or 3 disease. Similar requests could be formulated to study the correlation between tumor thickness or type of lymph node procedure and histologic status of lymph nodes.

Questions 12 and 13 provide a listing of the pathology and follow up attributes in the data base, while question 14 requests the values for status recorded in the data base. These three questions are helpful in formulating requests 15-19. Items 15-19 constitute a possible dialogue sequence that can be used to study the relationship between deeply invasive melanomas and recurrence in year one and year two after diagnosis. To respond to request 15, it is necessary to access the data base twice; the first access identifies patients who were followed in year 1, and the second access counts the number of these patients who had level 4 or 5 melanoma. Each access to the data base generates an English paraphrase of the system's understanding of the request at that point. The combined interpretation is the system's understanding of the entire request.

Request 16 illustrates the use of pronoun reference, where the pronoun "them" refers to the set of patients with level 4 or 5 identified in the previous request. The use of negation, combined with time, is also shown by this request. MEDINQUIRY contains sufficient knowledge to possess a basic contextual understanding of the concept of negation, such that the phrase "no evidence of disease" in the context of a time related statement, is interpreted as no histologic recurrence, no possible recurrence, no definite clinical recurrence, or not dead of disease within a specified time interval. Question 17 illustrates the ellipsis add-on facility, where a tabulated attribute is specified and added-on in the appropriate context with access to the desired subset of patients. Questions 18 and 19 use the pronouns "those" and "these" to select individuals with level 4 or 5 melanoma who had histologic recurrence in year 2, and to display the tumor thickness, level of invasion, and mitotic rate for these patients.

Appendix F contains a complete transcript of a MEDINQUIRY session including the user initialization procedure, help information about the classes of questions supported, and guidance on the use of the system. Several relevant hypotheses about melanoma are pursued and the results are provided.

## Chapter 6

ISSUES IN THE DESIGN, IMPLEMENTATION AND USE OF MEDINQUIRY

This chapter discusses issues concerned with the overall design and implementation of MEDINQUIRY, covers processing of temporal relations and negation, and describes how comments are recorded in the data base. A set of criteria are suggested to eventually evaluate MEDINQUIRY, and some preliminary results on the performance of the system are given.

6.1 Overall Design and Implementation Issues1. Responsibility:

The responsibility for processing well formed requests resides with the system's builder rather than the user of the system. Requests posed by users should be meaningful from a medical standpoint and should reflect an awareness of the content of the data base. Thus, it would not be appropriate to expect a response to requests for which information is not present in the data base or for those requests that are outside the domain of melanoma. The language structure of requests should be in keeping with how experts use language in talking about the problem domain of melanoma, rather than how computer scientists or other information scientists might phrase requests. Although the user of the system need not be aware of how the data are stored or the structure of the application language, the user should have a reasonable request or hypothesis in mind and must be aware of the types of data included in the data base and the scales of measurement used to express these results. The current prototype system reflects this designer's

perspective on what questions should be supported; with continued use of the system these classes of requests will be refined and augmented in a stepwise manner.

## 2. Completeness of the data base:

The validity, completeness, relevance, and quality of data in the data base are important issues. Efforts must be made to insure that the data are recorded accurately and that they reflect the information in the clinic and medical records. It is essential to have established procedures for accurately abstracting data, correcting errors, and maintaining consistency in coding and classifying data.

For certain attributes in the data base, results may not be available. For example, if the primary is excised before the patient is first seen in the clinic, certain items will be unknown, missing, or not available. Values for other attributes that involve recall of patient history, history of the primary, or family history may be unavailable at the time of the clinic encounter. Other attributes, such as tumor thickness, were not recorded regularly three or four years ago and thus, are not available without a review of the slides.

The issue of whether all potentially relevant attributes have been collected is outside the scope of this study. Even with the most ambitious system for data acquisition, the best that can be done is to assume that the consensus reached by experts in defining the items to be included in the study are reasonable, and that appropriate criteria have been developed for assigning categories to the data items. The new study, currently in progress, has identified additional attributes and suggested changes to the current attributes based on a review of the



attributes and values in the current data base and on new knowledge about melanoma. (i)

It is impossible to eliminate all aspects of subjectivity from the data base. The patient may not remember correctly for how many months the primary tumor bled prior to initial definitive therapy, or the interviewer may not have phrased a question in comprehensible terms, or may have failed to record the answer correctly or completely. There are differences in the state of the patient when the data are collected. For example, the results may be different for patients who are seen with the primary lesion intact vs. those who had the primary previously excised. Certain data are not as easily determined once the primary has been excised, and those results would be expected to be more subjective or missing in the data base. There also are problems of reliability associated with inter-and intra-individual variation among experts in assigning a value for a finding. In these respects, the data contained in MEDINQUIRY are similar to those encountered in other areas of medical research. Paraclinical findings will tend to be more accurate than subjective clinical observations; inferentially derived attributes are subject to interpretation. The experience with the prototype MEDINQUIRY system has prompted a review of all the pathology data. If it proves desirable, confidence levels can be assigned to certain classes of attributes. The effects of subjective judgment can be minimized in some cases by careful re-evaluation, but they cannot be completely eliminated.

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(i) The study in progress is a collaborative effort between the University of California, San Francisco, the University of Pennsylvania, SRI International, and the author, at the National Institutes of Health, to compile a larger data base of patients with melanoma to test and evaluate MEDINQUIRY.



### 3. Completeness and Correctness of Requests:

The ease with which English language requests can be composed introduces problems related to the completeness of the request with respect to the information present both in the application language and in the data base. For example, in the request "what is the recurrence rate for patients with ssm 5?", recurrence rate is incompletely defined in time as stated. Although an answer will be given concerning the overall recurrence rates for these patients, this would not be a complete response, and possibly even a misleading one. A more complete request would include a statement of the time interval involved such as, "what is the recurrence rate in the first 2 years for patients with ssm 5?".

Ambiguities in language may arise due to the way in which the question is posed or how the attributes are recorded in the data base. For example, interpretation of the requests, "how many patients with lymph node procedures?" and "how many lymph node procedures?", involves the system understanding the distinction between patients having a lymph node procedure and the total number of lymph node procedures performed. This is accomplished by appropriately ordering the rules to enable the system to properly understand each of the requests.

A second type of ambiguity has to do with how items are named on the forms and how this provides a context for referencing these attributes in the data base. For example, the variables "pre-existing lesion" and "examiner's opinion about how melanoma arose" are both included under history of the primary, while the attribute "presence of nevus" is associated with histologic exam of the primary. Thus, there



are at least three ways to reference the term "pre-existing lesion", and at times, depending on how the request is formulated, it may be difficult to understand the intent of the user. (i)

In those instances where the request contains sufficient context, such as, "How many patients with melanoma ordered by presence of a pre-existing lesion, how the melanoma arose, and histologically confirmed nevus?", there is no problem in determining which data base attributes are relevant. However, in those questions that contain insufficient context, references to "pre-existing lesion" can be ambiguous. The results of the above request indicate a high degree of disagreement when comparing the values in the groupings of the three attributes. A portion of this disagreement is due to the relative subjectivity of each of the attributes. Since responses will be very different based on the attributes referenced, this issue deserves further study. (ii)

The concept of "sun exposure" illustrates another instance of ambiguity. For example, the request "list the sun exposure for pts. with ssm 5." may relate to lesion sun exposure, patient sun exposure, tan on sun exposure, or sunburn on sun exposure. At present, this request is answered by including values for all four attributes in the response. To access a particular attribute, sufficient context such as lesion sun exposure or patient sun exposure must be specified in the request.

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(i) See Chapter 4 under discussion of scales of measurement, and Appendix A for the forms which were used to collect the data.

(ii) In order of decreasing subjectivity, the attributes are pre-existing lesion associated with patient background, examiner's opinion of how the melanoma arose, and presence of nevus on histologic examination.



The attribute "presence of freckles as a melanocytic disorder" appears associated with patient background, while the discrete dimensional variable "number of freckles" appears under physical examination of the patient. A request such as "count the number of patients tabulated by presence of freckles as a melanocytic disorder and number of freckles" would be analyzed unambiguously. However, in response to this request, there were some inconsistencies in the data base. There were 44 patients with no freckles recorded in answer to the question "have you ever had freckles?", while on physical examination the number of freckles was recorded as between one and 25; three patients, recorded with no freckles on history, had 26 to 100 freckles on physical exam; while two patients with no freckles had greater than 100 on physical examination. Similar anomalies and ambiguities exist for other data base attributes. In future releases of MEDINQUIRY, a prompting mechanism will be developed to resolve some of these types of ambiguities by allowing the user to select the most appropriate interpretation. It is worth noting that even in the current system, many of these ambiguities can be detected by a knowledgeable user through the system's interpretation of each request and through understanding the nature of the information in the data base.

#### 4. Complexity of Requests:

In order to respond to certain types of questions, it is necessary to perform multiple accesses of the data base. In the current version of MEDINQUIRY this must be done for requests involving negation of repeating groups, for follow up time intervals, and in general, for access to time related information that requires access to more than one table in the data base.



The time requirements to parse a request depends on such items as the length of the request, complexity of operations to be performed to produce a response, and the number of data base accesses required. For relatively straightforward requests, it takes approximately .5 seconds of cpu time on a DEC KL-10 to analyze a request, and another second of cpu time to access and search the data base and construct an appropriate response to a question. Requests that involve proportions, negation, or the specification of relatively complex time constraints involve a significant increase in processing time to both analyze the request and construct a response. In the future, developing more efficient methods for storing and accessing the data would reduce these time requirements.

The capability exists for an expert to construct more complex requests by entering his own definition of a concept, or by specifying meta-questions. A concept can be defined based on other attributes that are stored explicitly in the data base; then these defined concepts can be used to more easily explore relationship with other items in the data base (see Page 110). Meta-questions can be used to extend the application language and thus allow the user to more easily formulate complex requests (see Page 106).

#### 5. Correctness and Completeness of Responses:

As noted in Chapters 4 and 5, for each request which requires access to the data base, the user is provided with the system's interpretation of the request. This presents the user with a re-statement of the request, and is a first step in assuring that a correct and complete response is returned to the requestor.

To provide a correct and complete response to a request posed by an



expert, it is also important to consider the issues of how the application language is organized and how the rules are accessed. The approach followed in this research considers the first interpretation found by the parser to be the most appropriate one in response to the request. This, in turn, depends on the order in which the rules are stored and evaluated.

Stratification also is an issue of importance in providing useful results. There may be a small number of items in each group that is tabulated, especially if stratification or tabulation is performed on several variables. In these instances, the responses produced may not be statistically significant, but still may suggest a hypothesis worthy of testing. Another related problem is created by a mismatch between the constraints included in the request and the contents of the data base. This may occur when the sample size or the follow up intervals are too small for meaningful calculations. These logical inconsistencies are identified by MEDINQUIRY, but additional procedures need to be developed for dealing with them.

For continuous dimensional categories of data such as tumor thickness, time since definitive initial therapy, months since bleeding of the lesion, or age, it is necessary to assign values to groups. Thus, for tumor thickness the intervals in mm. are defined as 0 - .76, .77 - 1.25, 1.26 - 1.50, 1.51 - 4.99 , 5.00 - 15. This grouping is a reasonable first approximation to what has been described in the literature by experts. However, the groupings can be modified in response to the need to organize the results in alternative ways to test various hypotheses. For example, the INTERLISP statement

```
PUT (THICKNESS (BUCKETS ((0 . .75) (.76 . 1.25) (1.26 . 1.50)
                        (1.51 . 2.5) (2.51 . 3.99) (4.0 . 5.0) (5.1 . 20]
```





could be used to change the grouping of values for tumor thickness to 0 - .75, .76 - 1.25, 1.26 - 1.50, 1.51 - 2.5, 2.51 - 3.99, 4.0 - 5.0, and 5.1 - 20 mm.

Intervals for time since initial definitive therapy are defined as 0 - 12, 13 - 24, 25 - 36 ... months, and provide for grouping of results by yearly follow up. Other dimensional categories such as months since bleeding of the primary was noted, or months since itching of the lesion was noted are defined in six month chunks.

For calculations such as averages or proportions, missing data are not included in the calculations for subsets of patients retrieved. However, all missing data are identified for both calculations as well as in output displays so that the user of the system is made aware that these data are missing.

In response to certain classes of requests, it may be necessary to provide information in addition to that specified by the requestor. For example, the response to the request, "list the stage of disease for patients with ssm 5." will display the stage as well as the status and months since initial therapy corresponding to each follow up visit. Including such implied attributes is essential to provide more complete and meaningful responses.

Note that issues relating to the correctness and completeness of responses directly depend on the completeness and correctness of both the requests and the data base. This has been discussed above, under those topics.

#### 6. Structure, completeness, and extendability of application language:

The application language embodies domain specific knowledge about melanoma in the form of rules that are mappings between the language



used by the requestor, and the structured organization of the data base that contains patient specific information. The application language uses a semantic grammar, so that in most cases category names are assigned with consideration of their meaning and use. In the semantic grammar, names such as <NOUN-HIST> are assigned to phrases and concepts dealing with histology results, rather than the traditional linguistic class NP; <HOW-MANY> is used to indicate required counts rather than linguistic classes such as WH Q PHRASE; and the semantic category <CONSTRAINTS> is used for verb phrases such as "having nodular melanoma", rather than the linguistic class VP. This was illustrated in the extract of the application language presented in Section 4.6.

MEDINQUIRY separates the task of analysis of requests from those of access to the data base and generation of responses. In the future this approach will allow alternative data base management systems to be used to store the data base with minimal changes to the basic structure that supports English language access.

As new types of requests, or gaps in coverage in the currently supported system are identified, modifications may need to be made to the application language and to the response functions that construct a formal query language request or produce a response. The classes of requests described in Section 5.1 constitute a basic set. It is unlikely that any of these queries will be eliminated, but additional patterns and new classes of requests, especially those dealing with simple statistical calculations and time oriented requests, will have to be added as more experience is gained with the system.

The interactive editor available with INTERLISP is used to modify

the application vocabulary and to immediately test new rules. There is an art associated with writing large systems as the one described in this research, and a clear understanding of the organization of the system and potential side effects is essential to minimize problems which may arise.

## 6.2 Issues Related to Processing Temporal Relations and Negation

In this section, issues related to processing time and negation are discussed and several examples are given to illustrate how time and negation can be used together to process certain very useful types of requests.

### 6.2.1 Temporal Relations

Temporal relations are one of the most complex parts of English semantics, and are of great importance in querying medical data bases. The prototype version of MEDINQUIRY can process certain classes of time dependent data. Events such as follow up visits, lymph node procedures, or data collected as part of the history of the primary, have dates or time intervals assigned to them. In composing requests, the user may refer to time intervals between these dates and the date of the definitive initial therapy of the primary. Requests can specify (1) events that follow initial therapy of the primary such as follow up status, stage of disease, or type of lymph node procedure, (2) events that precede the diagnosis of melanoma such as months since the presence of itching, bleeding, or ulceration of the primary was first noted, or (3) groups of patients that were followed (or are at risk) for a



specified period of time. Calculations based on intervals between the reference date of initial definitive therapy can be used to identify patients based on disease free intervals, months to recurrence, or months since bleeding of the primary was first noted.

In the prototype system, it was felt that providing the requestor with a facility to ask these types of questions was most important, although there are obviously additional types of questions relating to time that eventually need to be supported.

The three basic types of time related data that are processed are now described.

#### 1. Events following initial definitive therapy of the primary:

The following simplified extract from the application language illustrates some of the capabilities available to process time dependent requests related to the status of patients at follow up encounters.

SYMBOL: <NOUN-FUP>

GRAMMAR

=> (<STATUS> <STATUS-T1>) ; F0100

SYMBOL: <STATUS-T1>

GRAMMAR

=> (<NUM-COMP> <NUM2> <MELANOMA>) ; F0109

=> (<NUM-COMP> <NUM2>) ; F0109

=> (<NUM2> <NUM-COMP> <MELANOMA2>) ; F0109

=> (<NUM-COMP2> <NUM3> <MELANOMA2>) ; F0109

=> (<NUM-COMP2> <NUM3>) ; F0109

=> (<NUM-COMP1> <NUM3> <MELANOMA2>) ; F0108

=> (<NUM-COMP1> <NUM3>) ; F0108

=> (<NUM-COMP3> <NUM3> <MELANOMA2>) ; F0078

=> (<NUM-COMP3> <NUM3>) ; F0078

In the rules above, the word class <STATUS> is used to recognize such entries as "histologically confirmed recurrence", "histologic recurrence", "recurrence", "definite clinical recurrence", "recurrent disease", "dead of melanoma", and "local recurrence". (i)

The semantic class <STATUS-T1> is a subgrammar category under <NOUN-FUP> that recognizes time related information concerning the time following initial therapy in the context of follow up status; <MELANOMA> accepts entries like "primary lesion", "primary", and "lesion"; <MELANOMA2> recognizes "after excision of the primary", "following date of initial therapy", and "of excision of the tumor". The semantic classes of the form <NUMERIC-COMP> specify the time related operation to be performed, while semantic classes of the form <NUM> specify the time interval to be used, when matching the formal query request against the data base.

The response function F0109 that sets up the time related information as a formal query request suitable for querying the data base, is defined by the following INTERLISP function:

```
(F0109
  [LAMBDA (OPERATOR TIME)
    (LIST (QUOTE MONTHS.SINCE.INITIAL.THERAPY)
          (LIST (QUOTE AND)
                (QUOTE (NUMBERP *)))
          (RANGE.ADJUST OPERATOR TIME]))
```

The function RANGE.ADJUST sets up a time interval in the proper

---

(i) Note that the category <STATUS> is also used in analyzing and processing other follow up information.





format to be matched against the data base. Note that the time interval is specified in the data base as months since initial therapy for attributes such as status and lymph node procedure. Therefore, the response function must convert all time related information to that scale.

The patterns under <STATUS-T1> are briefly described, by examples, to illustrate the types of request fragments that can be processed:

a) The patterns <NUM-COMP> <NUM2> and <NUM-COMP> <NUM2> <MELANOMA> can be used to recognize such time dependent information as:

within 24 months  
in 2 years  
in less than 3 years  
after one year

where <NUM-COMP> includes terms and phrases such as "less than", "at least", "after", "before", "following", "within", "in", and <NUM2> handles entries like "24 months", "1 month", "15 months", "1 year", "two years", "five years".

b) The pattern <NUM2> <NUM-COMP> <MELANOMA2> will handle such fragments as:

24 months following initial therapy  
1 year after diagnosis of the primary

c) The rules <NUM-COMP2> <NUM3> and <NUM-COMP2> <NUM3> <MELANOMA2> will process entries like:

prior to the end of year 1  
before the end of the second year  
following year 2  
after yr 3

where <NUM-COMP2> includes entries like "prior to the end of", "before the end of", "after", "following", and "since", and <NUM3> will handle phrases like "year 1", "yr 2", "1st year", "third year".

d) The patterns <NUM-COMP1> <NUM3> and <NUM-COMP1> <NUM3> <MELANOMA2> will analyze entries such as:

in the second year after initial therapy



during year one of follow up  
in the first year

where <NUM-COMP1> includes words such as "during", "in", "within".

e) The rules <NUM-COMP3> <NUM3> <MELANOMA2> AND <NUM-COMP3> <NUM3>  
will process entries like:

before year 3  
prior to the 3rd year  
prior to the start of the third year after therapy

where <NUM-COMP3> includes phrases like "previous to", "preceeding",  
"before", "prior to the start of", "prior to"

## 2. Events prior to definitive initial therapy of the primary:

Sets of rules similar to the ones described above, have been developed to process requests which deal with time related events prior to initial therapy. The attributes in the data base that may be queried in this manner are: "months since bleeding of the primary", "months since color change", "months since elevation change", "months since size change", "months since tenderness of the lesion", and "months since ulceration of the primary".

Examples of entries that include information about events prior to initial therapy are:

bleeding of the primary for 24 months before therapy  
itching of the lesion during 1 year prior to diagnosis  
increase in lesion size for less than 1 yr prior to diagnosis  
no increase in size of lesion for greater than 1 year prior to tx

Requests that are currently supported include:

How many pts with ssm of the upper extremities with regression of the primary were males who had bleeding of the primary for less than 24 months prior to initial therapy?

What is the average time since bleeding of the primary was noted for patients with level 4 or 5 melanoma?

## 3. Specification of time intervals to identify individuals at risk:



Sometimes when submitting a sequence of requests, it is desirable to identify subsets of patients that meet time related criteria so that the subsets of patients retrieved can be used in subsequent requests. This is especially important in identifying groups of patients that were seen for a specified time or were at risk for recurrence within a particular time interval. Examples of such requests are:

How many pts with level 4 or 5 melanoma were at risk in year one?

Count the number of pts in the data base who were followed for at least 24 months.

List the patients with level 5 melanoma who were seen for 48 months.

### 6.2.2 Negation

The nature of medical information requires that a facility be available to process negation for a single valued field, or for repeating groups in the data base. In both of these cases, it is necessary to recognize the scope of negation so that it can be associated with the appropriate attribute. Rules have been written that recognize the scope of negation, and map the negated values present in the request into one or more formal query requests.

The following examples illustrate some of the types of fragments currently supported that contain negation:

practically no tan  
 no tan on sun exposure  
 regression not confirmed histologically  
 no areas of regression of the primary  
 who did not demonstrate a cellular host response of lymphocytes  
 absence of mitotic activity  
 no biopsy of the primary  
 no elective lymph node procedures  
 no change in the color of the primary  
 without any change in lesion elevation  
 with no increase in size  
 without decrease in elevation

no positive nodes  
 no nodal involvement  
 did not have an elective lymph node procedure

For repeating groups in the data base, such as follow up status, the problems of scope of negation are more difficult, and usually involve multiple accesses to the data base to retrieve the required patient data. For example, for a patient with multiple follow up visits, histologic evidence for recurrence might be associated with some but not all follow up visits. Thus, to respond to a request such as "how many patients with tumor thickness greater than 1.5 mm. had no evidence of histologic recurrence within 24 months?", it is necessary to identify the patient state at each follow up visit in the specified time interval. This capability exists in the prototype system, and the above request as well as the following can be answered:

How many pts with level 5 melanoma were without evidence of disease within 12 months?

How many pts with histologic recurrence in yr 1 had no evidence of disease in year 2?

What proportion of pts with tumor thickness > 1.9 mm. were disease free after 24 months?

### 6.2.3 Dialogue Sequences that Include Both Time and Negation

Both negation and temporal information relative to the date of definitive therapy can be handled in the current prototype system. The following dialogue illustrates how both time and negation are used in requests about lymph node procedures.

2\_how many individuals with recurrence had node dissections within 4 months of diagnosis, arranged by level of invasion and tumor thickness?

ANALYZED



MEDINQUIRY has interpreted your request as follows:

Count the number of patients with LNP TYPE equal to a member of the set (ELND TLND BIOPSY) and PATHOLOGIC STAGE equal to a member of the set (IF IIA IIB IIC) and MONTHS SINCE INITIAL THERAPY less than 5.

MEDINQUIRY has interpreted your request as follows:

How many individuals with STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEFINITE.RECURRENCE DEAD) organized with respect to DEFINITIVE PATHOLOGICAL LEVEL and TUMOR THICKNESS (MM.).

DEFINITIVE PATHOLOGICAL LEVEL = 2  
TUMOR THICKNESS (MM.) = ( 0 . 0.76)  
Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = 3  
TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 4  
TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
Number of items in this category = 7

DEFINITIVE PATHOLOGICAL LEVEL = 4  
TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
Number of items in this category = 3

DEFINITIVE PATHOLOGICAL LEVEL = 5  
TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 5  
TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
Number of items in this category = 6

DEFINITIVE PATHOLOGICAL LEVEL = 5  
TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = NS  
TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
Number of items in this category = 1

3\_with no recurrence [analysis of incomplete sentence]

Trying Ellipsis:

HOW MANY INDIVIDUALS WITH NO RECURRENCE HAD NODE DISSECTIONS WITHIN 4 MONTHS OF DIAGNOSIS ARRANGED BY LEVEL OF INVASION AND TUMOR THICKNESS





MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS not equal to a member of the set (HISTOLOGIC.RECURRENCE DEFINITE.RECURRENCE DEAD).

MEDINQUIRY has interpreted your request as follows:

How many individuals organized with respect to DEFINITIVE PATHOLOGICAL LEVEL and TUMOR THICKNESS (MM.).

DEFINITIVE PATHOLOGICAL LEVEL = 2  
 TUMOR THICKNESS (MM.) = (0 . 0.76)  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 2  
 TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 2  
 TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
 Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = 3  
 TUMOR THICKNESS (MM.) = (0 . 0.76)  
 Number of items in this category = 3

DEFINITIVE PATHOLOGICAL LEVEL = 3  
 TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
 Number of items in this category = 4

DEFINITIVE PATHOLOGICAL LEVEL = 3  
 TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
 Number of items in this category = 4

DEFINITIVE PATHOLOGICAL LEVEL = 3  
 TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
 Number of items in this category = 3

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*



Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = 5  
 TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
 Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = UNCLASSIFIED  
 TUMOR THICKNESS (MM.) = (0 . 0.76)  
 Number of items in this category = 1

4\_count pts with recurrence who had no node dissection within 4 months  
 of initial therapy, broken down by level and thickness of primary.

#### ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with LNP TYPE equal to a member of the set  
 (ELND TLND BIOPSY) and PATHOLOGIC STAGE not equal to a member of the  
 set (IF IIA IIB IIC) and MONTHS SINCE INITIAL THERAPY less than 5.

MEDINQUIRY has interpreted your request as follows:

How many individuals with STATUS equal to a member of the set  
 (HISTOLOGIC.RECURRENCE DEFINITE.RECURRENCE DEAD) organized with respect  
 to DEFINITIVE PATHOLOGICAL LEVEL and TUMOR THICKNESS (MM.).

DEFINITIVE PATHOLOGICAL LEVEL = 2  
 TUMOR THICKNESS (MM.) = (0 . 0.76)  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 3  
 TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
 Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
 Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 5  
 TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
 Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = 5  
 TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
 Number of items in this category = 1



5\_with no recurrence?

Trying Ellipsis:

COUNT PTS WITH NO RECURRENCE WHO HAD NO NODE DISSECTION WITHIN 4 MONTHS OF INITIAL THERAPY BROKEN DOWN BY LEVEL AND THICKNESS OF PRIMARY

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS not equal to a member of the set (HISTOLOGIC.RECURRENCE DEFINITE.RECURRENCE DEAD).

MEDINQUIRY has interpreted your request as follows:

How many individuals organized with respect to DEFINITIVE PATHOLOGICAL LEVEL and TUMOR THICKNESS (MM.).

DEFINITIVE PATHOLOGICAL LEVEL = 2  
TUMOR THICKNESS (MM.) = (0 . 0.76)  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 2  
TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 3  
TUMOR THICKNESS (MM.) = (0 . 0.76)  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 3  
TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = 3  
TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 4  
TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 4  
TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 4  
TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
Number of items in this category = 1

DEFINITIVE PATHOLOGICAL LEVEL = 5  
TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)



Number of items in this category = 2

DEFINITIVE PATHOLOGICAL LEVEL = UNCLASSIFIED

TUMOR THICKNESS (MM.) = (0 . 0.76)

Number of items in this category = 1

### 6.3 Comments in the Data Base

In many instances it is difficult to include all the relevant data about the course of the disease in the form of categorized values, and thus there is a loss of information. In these cases, it is most useful to have the facility to insert comments in the data base where appropriate. The prototype system supports storing comments in the data base, and numerous comments have been included associated with attributes such as status, site of the primary, or level of invasion. The qualifications included with comments provides the investigator with additional information in response to a request. To date, little work has been done to develop formats to display information concerning comments. The following examples illustrate how comments can be accessed. In these examples, the comments associated with status provide additional information on the disease state of the patient than the categorized values alone. This also provides a more complete picture of the clinical course of the disease for these patients.

21\_please include comments. [enable feature that provides comments  
ANALYZED when present for selected values in the  
data base]

22\_list the months since initial therapy, status and stage for pts  
with many mitoses and tumor thickness > 4 mm. ordered by patient id.  
ANALYZED

MEDINQUIRY has interpreted your request as follows:



Stratified by ID display the MONTHS SINCE INITIAL THERAPY and STATUS and PATHOLOGIC STAGE for people with MITOSES equal MANY and TUMOR THICKNESS (MM.) greater than 4.

ID = S-74-066

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 1 STATUS  
(HISTOLOGIC.RECURRENCE \* BIOPSY OF RIGHT INGUINAL NODE POSITIVE  
STAGE IIC)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 3 STATUS  
(POSSIBLE.RECURRENCE \* RIGHT AXILLARY NODE, NO CHANGE IN SIZE)  
STAGE IIC)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 5 STATUS  
POSSIBLE.RECURRENCE \* PALPABLE RIGHT AXILLARY NODE, NO CHANGE IN  
SIZE) STAGE IIC)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 7 STATUS  
HISTOLOGIC.RECURRENCE \* CUTANEOUS LESION RIGHT UPPER THIGH,  
METASTATIC MELANOMA) STAGE IIC)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 10 STATUS  
(DEFINITE.RECURRENCE \* NEW CUTANEOUS NODULES) STAGE IIC)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 13 STATUS  
(DEFINITE.RECURRENCE \* CXR SHOWS MULTIPLE PULMONARY NODULES)  
STAGE IIID)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 15 STATUS  
(DEFINITE.RECURRENCE \* LUNG METASTASES) STAGE IIID)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 16 STATUS  
(DEFINITE.RECURRENCE \* INFECTED MELANOMA RIGHT THIGH; LUNG MASS)  
STAGE IIID)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 17 STATUS  
(DEFINITE.RECURRENCE \* LOW BACK PAIN) STAGE IIID)

(ID S-74-066 MONTHS.SINCE.INITIAL.THERAPY 19 STATUS  
(DEAD \* 12/31/75: RESPIRATORY ARREST WITH WIDESPREAD METASTASES)  
STAGE NOT-APPL)

-----  
ID = S-75-033

(ID S-75-033 MONTHS.SINCE.INITIAL.THERAPY 8 STATUS  
(HISTOLOGIC.RECURRENCE \* SATELLITES) STAGE IB)

(ID S-75-033 MONTHS.SINCE.INITIAL.THERAPY 9 STATUS  
(HISTOLOGIC.RECURRENCE \* CERVICAL NODES POSITIVE) STAGE IIB)

(ID S-75-033 MONTHS.SINCE.INITIAL.THERAPY 14 STATUS NED STAGE IIB)



(ID S-75-033 MONTHS.SINCE.INITIAL.THERAPY 17 STATUS NED STAGE IIB)

(ID S-75-033 MONTHS.SINCE.INITIAL.THERAPY 20 STATUS NED STAGE IIB)

(ID S-75-033 MONTHS.SINCE.INITIAL.THERAPY 23 STATUS NED STAGE IIB)

-----  
ID = S-76-003

(ID S-76-003 MONTHS.SINCE.INITIAL.THERAPY 1 STATUS (NED \*  
INGUINAL NODE BIOPSY: NEGATIVE) STAGE IF)

(ID S-76-003 MONTHS.SINCE.INITIAL.THERAPY 3 STATUS (NED \*  
RIGHT AND LEFT AXILLARY DISSECTION: NEGATIVE) STAGE IF)

(ID S-76-003 MONTHS.SINCE.INITIAL.THERAPY 4 STATUS (OTHER \*  
PERSISTENT ACTIVE DISEASE, CUTANEOUS MELANOMA WITHOUT  
NODAL OR VISCERAL INVOLVEMENT- 1/30/76 LAPAROTOMY) STAGE ID)

(ID S-76-003 MONTHS.SINCE.INITIAL.THERAPY 9 STATUS  
(HISTOLOGIC.RECURRENCE \* 7/76 ESOPHAGEAL MASS- MALIGNANT MELANOMA.  
RECURRENT PLEURAL EFFUSION- MALIGNANT CELLS) STAGE IIID)

(ID S-76-003 MONTHS.SINCE.INITIAL.THERAPY 12 STATUS  
(POSSIBLE.RECURRENCE \* INCREASE IN SIZE OF NODULES) STAGE IIID)

-----  
[remainder of output omitted]

.  
.  
.

23\_please exclude comments [turns off feature that produces comments]

#### .4 Use of MEDINQUIRY

##### .4.1 General Framework for Studying Use of the System

In order to understand requests about the domain being studied, the relevant concepts and language for that domain must be compiled, represented, and stored in a suitable form. It is the responsibility of the system builder to define the conceptual and linguistic coverage required for the domain being studied (see Tennant 1978). Conceptual coverage includes the system's knowledge of concepts that depend on the contents of the data base, and domain specific knowledge not present explicitly in the data base. Linguistic coverage describes the ability of the system to understand diverse forms of expression of language about the domain.

In MEDINQUIRY, the application language contains both the linguistic and conceptual coverage relevant to malignant melanoma. It also serves as the basis for meeting the needs of users of the system. In this research, the author designed and implemented the application language through review of the literature (see Chapter 3), study and understanding of the nature of the medical information in the data base (see Chapter 4), and observing clinical conferences where particular issues relating to management of patients with melanoma were discussed. In addition, it is necessary to understand the sequence of events followed in collecting the data, relationships among attributes, and concepts that represent general knowledge about melanoma such as recurrence, staging, prognosis, histology, as well as concepts that may be derived from the data base about melanoma in the course of the research.

From the standpoint of the user, the conceptual and linguistic completeness of the question answering system, and the ability of the system to respond completely and correctly to his requests is of primary importance. To the user, conceptual completeness implies that the system will be able to completely and correctly analyze any request which can logically be answered from the data base; while linguistic coverage implies that the system can understand the many different ways of expressing a request. The user would like to be able to ask questions in his accustomed manner without tailoring his requests so that the system can respond.

The concepts of linguistic and conceptual completeness of the system provide a basis to evaluate the system's capabilities.

#### 6.4.2 Experience with MEDINQUIRY

Barnett (1977) describes several stages that a project goes through from its start until it may potentially prove useful in practice. These stages in the development of an information system are summarized as follows:

1. develop an idea worth trying
2. formulate, specify, and design an initial system
3. implement a prototype system
4. provide an operational system available in a real environment
5. support of information system is assumed by users
6. transfer system to another site
7. support and dissemination of system by industry

The MEDINQUIRY system currently is undergoing transition between the third and fourth stages. The prototype system has been demonstrated and used, and based on what has been learned, revisions are being made to the application language and two larger data bases are being

collected at the University of California, San Francisco, and the University of Pennsylvania. This will allow evaluation of the system in a real environment. Although at present it is still too early to completely evaluate the system, a discussion of criteria that can be used to evaluate the system and their application to the prototype system is presented in the next section.

To date, MEDINQUIRY has been demonstrated to physicians who are specialists in melanoma, other cancers, and other areas of medicine. Their reactions have been uniformly positive, even though in most cases the existing data base is not large enough to provide statistically significant results. The ability to formulate queries in ordinary English and to have the results displayed immediately is extremely appealing. The facility for correcting spelling errors received special commendation. Several preliminary studies, which have been undertaken to confirm results reported in the literature and to test hypotheses, are presented elsewhere in this paper. In particular, it has been possible to explore issues that include: (1) consider data on a particular patient in relation to those patients with similar types of melanoma and comparable levels of invasion and to relate this to follow up results; (2) explore the relationship among variables such as mitotic rate, regression of the primary and tumor thickness to determine their value as prognostic indicators.

The availability to physicians of on-line English language access, has encouraged more active interest and participation by physicians in the data acquisition process, in completing missing values in the data base, and in actively perusing the data in the data base.



It is possible to characterize at least four general classes of users who have made use of the prototype system. To date, none of these people have been trained in the use of the system or received extensive guidance from the system builder. The only explicit guidance provided is in the introductory help file which may be read by the user when logging onto the system (see Appendix F).

These users include:

- 1) Casual users with no experience in medicine who are usually computer or information scientists, or computational linguists interested in the general capabilities of the system.
- 2) Casual users with a background in medicine who are experts in an area of medicine other than melanoma, and are interested in the applicability of such an approach to solution of their own data management requirements.
- 3) Experts in melanoma not familiar with the contents of the particular data base that is currently available.
- 4) Experts in melanoma familiar with the data collected for this study.

In the initial experiences with the prototype system, it has been observed that many of these users tend to base their expectations on prior experience with computer systems in other areas, and most importantly, on what questions the system expects them to ask. Most users do not ask questions in what might be conjectured to be their accustomed manner. Many of the requests submitted are tailored to what they expect the system to be able to process, and usually the requests are exploratory in nature without a specific hypothesis that they would



like to pursue. It also has been noted that a user tends to pick up on words and phrases that are used by the system to restate the user's request and to use these terms in subsequent requests. In addition, when a request cannot be analyzed by the system, the user will persist in trying alternative requests, when it is probably the case that either the conceptual or linguistic coverage is not available to respond to their question. This latter difficulty will be resolved through an iterative process of enhancements to the application language, as hypotheses to be tested and the concepts that are used become more clearly defined, and more of general English, required to understand requests about melanoma, is incorporated into the application language.

MEDINQUIRY makes strong assumptions about the types of requests that are to be entered into the system. The questions should be relevant to the medical content of the data base; questions about information not in the data base cannot be parsed. Users who plan to use the system who are not experts in melanoma should read the literature review of melanoma in Chapter 2, and be familiar with how the data are collected, the attributes in the data base, and the vocabulary currently available in the system (see Appendices A, C and D). The examples in Chapter 5 and those in Appendix E illustrate the conceptual and linguistic coverage currently provided. Thus, the prospective user can learn by example about those requests or classes of requests which might be considered "reasonable" in the prototype system.

#### 6.4.3 Evaluation Criteria

In evaluating the capabilities of MEDINQUIRY, it is certainly easier to be critical than constructive. Prior systems that use formal

query languages or branching logic approaches were limited in that only those people well versed in the use of the system could formulate queries or an intermediary would have to be called upon to assist in this process. When a natural language approach is attempted, difficult issues such as the multiple points of view and perspectives of users, alternative ways of phrasing requests due to the richness of language, and implied information that may be omitted from natural language requests require careful study. However, there is little reason to believe that computer scientists or physicians with little need to access the information who attempt to use such a system would succeed. In fact, these people become overly concerned with the linguistic and conceptual coverage in an abstract sense and may easily find fault with the system. Also, to effectively use a natural language access formalism, it is necessary to be trained with emphasis on the domain as well as what exists in the data base. MEDINQUIRY supports this type of inquiry by allowing subject matter specialists to find out what is in the data base by asking appropriate questions. A complete manual describing the capabilities and use of the system is being prepared.

#### 6.4.4 Criteria for Studying System Performance

The criteria for studying system performance are based on the completeness of the conceptual and linguistic coverage of the system in responding to requests. The requests submitted by users can be assigned to one of two classes. The first class consists of those requests that are judged by experts to be reasonable and appropriate in terms of the contents of the data base, and relevant to the domain of malignant

melanoma. For these requests, the system should be able to analyze the request and provide a response relevant to the request. The second class consists of those requests that are judged to be inappropriate, conceptually incomplete, or nonsense in terms of the contents of the data base, or the relevance of the request to malignant melanoma. Requests that are inappropriate from either a linguistic or conceptual point of view should not be analyzed to begin with, but should be flagged at parse time as being inappropriate. See questions 8-9 and 13-17 in Section 5.2 for examples of inappropriate requests which are blocked.

Both general and specific criteria can be defined to assess system performance for requests judged by experts to be appropriate. These criteria are now briefly outlined.

#### General Criteria:

1. The system understands the concepts in the request and responds correctly and completely. This implies that the conceptual and linguistic coverage for that particular query is complete from the standpoint of the user.
2. The concept is understood and the system responds poorly. This is usually due to deficiencies in how the data are processed and presented to the user upon retrieval from the data base. The linguistic coverage is complete, but the mapping of the data to the desired response does not reflect the concept that the user has in mind.
3. The system understands the concepts, but blocks due to gaps in

linguistic coverage. In this case, the concepts needed to process the request are present in the application language, but the linguistic coverage associated with this concept is incomplete. This usually can be remedied by adding the missing terms or syntactic rules to the application language.

4. A concept in the request is not understood to begin with and the request blocks. This is due to inadequate conceptual coverage, and probably involves a rethinking of the way this concept is represented in the knowledge base (application language).

5. The system misinterprets a concept in a request and responds incorrectly. These types of requests should have been blocked and no response provided.

Specific factors related to ease of use and responsiveness of the system:

6. The system should have the capability to process incomplete requests or sentence fragments by reference to the context of previous requests.

7. There should exist a capability to understand and process anaphoric references to pronouns that relate to other concepts in the current or prior request.

8. In those cases where a concept in a request cannot be understood or if ambiguities exist due to multiple interpretations of a request, the system should be able to engage the user in a clarification dialogue that attempts to resolve the ambiguous portions of the request.



9. The system takes into account errors in spelling and processes punctuation.

10. For blocked requests, the user is provided with guidance on why and where the request blocked, and suggests alternative ways of stating the request.

11. In medical data base systems, the capability must exist to process time related information and negation of concepts.

12. The system should allow the user to submit sequences of questions which depend on each other. This criterion supports dialogue interactions and allows the user to test a hypothesis that involves several related questions.

13. The user should be able to define new concepts that are unique to his needs based on existing concepts in the data base or application language.

14. In the case of programming errors, the system should be able to gracefully recover from these errors without causing the session to terminate.

15. In response to new requirements, additions and modifications to the application language should be accomplished easily by the system builder.

16. The system should be able to provide information about the contents of the application language and the contents of the data base.

A discussion is now given of how the prototype version of MEDINQUIRY performs with respect to these criteria.

1. Request understood and proper response provided:

In MEDINQUIRY a large number of requests can already be processed in which the linguistic and conceptual coverage is complete. Many examples of such requests are given in Section 5.1, Section 5.4, and in Appendix E. For each request that requires access to the data base, the user is presented with the system's paraphrase of the request to ensure that it has been understood properly. The tabular format of the data base provides a simple and explicit model that is compatible with translating natural language requests into a formal query language. The fact that the process of constructing a formal query request is distinct from the process of searching the data base supports modularity of system components and makes it relatively convenient to identify for the user, what the system is doing.

2. Request understood but system responds poorly:

The linguistic and conceptual coverage in MEDINQUIRY is complete, but the response is considered poor by the user. This may be due to (1) poor methods of displaying and organizing the results, (2) insufficient information may be provided to the user, (3) requests that may be incomplete and the system cannot predict what the user really intended although the interpretation may be judged appropriate in some contexts, or (4) incompatibilities exist in the contents of the data base which do not contain all the information that the user might desire. In future





releases of the system, better output formats will be provided to help alleviate this problem.

### 3. Problems with linguistic coverage:

In MEDINQUIRY, as in other systems for natural language understanding, there is the general problem of the multitude of paraphrases that are possible in formulating English language requests. The linguistic completeness and fluency of the system will improve over time, as it is used extensively, and the linguistic coverage required by multiple experts with differing linguistic points of view are identified. See item 15 below for a discussion of enhancements to the application language.

### 4. Conceptual coverage is incomplete:

In the prototype system, there are instances where the conceptual coverage provided by both the application language and the response functions are incomplete and the system is unable to process the request. At present, this is true for certain types of time dependent information and concepts such as "first instance of recurrence", or requests that require an understanding of begin-end time intervals not anchored to date of initial definitive therapy. This is illustrated by examples such as "how many patients had immunotherapy for less than 2 years?" or "how many pts had the first instance of definite clinical recurrence followed by a 6 month disease free interval?". Solving problems which deal with deficiencies in conceptual coverage require adding these concepts into the application language and augmenting the linguistic coverage.

### 5. Misunderstood requests:

In the prototype system, requests may be misunderstood and an incorrect response generated. This usually occurs when the system corrects spelling errors incorrectly because the conceptual or linguistic coverage of the system is incomplete or when, from the user's standpoint, incorrect elliptical substitutions are made. In these cases, the system responds to the transformed request in an incorrect or illogical manner given what the user had in mind at the start. In general, the user will be aware that the system has misunderstood the request since the system's paraphrase of the request will not be what the user intended.

### 6. Incomplete sentences:

LIFER's ellipsis, and ellipsis-add-on capabilities, allow the user to enter requests that are sentence fragments by reference to the context of the previously analyzed request (see questions 6 and 7 in Section 5.2). In the present implementation, the elliptical substitutions are made based on the first admissible interpretation in the previous request. For example, if the request "how many patients with regression and many mitoses?" is followed by the sentence fragment "level 5", MEDINQUIRY would respond to the request "how many patients with level 5 and many mitoses?". However, the user may have intended the request to read "how many patients with regression and level 5?". To handle such potential ambiguities, it is planned to modify the system to ask the user which of the possible interpretations is most appropriate. It has also been observed that incomplete sentences that are not understood,

are frequently appended to the end of the previous request using the ellipsis-add-on facility, and the user is asked to confirm whether this was his intent. To prevent this from occurring, there is a need to augment the semantic checks used to verify the reasonableness of the request.

#### 7. Pronoun references:

Pronouns such as "it", "that", "this", "their", "them", and "those" may be used to reference query constraints in the same or previous requests. In part, this feature supports dialogue interactions by providing a mechanism to reference patients identified in a previous request. See Section 5.3 for examples of such dialogues. Problems may be encountered with omitted pronoun references. For example, when the request "how many pts with regression?" is followed by "how many were males?", the issue is whether these two requests are independent or related. At present, these are treated as independent requests, which may not have been what the user intended. It should be possible to ask the user whether these questions are related, and respond accordingly.

#### 8. Clarification dialogues:

As has been already noted, there is only a very limited facility to engage the user in a dialogue to clarify ambiguous requests or parts of requests that are not understood. This is a rather difficult problem and several enhancements to deal with this problem are being considered. The option of using a multiple choice mode of interrogation in an attempt to clarify requests has been considered (see Codd, 1977), although there



are numerous difficulties associated with this approach both in terms of additional system overhead and complexity of implementation. The system does support restatement of the user's request and asks whether certain interpretations are correct (for example, with the ellipsis add-on facility). There also is an option that allows MEDINQUIRY to display all the possible interpretations and have the user select the one most appropriate. However, interpreting these results and making a selection is not appropriate for the naive user.

#### 9. Spelling errors:

The ability to correct spelling errors is of great value in enhancing the acceptability of the system. On occasion, due to incomplete linguistic or conceptual completeness of MEDINQUIRY, a word is corrected improperly and the request blocks or an incorrect response is provided. With continued enhancement of the system, these problems should occur far less frequently.

#### 10. Blocked requests:

When a request cannot be analyzed, MEDINQUIRY attempts to provide some information about why the request blocked. The request may be blocked at the first word in the input, or part of the request may have been processed before an unrecognized word appeared. If the next word at the point the request blocked is not in the MEDINQUIRY vocabulary, a message detailing possible words or word classes appropriate at this point is presented to the user. A synonymous word may be appropriate or, it is more likely that, the concept is not contained in the MEDINQUIRY



vocabulary. In the case where the word is in the application vocabulary, but for some reason is inappropriate in the context specified, MEDINQUIRY also displays the possible word classes or words appropriate at this point in the analysis. A third type of message is displayed when the entire request has been analyzed, but additional input is required to produce a complete request. See Section 5.2, questions 8 through 16, for examples of these types of messages associated with blocked requests. The information currently provided for blocked requests is not as robust as one would like, and there are plans to enhance the capability to provide better guidance for users.

#### 11. Time related information and negation:

Questions concerning time can be asked using those attributes containing information about time intervals prior to, or following the date of initial therapy. Questions can also be formulated that involve negation where the scope of negation relates to single valued variables, as well as repeating groups in the data base. MEDINQUIRY can respond to requests that involve repeating groups for multiple follow up visits where evidence of recurrence (or no recurrence) is indicated with some but not all follow up visits. See Section 6.2 for examples of requests where time and negation are used together. There remains the need for more complex facilities to process certain aspects of time such as, "average disease free intervals" and "average time to recurrence", and transitions between disease states, based on time, such as "what percentage of patients with level 4 melanoma move from Stage Ia to Stage II within the first 24 months?". To implement these additional





capabilities, it is necessary to extend the conceptual coverage, to understand how and when to perform the appropriate calculations on the data base, and in particular, to be able to represent time intervals in a robust fashion. Extending the linguistic coverage for these classes of questions is a relatively straightforward task while, in certain cases, extending the conceptual coverage may be quite difficult. The ability to process these types of requests will be added in later releases of MEDINQUIRY. In general, more efficient methods for processing time and negation need to be developed that may involve a reorganization of the data base and the use of more efficient data base access strategies.

#### 12. Dialogue interactions:

Dialogue interactions which involve entering a sequence of requests that depend on each other, are supported by the pronoun reference facility (see examples in Section 5.3). It also is possible to define meta-questions using the paraphrase facility at the sentence level. This allows the definition of patterns that extend the language facility to automatically respond to sequences of requests (see questions 24 and 25 in Section 5.3). The capability to enter sequences of requests provides the user with a way of specifying and testing hypotheses in a convenient manner. This is especially important if the physician is to find the system acceptable and responsive to his needs.

#### 13. Defining new concepts:

MEDINQUIRY provides a facility that allows the user to define higher order concepts at both the phrase and sentence level, and to tailor



concepts to his own requirements. It is important for the physician to be able to specify his own definitions for concepts like risk, prognosis, and outcome. For example, risk factors can be defined in terms of values derived from attributes in the data base. The physician can determine how this concept relates to other findings for the patients. Questions 26 and 27 in Section 5.3 illustrate this capability. There, "hrp2" (for high risk primary 2") is defined as a composite of tumor thickness greater than 1.5 mm., and presence of many mitoses. Sequences of questions can be formulated to determine recurrence rates for patients with these characteristics.

#### 14. Error recovery:

The prototype system has been used extensively; it is not expected that catastrophic errors or bugs will often occur that will inhibit the user from proceeding. In the event that some obscure message does appear the user can usually type a <control> D and proceed. See the introduction, on use of MEDINQUIRY in Appendix F, that details additional capabilities that are available whereby a user can correct typing errors in the course of entering a request.

#### 15. Changes to the application language:

The extensive paraphrase capability of English poses problems related to completeness of the application language, and thus it is necessary to be able to easily augment and modify the application language. Requests may be blocked due to deficiencies in the syntax of general English present in MEDINQUIRY, or to gaps in the conceptual coverage about

melanoma. The former can be easily augmented once the missing syntactic constructs are identified through user experience with the system. The latter may require additions to the set of concepts understood by MEDINQUIRY.

As the set of data base attributes change, and new types of questions are identified, modifications and enhancements can be made to the application language and to the functions that operate on the data retrieved. The questions that can be processed to date constitute a basic set; it is unlikely that any of these query types will be eliminated, but additional types of questions will be added, especially alternative paraphrases for the same question. The interactive editor makes it easy to make changes to the application language and these changes can be tested immediately.

#### 16. Information about the system:

To learn more about the range of questions that MEDINQUIRY can accept, the user may ask questions about the contents of the application language or the data base. The ability to ask questions about the application language is in keeping with the notion that what has been developed is a knowledge base of concepts relevant to melanoma. The user may ask how a symbol is used, what rules are generated from a given symbol, and in certain cases how a concept is defined. Examples of these capabilities were presented in Section 5.1 under Information about the Contents and Characteristics of the Data Base, and Information about the Grammar and Application Vocabulary. Appendix E, under the same headings, provides additional examples of these capabilities. As the system is



enhanced, these capabilities will be extended, especially those which relate to information about how a concept is defined.

In concluding, it is worth mentioning several studies that have attempted to evaluate the use of natural language methods to access data.

Hershman et al. (1979) conducted a preliminary evaluation of LADDER (Language Access to Distributed Data with Error Recovery), a LIFER based system, to identify significant performance characteristics associated with its use in a Navy Command and Control environment (see Hendrix et al., 1978 for a description of the LADDER system). Ten officers received an average of 10.5 hours of training in the use of LADDER, and used it in a search and rescue scenario. The authors concluded that LADDER has impressive capabilities in interpreting natural language requests and in retrieving information from the data base. Answers to requests were well understood, experts in the use of the system performed best, and the system provided responses much more rapidly than alternative procedures that were currently in use. However, at times the response time was too high and the rejection rate was excessive for requests dealing with user defined concepts or those that were time related. A large proportion of rejected queries were due to gaps in linguistic coverage. They also noted that the time to reject requests which could not be processed was too high, and that users experienced difficulties in constructing appropriate requests. They suggested that additional work was needed before such systems could be routinely used.

Codd (1978) uses a similar method to evaluate the conceptual and linguistic completeness of the RENDEZVOUS natural language question

answering system. He conducts his tests with subjects interacting with a sample data base containing information on suppliers, parts, projects, and shipments. The subjects were presented with seven short descriptions of situations which potentially can be answered from the data base. The user reads these descriptions, and is requested to use his own words and phrasing to pose questions in English concerning the descriptions. Then, the results of the interaction can be evaluated to identify the types of problems encountered by the user in formulating requests and engaging in clarification dialogues. Such an approach might also be of value in evaluating the conceptual and linguistic coverage of MEDINQUIRY.

The evaluation of the CASE system, which uses a limited natural language facility in the area of computer assisted instruction, also suggests several criteria that can be used to evaluate system performance (see Harless et al., 1973b).

## Chapter 7

### MODELS OF THE MEDICAL INQUIRY PROCESS

This chapter begins with an overview of models for decision making, and a discussion of the process of prognosis. A process model and knowledge representation model are proposed which describe how information might be organized, and how these models may be used to gain insights into strategies required to support medical inquiry. Several comments are made and examples given of the applicability of these models to MEDINQUIRY.

#### 7.1 Overview

In order to develop computer based systems which accomplish higher order processing in medicine, it is important to first explore the framework of the medical decision making process and its associated representation. A review of the literature on existing systems of artificial intelligence, computational linguistics and statistical methods confirms the complexity of the problem (see Section 2.5). Before the question "what is the current status of our ability to represent knowledge in a computer?" can be answered, it is necessary to first ask "what do we need to represent?", and "how is this knowledge to be used?". At this juncture, the role of criteria for the definition of necessary tasks and goals is apparent.

Epstein and Kaplan (1977) describe a generalized model of clinical decision making which embodies the following components: a knowledge representation model, a patient data base, a process model for





manipulating elements in the knowledge base, and a translation model for interacting with the outside world. A preliminary set of criteria were derived from these elements, and were used to develop a response to the initial questions.

A general framework is provided within which the clinical decision making process can be viewed. This framework is composed of four modules: the decision making module, the input module, the question answering module, and the data base. The focus of that research was on the decision making module which embodied the processes and knowledge necessary to arrive at diagnostic and therapeutic decisions.

The input module and question answering module interface the decision module with the outside world. The major role of the input module is to preprocess data used in the decision making process. In order to perform this function, it must handle paraphrases of medical concepts as well as synonymous concepts. The input module includes both patient specific data and control information which activates or terminates the decision making process. The question answering module allows access to data about the individual patient. The data base contains specific patient data.

The internal structure of each module, with the exception of the data base, consists of the process model and a corresponding knowledge base. The process model performs the basic task of hypothesis generation and testing, while the knowledge base contains those elements and relations pertinent to the problem domain.

In the present research, the focus is on the question answering module as representative of the process of medical inquiry. In

subsequent sections, an analogous process model and knowledge representation model is developed for the question answering module.

These initial models provide a conceptual framework for analyzing the problem solving process and assist in developing models of these processes. In addition, understanding the strategies used can aid in creating programs that better support the problem solving needs of experts. The models suggest how variables may be combined in the question answering process, and can be used to mirror the process of hypothesis generation and testing.

The intent is to provide a way of describing the process of inquiry and a suitable knowledge representation scheme to organize information relevant to the inquirer. By observing how experts use MEDINQUIRY, it may be possible to gain an understanding of how questions are formulated, how dialogue interactions are performed, how information about a medical domain is organized, and how hypotheses are formulated both for patient management and clinical research. At the same time, understanding the organization of information relevant to inquiry will aid in determining additions and modifications to MEDINQUIRY. The hope is that process and knowledge representation models might be eventually incorporated in question answering systems such as MEDINQUIRY to aid the requestor.

Before proceeding, it is useful to discuss the distinction between a data base and a knowledge base. A data base is a collection of records or items and access methods to locate these items. The way in which the data are viewed and manipulated is defined by the access method. A knowledge base consists of data coupled with an explicit statement of



the relations that exist between data items. These relations are specified by rules which aggregate data items, or from sources external to the data base that specify the relations between data items. Knowledge bases require more complex representations and access methods. This chapter is concerned with the general concepts required to build knowledge bases to augment a patient data base in the inquiry process.

The information processing approach to problem solving followed in this research is based on understanding the inquiry process that takes place between the initial state (input) and the final state (desired goal), and to record the sequence of steps followed in the process (i). These models support the view of problem solving as a memory search of information organized into a hierarchy of categories. The problem solving process requires the problem solver to examine, evaluate and select information to identify relevant questions. The problem solver also must consider the relations between items in the data base to determine effective strategies. Process models seek to support the problem solver (or expert) in his attempt to learn more about the clinical course of disease, and to understand his problem solving needs. In this research, the models proposed are based on the clinical data base used in MEDINQUIRY.

## 7.2 Prognosis

An important issue in formulating relevant hypotheses to study the clinical course of patients with melanoma, involves an understanding of the process of prognosis. Prognosis is an inference process concerned

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(i) See Section 2.5 for further discussion of the information processing approach.



with predicting the probable course (or outcome) of a disease for a particular patient or a group of patients. It is based on the findings for a patient, the physician's current model of the clinical course of the disease, experience with patients of similar disease extent, and the effectiveness of alternative therapies. Prognosis describes the clinician's expectation for a patient with disease (that is, it is prospective), while outcome is concerned with the analysis of evidence that has already been collected and is retrospective. In the case of malignant neoplasms, such as melanoma, commonly used measures of outcome are survival for a stated period, and recurrence rates. These are the target variables and are usually expressed in the form of five year survival, dead or alive, time to first recurrence, recurrence or disease free intervals. Results of prognostic stratification are expressed as rates with which the target event is present or absent in a specified group.

Among the important questions to consider in prognosis are determining good predictor variables, aggregating or combining variables to obtain reasonable forecasts of outcome, and specifying the importance (or relevance) and certainty (or reliability) of variables associated with prediction.

A brief description is given describing how prognosis may be done by physicians for patients with malignant melanoma. A clinician bases his current model of a disease on his actual experience with patients who have it, on knowledge from the literature, and on his understanding of the basic principles of medicine. He retains in his memory the variables or risk factors that have proven useful for patient management

and prognosis; however, he cannot usually consider more than five or six variables at one time. Examples of variables (predictor variables) useful in assessing prognosis in melanoma are: site of the primary lesion, histologic type, level of invasion, tumor thickness, sex, and lymph node involvement (1). Attempts have been made to classify or categorize patients with melanoma into groups based on clinical or pathological stage, TNM classification, risk associated with the primary, and scores of disease severity. The disease states derived from these systems have been used to try to assess prognosis and to predict outcome.

Variables that describe an initial state are called predictor variables when examined in relation to a target event. Each variable is given a weight which is an aggregate of the importance and certainty associated with its predictive power. Thus, level of invasion is possibly more important than age, while paraclinical results of histologic examination of the primary are more certain than many subjective clinical observations. The physician interprets these variables in relation to his knowledge about melanoma. He might be described as intuitively computing plots that show the relation between recurrence and/or survival over time for each variable. Based on the findings for a patient, and taking into account the importance and certainty associated with each variable, an expectation of outcome is heuristically calculated. This heuristic involves a logical integration of data from these different plots from which the overall prognosis for the patient is inferred. By observing the outcome for different patients

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(1) See Page 45 for a review of the literature on prognosis for patients with malignant melanoma.





over time, the physician identifies those variables that appear to be the best predictors of outcome. This information is used to modify the weights assigned to the variables and thus the recurrence and survival curves, and serves to influence his prognostic judgments about future patients. It is appropriate to note in this process that heuristics and statistics function as complementary methodologies. Heuristics supports browsing, the selection of potentially relevant variables, and other actions requiring judgment. Statistical methods provide a mathematical formalism for evaluating hypotheses once they are formulated.

Since treatment of melanoma has not been especially successful, many studies have focused on identifying reliable predictor variables that might define subsets of patients that would benefit from currently available therapeutic modalities or experimental protocols. A data base of the kind provided in this study would allow exploration of many of the hypotheses concerning prognosis. Experience in the data base can be used to accumulate new knowledge about the "best" strategy to follow for a given patient.

Some important questions for consideration in studying prognosis with the aid of a clinical data base of patients with malignant melanoma are:

- 1) What characteristics of the primary serve as a guide to prognosis?
- 2) Are tumor thickness and/or level of invasion the best predictor variables of prognosis, or do other variables such as mitotic activity, regression of the primary, ulceration or bleeding of the primary, or host response contribute to determining prognosis?



- 3) Are stage and TNM the best high order indices to predict outcome, or are there other high order composite indices that afford better utility in predicting outcome?
- 4) How can disease states be defined to reflect the clinical course of disease and usefully discriminate subgroups of patients?

Over the long term, systems such as MEDINQUIRY will make it possible to study the way a physician actually uses patient data in assessing prognosis. Recording the sequences of questions and responses used in the inquiry process will allow determining those variables that may best explain the outcome for patients in the data base. The construction of a more accurate basis for prognosis, say a prognostic index, would lead to a more useful model of the clinical course of the disease. It might also prompt hypotheses that would motivate more sharply focused research on pathophysiological changes to clarify aspects of the disease at a more fundamental level.

The next section describes a process and knowledge representation model that presents a view for organizing information to assist an expert in formulating questions with respect to prognosis.

### 7.3 Models of Inquiry

The process and knowledge representation models proposed provide one approach for thinking about how questions are posed. These models are useful in providing a framework to support medical inquiry and as an aid in defining appropriate problem solving strategies.

### 7.3.1 Process Model for Inquiry

Figure 4 summarizes a process model for inquiry. The basic flow consists of successive iterations through the functional blocks of hypothesis generation, query formulation, and analysis of results with requisite feedback between functional modules. The clinical data base is accessed by each of these modules, and serves as a reference point throughout the inquiry process.

The process begins with data collection, specification of attributes, or selection of an area for inquiry. It is explicitly terminated by the realization of the goals of the inquiry, or implicitly terminated without an adequate response because of the limitation of the available data.

Each of the functional blocks are now reviewed.

1. Hypothesis generation: Hypotheses may be either simple or complex. The underlying framework for the inquiry to be followed may be based on actual data for a patient under consideration (data acquisition), an attempt to determine relationships between attributes in the data base, or an attempt to relate findings to outcome, therapy selection, or diagnostic procedures to be performed. An understanding of the organization of the information in the data base from the perspective of the expert is essential to this process.

2. Query formulation: The expert translates the hypothesis from a conceptual form into a concrete form suitable for submitting a request and receiving a response from the system. A hypothesis to be tested may



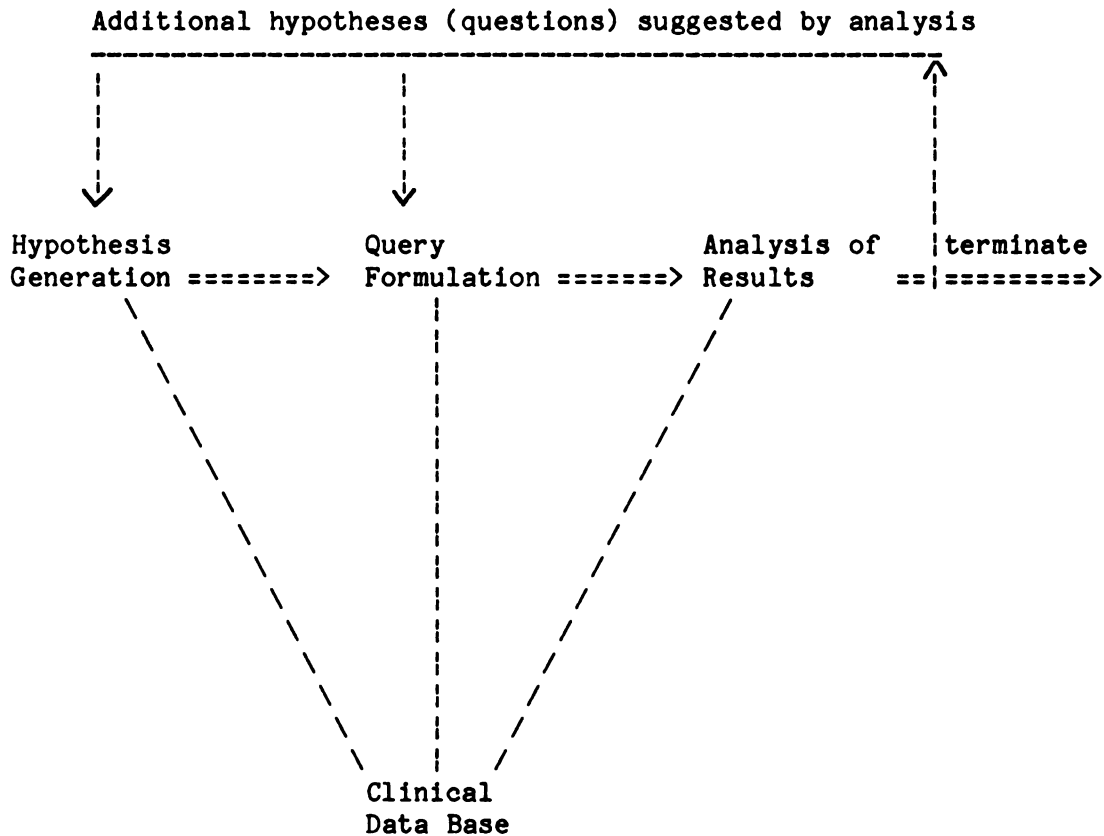


Figure 4. Process Model for Inquiry

involve one or more requests of the clinical data base. This corresponds to the process of hypothesis testing.

**3. Analysis of results:** The response is evaluated by the expert based on measures such as the utility, value or importance of the results, how well the actual results from the data base compare with the expected results, the adequacy and completeness of the response, and the





suitability of the response for plan formulation and decision making. The results may be complete and adequate to deal with the question considered. The expert may then make certain inferences, and use the results to confirm hypotheses and support his decision making processes. The results may aid in gaining insights into interactions between variables or resolving interactions among variables. Additional queries concerning the same hypothesis may be suggested, the hypothesis may be refined and followed by additional query requests, or additional closely related hypotheses may be pursued.

The steps of hypothesis generation, query formulation, and analysis of results continue until a satisfactory response is obtained. If the information is not available or the linguistic or conceptual coverage is inadequate, it may not be possible to obtain an adequate response from the system.

The process model can be viewed as analogous to a mode of exploratory data analysis (see Tukey, 1977). It is a prerequisite to confirmatory data analysis which would be undertaken to validate the intuitive preliminary conclusions developed through the heuristic mode of inquiry described.

The modes of inquiry used by experts can be classified under the general headings of recall, browsing, and conjectures which relate to the level of complexity of the inquiry. A description of how these modes are used in the context of the process model is now given.

1. Recall: These concrete questions may involve comparing a particular patient with similar patients in the clinical data base, summarizing available data on a given patient, or selecting subsets of patients with



specified characteristics. The inquirer must identify the appropriate set of characteristics present in the patient being considered, and submit a request that would allow him to review the outcomes for similar patients in the data base. Alternately, a set of characteristics of general interest may be identified, and a request submitted to locate patients with these characteristics. Responses to such questions usually return a count, a list of individuals satisfying the request, or a summary table of results. This mode of inquiry implies the existence of a knowledge representation model in the mind of the expert which reflects the organization of information relevant to the domain of inquiry.

For example, a patient may present with melanoma of the upper extremities, and on histologic examination of the primary the tumor thickness is found to be 1.5 mm. with a high mitotic rate. (1)

The expert may now wish to determine the outcome for patients in the data base with similar characteristics. The following sequence of questions may be posed.

- a) What are the values in the data base for mitotic rate?  
[to understand how the information is recorded in the data base]
- b) how is many mitoses defined?  
[an ordinal scale rather than an interval scale is used to record the results in the data base]
- c) list the age, site of primary, and tumor thickness for patients with melanoma of the extremities with tumor thickness between 1.30 and 1.70 mm., age between 30 and 40, and many mitoses.  
[to list the relevant attributes for patients with the above constraints and determine the number of patients with these characteristics]

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(1) These characteristics are identified by the expert as being important.



d) list the outcome for these patients

[displays the status, stage, and time since initial therapy for the patients identified in c)]

If the results to question c) and d) are not satisfactory, additional questions may be posed modifying the constraints in the requests. Eventually this process would give the inquirer cases of patients with somewhat similar characteristics to the one being considered. Subsequent questions can be posed about outcome, and therapeutic or diagnostic maneuvers which have been recorded as part of the experiential knowledge in the data base.

2. Browsing: These questions are more speculative and seek to establish relationships between attributes in the data base, or to establish relationships between one or more attributes (or aggregates of attributes) and outcome. Data can be tabulated and correlated with outcome. Once intuitively satisfactory relationships between variables have been identified, statistical tests to determine the significance of these results can be performed. Such questions usually generate responses in the form of tabulations, distributions, or simple calculations.

Examples of speculative hypotheses which are amenable to browsing include:

- 1) study whether patients with tumors of different histologic types invasive to the same level have similar outcomes.
- 2) study whether tumors of similar thickness and varying mitotic rates, or degree of lymphocytic infiltration exhibit differences in survival.



- 3) identify differences in the clinical course of disease for patients with tumor thickness greater than 4 mm. who had elective lymph node dissections

The following sequence of questions could be formulated to respond to item 1.

How many patients with level 2 ordered by type?

How many of them had histologically demonstrated recurrence within 24 months of initial therapy ordered by type?

Similar requests could be posed for level 3, 4 and 5 melanomas. There are many other ways to pose questions testing this hypothesis.

The purpose of these examples is to illustrate how the process model mirrors the process of inquiry, and how complex questions can be broken down into simpler ones and posed using the data base. The general paradigm of hypothesis generation, query formulation, and analysis of results might be one way in which experts think about information about a disease, as represented by a clinical data base.

3. Conjectures: These are the most difficult type of questions. To adequately respond, the system must have inference making capabilities. Requests in this group may involve selecting "best" predictor variables from those in the data base to predict the value of a "target" variable. For example, an expert may be interested in determining high risk factors in patients with recurrence in the first year, finding the salient characteristics that would identify those patients who had "low risk", "intermediate risk", or "high risk" primaries, or identifying common factors in patients who survive for five years. Direct responses





to such requests are beyond the current capabilities of MEDINQUIRY. These requests can be answered if broken into simpler questions, with the inference making capabilities provided by the expert. An interesting extension of the current system would be to use a knowledge base to aid in analyzing such conjectures.

### 7.3.2 Knowledge Representation Model

Figure 5 is a generalized knowledge representation model modified from the work of Weiss et al. (1978). This model provides a conceptual structure for the knowledge base associated with the process model. The function of the knowledge base is to provide a representation of the entities, and potential relations between entities that can be accessed during instantiation of the process model. Items such as relations between variables, definitions of variables, and composite or aggregate variables are important criteria in describing how information is conceptually organized for inquiry. This representation can be viewed as levels of abstraction consisting of a set of planes, and mapping functions between and within planes. The information in each plane consists of attributes present or derived from elements in the clinical data base.

The planes are ordered hierarchically with the most primitive observations or entities in the lowest plane (clinical observations, or clinical findings), data derived from intervention (paraclinical findings) in the middle plane, and what might be thought of as "goal" inferences (disease states) in the upper plane.

Figure 5 also illustrates the types of data elements that are



## Type of Information

Nomenclature of  
Disease States

Stage, TNM, risk-assessment  
user defined concepts  
(aggregate of factors,  
composite relations)

Prognosis

recurrence  
survival  
1st recurr  
2nd recurr

Data derived  
from intervention  
(paraclinical  
findings)

histologic information  
(type, level, thickness,  
mitotic rate, lymph node  
lnp-histology, histologic  
evidence for recurrence)

Therapeutic  
Procedures

TLND  
immunotx  
chemotx  
wide re-  
excision

Clinical  
observations  
Clinical facts  
Clinical findings

demographic information,  
patient background,  
family history,  
PE of primary, history of/  
primary, patient PE

Diagnostic  
Procedures

biopsy  
excision  
ELND

Figure 5. Knowledge Representation Model



assigned at each level. This view of the information about melanoma has been selected as being appropriate to represent and organize information to support the process of medical inquiry. The organization of information in the knowledge representation model presents the multiple viewpoints used in formulating questions. The process model must have access to the items in the knowledge representation model to support generation of hypotheses for recall, browsing, or conjectures.

Each attribute-value pair in the data base consists of observations or aggregates of basic evidence. The values assigned to attributes not only affects the representation, but also the interpretations which can be assigned to the data in subsequent analysis.

The criteria associated with the knowledge representation model are of two types, mapping functions and entities. Mapping functions include relations such as causality, association, proximity, subset, superset, negation, and time; while strength of relations includes probability of the event, measure of belief, and weight of evidence. Entities include links from therapeutic and diagnostic procedures to levels of information present at the three levels.

Procedures are associated with outcomes and complications which have probabilities and values. For example, a lymph node procedure has outcomes of positive or negative nodes, as well as a possible complication of infection. The probabilities and values will change depending on the context in which the procedure is performed. Diagnostic procedures also have reliabilities associated with their outcomes. That is, when a pathologist reports histologically negative nodes, his judgment may be correct only 90 percent of the time.



Most of the relations are well known and have been discussed elsewhere. Strength of relations has been treated in various ways from data base determined probabilities, to certainty factors, to measures of belief. All apply some semi-quantitative measure to the relations. For example, if high mitotic rate is associated with poor prognosis in 70 percent of cases, then .7 is the strength of the relation. In considering mapping functions, it is significant to note that efficient solutions to complex problems occasionally involve multiple approaches or viewpoints. This suggests that redundant representations with different organizations or multiple paths between entities may be a necessary implementation characteristic. In Figure 5, this may be viewed as skipping levels.

To formulate requests about malignant melanoma with respect to a clinical data base, the inquirer must consider the relation between items in each plane, relations between items in different planes, mapping of items (or aggregates) to prognosis, and diagnostic and therapeutic procedures. The names assigned to disease states provide a reduced observation space and allow formulating requests that relate to outcome, prognosis, and to the utility and importance of diagnostic and therapeutic procedures.

An example from the data base on malignant melanoma can serve to illustrate these ideas.

Suppose a 30 year old male presents with a dark mole which was first noted six months ago, and has been bleeding intermittently for the past several weeks. The lesion is ulcerated, approximately one cm. in diameter, and there are no clinically palpable lymph nodes. These items





represent primitive inferences (clinical observations and findings). The intermediate inferences derived through intervention such as an excisional biopsy or an elective lymph node dissection might be a level 4 melanoma, tumor thickness 1.6 mm., high mitotic rate, and lymph nodes that are histologically negative. The "goal" inferences (disease states) are stage IF, high risk primary, and a TNM classification of T1N0M0.

Figure 6 is an instantiation of the knowledge representation model using several of these attributes. This illustrates the links between the three levels of information, links between variables at a given level, links between variables or aggregates of variables and outcome. In Figure 6, links between procedures and outcome are denoted by "L"; relations between items within a level are denoted by "R"; while strength of relations between levels or strength of relations concerning prognosis are denoted by "SOR".

Tumor thickness and level of invasion are strongly related. Depending on the viewpoint of the inquirer, an elective lymph node dissection may be a diagnostic or therapeutic procedure; an excisional biopsy is considered a diagnostic maneuver, while a wide re-excision might be considered a therapeutic maneuver. These procedures are linked to paraclinical findings. Tumor thickness, and histologically negative nodes are linked to diagnostic or therapeutic procedures, which in turn are linked to Stage, TNM, risk assignment, and finally to prognosis. Inferences must also be linked to related procedures. For example, data derived from histologic examination of the primary would be linked to excisional biopsy, while stage IF melanoma would be linked to either TLND or ELND. Arithmetic relations such as "depth of invasion = 1.6 mm."



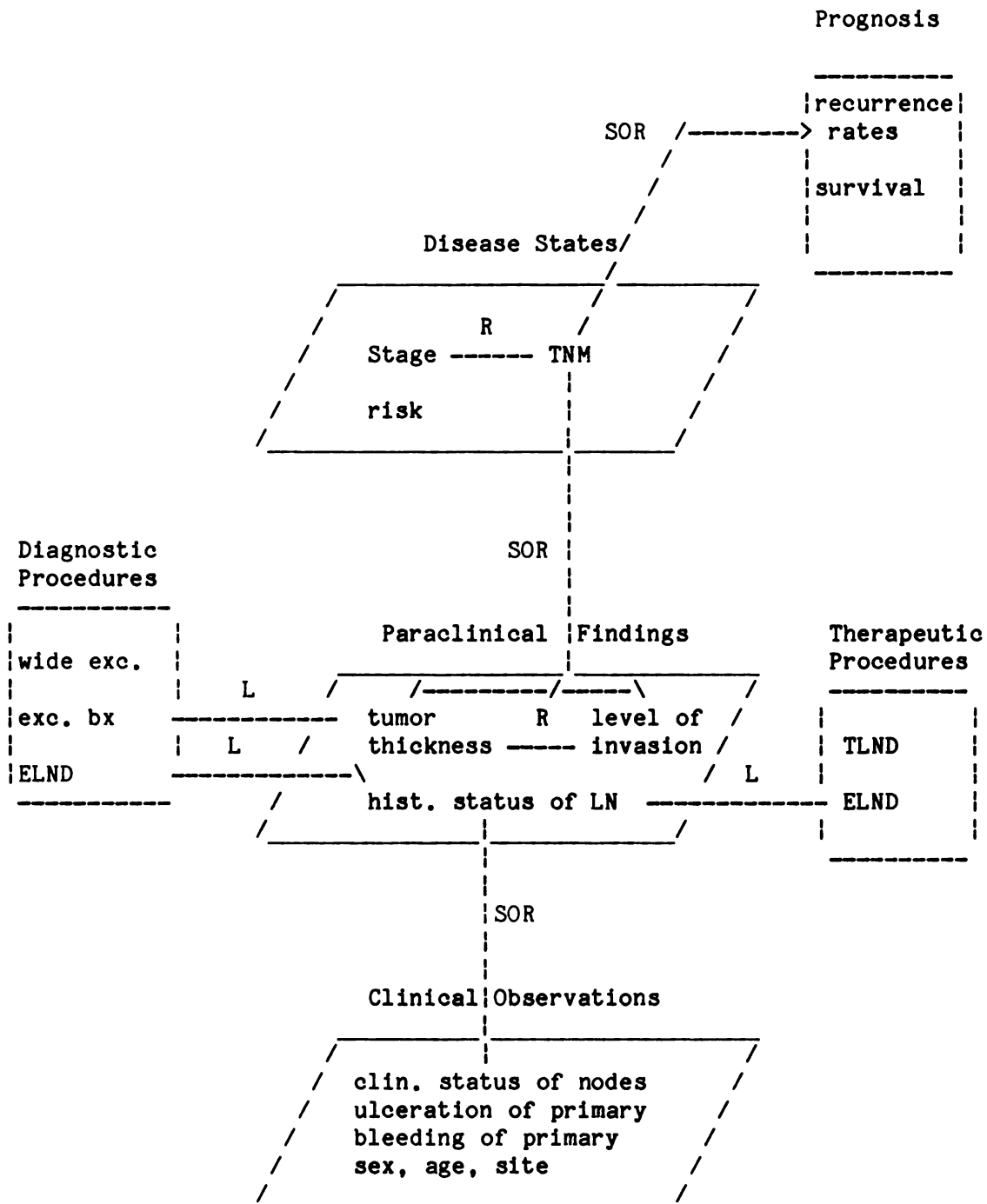


Figure 6. Instantiation of Knowledge Representation Model



must also be represented as an entity. A mapping function exists between the staging and TNM classification systems, which are used to classify patients with melanoma and to grade the prognostic severity of disease. The variable "risk" is assigned so as to best predict outcome; tumor thickness is related to risk associated with the primary. In turn, tumor thickness and risk are predictor variables of the target variables recurrence rates and survival. Tumor thickness and level may be related to prognosis; sex, site, and thickness also have been reported as being directly linked to prognosis.

The information in the data base may be organized and aggregated in various ways for purposes of inquiry. Several strategies that may be used in establishing relations among variables and in studying prognosis and outcome in patients with malignant melanoma are now described. These strategies correspond to rules for the aggregation of information in the mind of an expert, when in the course of the inquiry process, access is made to the knowledge representation model.

1. Conjunction of variables: Categories may consist of single items such as tumor thickness or level of invasion, or composite categories which are a function of variables such as type, level and duration of symptoms. To create compound variables (or a cluster of variables), a set of rules must be established to specify the pattern in which the combined elements are demarcated. For example, stage and TNM are compound variables.

Patient outcome may be prognosticated with the aid of an ordinal scale that specifies different degrees of risk. Thus, the variables "tumor thickness", "level of invasion", and "host response" may be reassigned



to name disease states such as "high risk primary", "intermediate risk primary", and "low risk primary" based on the values for each of these variables. These defined categories may then be used in questions relating to outcome. Other attributes may be aggregated in a similar manner to form new risk categories suitable for asking questions about prognosis or outcome. This process corresponds to the definition of disease states in the knowledge representation model in Figure 6.

The process of stratification is another way of creating composite variables. If level of invasion is partitioned into four categories, and sex into two categories, then requests which require information to be organized by level and sex will create composite variables in eight categories. Attributes may be stratified in this manner to form groupings which may then be compared to target variables.

2. Composite score: Another way of creating a composite attribute is to assign a single numerical score (or weight) based on the presence or absence of selected values for attributes considered to be important, and then to add these numerical values to obtain a prognostic score. A composite weight is calculated for each patient, and a cutoff point is defined separating low risk, intermediate risk, and high risk patients (see Page 46). Alternately, two dimensional attributes could be combined (say, multiplied together) to construct a score, and a cutoff point could be defined that separates low, intermediate, and high risk patients. A prognostic index has been defined as the product of tumor thickness and number of mitoses per square millimeter (see Page 46).

3. Transformations: Because the many expressions of a multi-axial scale





make results difficult to use, a multi-focal index can be transformed into a single index. The TNM system is named according to its three axes. Results of the TNM classification system may be expressed in the original multi-axial components (TNM), but can also be combined into a single index having categories I, II, and III (that is, stage). The categories are formed from specific combinations of results found in each of the T, N, and M axes.

4. Partitioning of attributes: Since categories are usually chosen before the target event is noted, the investigator may wish to alter the partition in the process of inquiry. Thus, for purposes of data analysis, the dimensional variable tumor thickness may be partitioned into ordinal categories such as thin, intermediate, or thick primaries. This process is called consolidation. The reverse process, called expansion, could be used to partition the ordinal variable mitotic rate into a dimensional scale such as mitoses per square millimeter.

One partition of values for tumor thickness is defined in mm. as 0 - .76, .77 - 1.5, 1.5 - 3.0, and greater than 3.0 mm. When using tumor thickness as a predictor variables in assessing prognosis, it may be desirable to repartition these values into alternate groupings such as, 0 - .75, .75 - 1.25, 1.26 - 1.75, and greater than 1.75 mm. Similar partitions may be desirable for other dimensional variables such as age, months since bleeding of the primary was noted, or months since initial therapy.

5. Temporal relations: Temporal criteria refer to the current state of the entity under consideration, to prediction about a future state, or



to a transition between two or more states. A single state description describes the current or immediate state of an entity. Predictions have been developed for prognostication and may be expressed as "excellent", "good", "fair", or "poor"; or as an ordinal scale of a staging system such as "I", "II", and "III". The validation of prognostic criteria require data from at least two different points in the patient's clinical course; the initial state and subsequent outcome upon which the prediction is based. A transition is expressed as the change noted in a direct comparison of two or more different states. The transition may represent the alteration that has occurred over time in a single entity. Transitions represent comparisons; it is necessary to be able to represent multiple events and formulate questions with respect to these events.

#### 7.4 Comments on Use of Models in MEDINQUIRY

Throughout this dissertation numerous examples have been presented which implicitly illustrate the strategies discussed in this chapter (i).

Several brief comments are now given on the use of these strategies. The definition of higher order concepts can be of great value in formulating requests to assess prognosis, and can be illustrated by the proposed knowledge representation model. The medical expert must be able to build definitions that include his own definition of risk, prognosis, and outcome. Risk associated with the primary can be

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(i) Examples of dialogue interactions are given on Page 105 and Page 246; meta-questions are illustrated on Page 106; definitions of risk associated with the primary on Page 110.



defined in terms of attributes or aggregates of attributes in the data base. The expert can then pose questions that relate these defined concepts to other attributes in the data base, or identify patients with similar characteristics. If "hrp5" is defined as "tumor thickness greater than 1.5 and presence of many mitoses on histologic examination of the primary", then sets of questions can be specified that use this constraint in the inquiry process.

In addition, meta-questions can be specified to study the influence of selected variables for subsets of patients who satisfy certain constraints. The following sequence of requests could be entered.

2\_let "hpv" equal "tumor thickness, mitotic rate, and cellular host response"

[define template for histologic prognostic variables]

3\_substitute "describe hpv1 for pts with ssm" for "list the hpv for pts with ssm. how many of these people had histologic recurrence within yr 1? list the personal data for those people. how many of them had NED in year 1 and histologic recurrence in year 2? list the personal data for them."

[define template for meta-question]

The expert can obtain a response to the original meta-question and also submit other requests such as:

4\_describe hpv1 for pts with level 5 disease.

5\_describe hpv1 for individuals with tumor thickness greater than 3.0 mm. and many mitoses.

6\_describe hpv1 for pts with tumor thickness greater than 1.5 mm. and many mitoses.

The following responses might then be obtained. For meta-question 4, ten of seventeen patients had histologic recurrence in year one; and one out of seven had no evidence of disease in year one and histologic recurrence in year two. For meta-question 5, eight of nine patients had histologic recurrence in year one, and no patients had no evidence of disease in year one and histologic recurrence in year two. For meta-question 6, ten of seventeen had histologic recurrence in year one, and no patients had no evidence of disease in year one and histologic recurrence in year two.

The inquirer may then define "h<sub>pv</sub>" to be "level of invasion and ulceration of the primary" and repeat the same sequence of meta-questions to determine if these variables are better predictors. The process involved in defining such sequences of questions is in keeping with the process model and knowledge representation model described earlier. The general paradigm of hypothesis generation, query formulation, and analysis of results may be one way in which experts think about information on melanoma in a clinical data base.

Following several of the methods proposed in this chapter and using the models developed, should make it possible to develop more detailed classification systems for patients with melanoma. These systems could then be used to identify disease states to inquire about prognosis and outcome for patients with melanoma.



## Chapter 8

SUMMARY AND FUTURE WORK

Creating systems that provide convenient access to a computerized clinical data base is essential to make relevant information available to researchers. A limitation of current medical data systems for inquiry is that they are difficult to use, for those not familiar with the specialized retrieval operations required, regardless of their simplicity. An intermediary must act as translator between an individual who wants to know and the data system that may have the answers. This inhibits intellectual access to data and prevents problem solvers, who may have collected the data, from having free and informal interaction with their data. An alternate approach to the problem of providing convenient access is the design and implementation of a clinical data base system that provides free and informal access through the use of natural language. The computer system developed as part of this research, called MEDINQUIRY, is designed to respond to requests posed at a terminal by subject matter experts, in a subset of English by accessing a data base of patients with malignant melanoma. The system accepts a wide range of natural language requests and, for each analyzed request, generates a formal query request that is passed to the data base, matches the request against the data base, and provides a relevant response to the submitted inquiry.

This dissertation begins with a review of the literature on methods used to access medical data, and recent work on problem solving strategies and artificial intelligence in medicine. The overview





presents a framework for the current research and indicates the need for natural language access to medical data bases. In the course of the literature review on malignant melanoma, medically important areas of inquiry were identified, and potential areas of inquiry were suggested. The review provided one mechanism for identifying potential hypotheses to be tested and requests to be posed using the melanoma data base, as well as clarifying the linguistic and conceptual coverage to be incorporated into MEDINQUIRY to understand requests about melanoma. The topics covered in the review also provided a basis for the process and knowledge representation models developed, to provide a framework to support medical inquiry and to aid in defining appropriate problem solving strategies.

An application language was built containing both domain specific knowledge about melanoma and general knowledge about language that allowed understanding English language requests formulated by experts. The goal was to handle that portion of language and knowledge required to understand a particular area of medicine. The application language, coupled with a data base access module, was then used in the design and implementation of a natural language question answering facility to provide a direct and convenient interface between a medical expert and a clinical data base on malignant melanoma. The prototype system, was implemented using the LIFER (Language Interface Facility with Ellipsis and Recursion) package to provide access to a data base of 130 patients with malignant melanoma. The English language facility provided medical experts with convenient and direct access to their data, as well as ease of browsing and perusing these data, and supported immediate hypothesis



generation and testing. The physician can input requests that retrieve specified data for particular patients or for groups of patients satisfying certain characteristics, that specify simple calculations to be performed, and that allow browsing through the data base. MEDINQUIRY can also be used to assist an expert in identifying and studying relationships among patient attributes, and in relating information in the data base to prognosis and outcome.

The application language, representing the set of requests to be processed by the system, was developed based on a comprehensive review of the literature on melanoma, an analysis of the elements in the data base, and conversations with experts in melanoma. LIFER interface functions were used to specify grammatical patterns, fixed phrases, words in sets, predicates, and pronoun references required to analyze English language requests. Functions were written by the author in INTERLISP to operate with the LIFER parser to construct a formal query request that is passed to the data base access module, as well as additional functions to respond to the user's requests. This research demonstrated that knowledge about melanoma can be formalized for use in question answering, and that an appropriate application language can be written. The system has the capability to respond to several different classes of questions. Dialogue interactions are supported allowing the user can follow a line of inquiry to test a particular hypothesis by entering a sequence of requests that depend on each other. Phrases rather than complete sentences can be used, where the meaning of a phrase is interpreted based on analysis of prior queries. It is possible to define new constructs at the phrase level, and a limited



capability exists, using a sequence of stored requests, to respond to meta-questions. It also is possible to process certain classes of time oriented requests and requests that involve negation. Extensive examples were given of the classes of requests currently supported, and how dialogue interactions and meta-questions can be used to augment the acceptability and responsiveness of the system.

A discussion was given of several issues involved in the design and implementation of the system. This included discussion of the issues of responsibility, completeness of the data base, completeness and correctness of requests, complexity of requests, completeness of responses, and the structure, completeness, and extendability of the application language. A description was given of the implementation of temporal relations and negation. A set of criteria were suggested to eventually evaluate MEDINQUIRY, and some preliminary results were given on the performance of the prototype system.

This research also is concerned with gaining an understanding of the medical inquiry process and supporting effective inquiry strategies. A model was proposed that describes how information about malignant melanoma might be organized. The model attempts to represent the process of hypothesis formation and testing, using a process and knowledge representation model, to provide a framework that can be used in subsequent work on MEDINQUIRY. The models support understanding of the conceptual strategies and structures used to solve problems about prognosis, and to identify questions asked about relationships among variables or about outcome.

This research attempts to provide the medical expert with resources



that allow him/her to enter requests and receive useful information about a disease, in this case malignant melanoma. By observing the process followed by experts in formulating requests and studying the results of their interactions with MEDINQUIRY, it may be possible to develop criteria for knowledge bases and process models about disease. This approach is distinctive in that it supports the physician in developing his own hypotheses about relations that hold among medical data. The subject matter expert who uses MEDINQUIRY can introduce into the application language higher order concepts that will help organize the data in the data base, but the primary purpose of this research is to make it easier for the expert to find out what information is present in the data base and to provide more effective and timely decision support.

The work on developing effective decision support systems is also relevant to the work described in this research. Such systems have as their objective improving the decision maker's ability to solve problems by providing more flexible access to information, better tools and techniques, and ways to analyze a particular type of decision. This research in natural language access to clinical data bases and in developing models of the medical inquiry process is an attempt to move towards such responsive and acceptable systems. MEDINQUIRY has been demonstrated in prototype form using a relatively small clinical data base base of patients with malignant melanoma. Potentially it offers significant advantages for improvement of patient care in specialty clinics by increasing the availability, in a timely manner, of data that supports decision making. MEDINQUIRY also can aid in the process of



clinical investigations, including the management of clinical protocols, by providing a facility that is flexible and easy for the investigator to use. In addition, the availability of the system is expected to motivate participating physicians to collect accurate and complete data, because they will be direct, rather than indirect beneficiaries of the resulting data base.

The prototype system described is only a start towards resolving many of the issues related to providing direct access by medical experts to their data. This research is continuing as a collaborative effort between the University of California, San Francisco, the University of Pennsylvania, SRI International, and the author to compile two 500 patient data bases of patients with melanoma to test and evaluate MEDINQUIRY. With these larger data bases, containing somewhat different attributes, the linguistic and conceptual coverage of the application language will be extended and changed. Work will then proceed on studying the use of the system by experts for inquiry, and its use in gaining a better understanding of the clinical course of the disease.

To make MEDINQUIRY more acceptable and responsive to the needs of medical experts, additional research is required in the following areas:

- 1) augment current procedures for processing time related information and negation
- 2) develop an interface to a statistical package
- 3) provide better procedures for handling ambiguous queries
- 4) include sophisticated prompts to aid the user in resolving blocked requests



- 5) develop more efficient methods to optimize requests that are submitted to the data base and minimize multiple accesses to the data base
- 6) develop more sophisticated ways to present the information to the user
- 7) extend coverage beyond the information currently in the data base by adding a knowledge base that supports inference making using the process and knowledge representation models developed in Chapter 7
- 8) use the knowledge base to aid in responding to requests about the clinical course of melanoma
- 9) develop more sophisticated methods to support conjectures and to determine the "best" variables to develop a prognostic index and to study prognosis
- 10) develop better classification systems for staging disease and use this as a framework to study prognosis and the clinical course of disease
- 11) include references to the published literature as part of the knowledge base both to augment the data base response and to respond to requests when relevant information concerning a topic is not present in the data base

In conclusion, the long range objectives are to use the medium of natural language to study the use of the system by medical experts, and to gain a better understanding of the medical inquiry process. The models proposed are a first step in developing a framework that can be used in subsequent work on medical inquiry. Following an information

processing approach to analyze and evaluate how interactions are performed should aid in gaining insights into the process of hypothesis formation by experts, and the strategies used in establishing relationships between variables and in studying prognosis and outcome for patients with melanoma. Such a system would require implementing a knowledge base that embodies process and knowledge representation models such as the ones described in Chapter 7.

REFERENCES

Barnett GO, Medical information systems- present illness and prognosis, in *Advanced Medical Systems: the 3rd Century*, EJ Hinman ed., New York, 1977, pp 1-8.

Barnett GO, Justice NS et al., COSTAR, a computer-based medical information system for ambulatory care, *Proceedings IEEE*, vol 67, no 9, pp 1226-1237, September 1979.

Barrett JP, Barnum RA, Gordon BB, Pesut RN, Evaluation of the Implementation of a Medical Information System in a general Community Hospital, Battelle Columbus Laboratories, Columbus, Ohio, December 1975.

Beaman PD, Justice NS, Barnett GO, A Medical information system and data language for ambulatory practices, *Computer*, vol 12, no 11, pp 9-17, November 1979.

Bernstein LM, Siegel ER, Goldstein CM, The hepatitis knowledge base: a prototype information transfer system, *Annals of Internal Medicine*, vol 93, no 1 (part 2), pp 165-222, July 1980.

Blum RL, Wiederhold G, Inferring knowledge from clinical data banks utilizing techniques from artificial intelligence, in *Proceedings of Second Annual Symposium on Computer Applications in Medical Care*, IEEE Society, New York, 1978, pp 303-307.

Blum RL, Automating the study of clinical hypotheses on a time oriented data base: the RX Project, manuscript, Department of Clinical Pharmacology and Department of Computer Science, Stanford University, Stanford, California, November 1979.

Bolt Beranek and Newman, An introduction to the CLINFO data management and analysis system, Bolt Beranek and Newman, Cambridge, Massachusetts, 1979.

Bonnet A, BAOBAB: a parser for a rule-based system using a semantic grammar, Report No. STAN-CS-78-668, Computer Science Department, Stanford University, Stanford, California, September 1978.

Bonnet A, Schema-shift strategies to understanding structured texts in natural language, Report No. STAN-CS-79-759, Department of Computer Science, Stanford University, Stanford, California, August 1979.

Bunker JP, Barnes BA, Mosteller F (eds.), *Costs, Risks, and Benefits of Surgery*, Oxford University Press, New York, 1977.

Ciesielski VB, Natural language input to a computer-based glaucoma consultation system, in *Proceedings 17th Annual Meeting of the Association for Computational Linguistics*, 1979, pp 103-107.



Codd EF, How about recently? (English dialog with relational data bases using RENDEZVOUS version 1), in Databases: Improving Usability and Responsiveness, B. Shneiderman (ed.), Academic press, New York, 1978, pp 3-28.

Copland JA, Hamel B, Bourne JR, An exploratory data analysis system for support in medical decision-making, in Proceedings Third Annual Symposium on Computer Application in Medical Care, IEEE Computer Society, New York, 1979, pp 85-90.

Corley JH, Underwood WE, SCOTCH and SODAS: Semantically oriented data access and storage for a medical record DBMS, in Proceedings of Third Annual Symposium on Computer Application in Medical Care, IEEE Computer Society New York, 1979, pp 98-104.

Cutler P, Problem Solving in Clinical Medicine, Williams and Wilkins, Baltimore, 1979.

Damerau FJ, Automatic language processing, in Annual Review of Information Science and Technology, vol 11, ME Williams (ed.), American Society for Information Science, Washington DC, 1976, pp 107-161.

Davis R, A DSS for diagnosis and therapy, Data Base (ACM SIGBDP), vol 8, no 3, pp 58-72, Winter 1977.

Deland EC (ed.), Information Technology in Health Science Education, Plenum Press, New York, 1978.

Doszkocs TE, Rapp BA, Schoolman HM, Automated information retrieval in science and technology, Science, vol 208, pp 25-30, April 4 1980.

Elstein AS, Shulman LS, Sprafka SA, Medical Problem Solving: An Analysis of Clinical reasoning, Harvard University Press, Cambridge, Massachusetts, 1978.

Engelhardt HT, Spicker SF, Towers B (eds.), Clinical judgment: a critical appraisal, D Reidel Publishing Company, Dordrecht, Holland, 1979.

Epstein MN, Harper SA, An Information Processing System for Pathology Data, Internal Report, Division of Computer Research and Technology, National Institutes of Health, Bethesda, Maryland, 1969.

Epstein MN, Kaplan EB, Criteria for clinical decision making, in Computational Linguistics in Medicine, W Schneider and AL Sagvall-Hein (eds.), North Holland, Amsterdam, 1977, pp 35-44.

Feinstein AR, Rubenstein JF, Ramshaw WA, Estimating prognosis with the aid of a conversational-mode computer program, Annals of Internal Medicine, vol 76, no 6, pp 911-921, June 1972.

Feinstein AR, Clinical Biostatistics, Mosby, Saint Louis, 1977.

Feinstein AR, Clinical Judgment, Krieger Publishing, New York, 1967.





Fitter M, Towards more "natural" interactive systems, International Journal of Man-Machine Studies, vol 11, pp 339-350, 1979.

Fox J, Medical computing and the user, International Journal of Man-Machine Studies, vol 9, no 6, pp 669-686, November 1977.

Fox MA, Natural language and context dependent retrieval using ACIS, Proceedings of the 2nd Annual WAMI Meeting, 1979, pp 164-172.

Fox MA, ACIS: A Clinical Information System, in Proceedings First Congress of the European Federation for Medical Informatics, J. Anderson (ed.), Springer Verlag, Berlin, 1978, pp 9-18.

Fries JF, Time oriented patient records and a computer databank, Journal of the American Medical Association, vol 222, pp 1536-1542, December 18 1972.

Fries JF, A data bank for clinicians, New England Journal of Medicine, vol 294, no 25, pp 1400-1402, June 17, 1976.

Greenes RA, Barnett GO, Klein SW et al., Recording, retrieval and review of medical data by physician-computer interaction, New England Journal of Medicine, vol 282, no 6, pp 307-315, February 5, 1970.

Grishman R, Hirschman L, Question Answering from natural language medical data bases, Artificial Intelligence, vol 11, no 1-2, pp 25-43, August 1978.

Groner GF, Hopwood MD, Palley NA, Sibley WL, An Introduction to the Clinfo Prototype Data Management and Analysis System, Report R-1541-NIH, Rand Corporation, Santa Monica, California, December 1977.

Hall WD, Camp HN, Reynolds KD, Slamecka V, Clinical decision-making: applications of the MARI system, in Proceedings Third Annual Symposium on Computer Application in Medical Care, IEEE, 1979, pp 77-80.

Harless WG, Drennon GG, Marxer JJ, et al., CASE- A natural language computer model, Computers in Biology in Medicine, vol 3, no 3, pp 227-246, October 1973a.

Harless WG, Drennon GG, Marxer JJ, et al., Genesys- a generating system for the CASE natural language model, Computers in Biology in Medicine, vol 3, no 3, pp 247-268, October 1973b.

Harris LR, The Robot system: natural language processing applied to data base query, in Proceedings 1978 ACM Annual Conference, New York, 1978, pp 165-172.

Hendrix GG, The LIFER Manual: A guide to building practical natural language interfaces, Technical Note 138, SRI Artificial Intelligence Center, Menlo Park, California, 1977.

Hendrix GG, Sacerdoti ED, Sagalowicz D, Slocum J, Developing a natural



language interface to complex data, ACM Transactions on Database Systems, vol 3, no 2, pp 105-147, June 1978.

Hershman RL, Kelly RT, Miller HC, User performance with a natural language query system for command control, Report NPRDC TR-79-7, Naval Personnel Research and Development Center, San Diego, California, January 1979.

Hodge MH, Medical Information Systems: A Resource for Hospitals, Aspen Systems Corp., Germantown, Maryland, 1977.

Hopwood MD, Groner GF, Palley NA et al., An Evaluation of the Clinfo Data Management and Analysis System, Report R-2260-NIH, Rand Corporation Santa Monica, California, November 1977.

Kamp M, Index to Computerized teaching in the Health Sciences, University of California, San Francisco, October 1975.

Kaplan SJ, On the difference between natural language and high level query languages, in Proceedings 1978 Annual Conference, Association for Computing Machinery, New York, 1978, pp 27-38.

Kassirer JP, Gorry GA, Clinical problem solving: a behavioral analysis, Annals of Internal medicine, vol 89, no 2, pp 245-255, August 1978.

Kenton C, Scott YB, MEDLINE Searching and Retrieval, Medical Informatics, vol 3, no 3, pp 225-235, September 1978.

King C, Goldstein L, Strong L, Data base management in medicine and health policy research, in Proceedings of the Fourth Annual Symposium on Computer Applications in Medical Care, IEEE, New York, 1980, pp 997-1006.

Kleinmuntz B, Clinical information processing by computer, in New Directions in Psychology 4, Holt, Rinehart and Winston, New York, 1970, pp 123-210.

Lewis TL, Macks GC, Adaptation of a general hospital computerized medical information system to the research hospital environment, in Proceedings of the First Annual Symposium on Computer Applications in Medical Care, IEEE, New York, 1977, pp 111-115.

Martin WA, Some comments on EQS, a near term natural language data base query system, in Proceedings 1978 Annual Conference, Association for Computing Machinery, New York, 1978, pp 156-164.

McShane DJ, Harlow A, Kraines RG, Fries JF, TOD: a software system for the ARAMIS data bank, Computer, vol 12, no 11, pp 34-40, November 1979.

Miller PB, Strong RM, Clinical care and research using MEDUS/A, a medically oriented data base management system, Proceedings of the Second Annual Symposium on Computer Applications in Medical Care, IEEE, New York, 1978, pp 288-297.



Osserman EF, Katz L, Sherman WH, Putney FB, Computer-based case tracing (COMTRAC), *Journal of the American Medical Association*, vol 239, no 17, pp 1772-1776, April 28 1978.

Okubo RS, Lampson BG, The human interface in natural language retrieval, in *Computational Linguistics in Medicine*, W Schneider, AL Sagvall-Hein (eds.), North Holland, Amsterdam, 1977, pp 65-77.

Pacak MG, Dunham GS, Computers and medical language, *Medical Informatics*, vol 4, no 1, pp 13-27, January 1979.

Palley N, Groner GA, Sibley W, Hopwood M, CLINFO Users Guide: Release one, Report R-1543-1, Rand Corporation, Santa Monica, California, April 1976.

Pauker SG, Gorry GA, Kassirer JP, Schwartz WB, Towards the simulation of clinical cognition: taking a present illness by computer, *American Journal of Medicine*, vol 60, no 7, pp 981-985, June 1976.

Pauker SG, Kassirer J, Clinical application of decision analysis: a detailed illustration, *Seminars in Nuclear Medicine*, vol 8, no 4, pp 324-335, October 1978.

Petrick SR, Automated syntactic and semantic analysis, in *Proceedings of the Conference on Methodological Problems in Automated Text Processing*, J Petofi, S Allen, and DE Walker (eds.), Walter de Gruyter, Berlin, in press

Platt R, Wong R, Lantner K, Gaynon P, POLARS: A pathology on-line logging and reporting system, *Computers and Biomedical Research*, vol 7, no 1, pp 83-99, 1974.

Pople HE, Myers JD, Miller RA, The DIALOG model of diagnostic logic and its use in internal medicine, *Proceedings of the Fourth International Joint Conference on Artificial Intelligence*, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1975, pp 848-855.

Pople HE, The formation of composite hypotheses in diagnostic problem solving: an exercise in semantic reasoning, *Proceedings of the Fifth International Joint Conference on Artificial Intelligence*, Carnegie-Mellon University, Pittsburgh, 1977, pp 1030-1037.

Pratt AW, Medicine, computers, and linguistics, in *Advances in Biomedical Engineering*, vol 3, 1973, Academic Press, New York, pp 97-140.

Rosati RA, McNeer JF, Starmer CF, et al., A new information system for medical practice, *Archives of Internal medicine*, vol 135, pp 1017-1024, August 1975.

Safran C, Desforges JF, Tsihchlis PN, Diagnostic planning and cancer management, Technical Report 169, MIT Laboratory for Computer Science, Cambridge, Mass., September 1976.



Sager N, Hirschman L, Lyman M, Computerized language processing for multiple use of narrative discharge summaries, in Proceedings of the Second Annual Symposium of Computer Applications in Medical Care, IEEE, 1978, pp 330-343.

Schoolman HM, Bernstein LM, Computer use in diagnosis, prognosis, and therapy, Science, vol 200, pp 926-931, May 26 1978.

Scott AC, Clancey WJ, Davis R, Shortliffe EH, Explanation capabilities of production-based consultation systems, American Journal of Computational Linguistics, Microfiche 62, 1977. (also Report No. STAN-CS-77-593, Computer Science Department, Stanford University, Stanford, California, February 1977).

Schwartz WB, Decision analysis: a look at the chief complaint, New England Journal of Medicine, vol 300, no 10, pp 556-559, March 8 1979.

Shneiderman B, Improving the human factors aspect of data base interactions, ACM Transactions on Database Systems, vol 3, no 4, pp 417-439, December 1978.

Shortliffe EH, Buchanan BG, Feigenbaum EA, Knowledge engineering for medical decision making: a review of computer-based clinical decision aids, Proceedings IEEE, vol 67, no 9, pp 1207-1224, September 1979.

Shortliffe EH, Computer Based medical Consultations: MYCIN, Elsevier-North Holland, New York, 1976.

Slamecka V, Camp HN, Badre AN, Hall WD, The Medical Aggregate Record Inquiry System (MARI), Technical report, School of Information and Computer Science, Georgia Institute of Technology, Atlanta, Georgia, January 1979.

Sneider RM, Boyce RE, Tapella CA, The MATRIX data base management system, Computer, vol 12, no 11, pp 28-31, November 1979.

Starmer CF, Rosati RA, A DSS for management of patients with chronic illness, Data Base (Special Interest Group on Business Data Processing), vol 8, no 3, pp 51-57, 1977.

Starmer CF, Rosati RA, McNeer JF, Data base use in management of chronic disease, Computers in Biomedical Research, vol 7, no 2, pp 111-116, April 1974.

Szlovits P, Pauker SG, Categorical and probabilistic reasoning in medical diagnosis, Artificial Intelligence, vol 11, no 1/2, pp 115-144, August 1978.

Teitelman W, INTERLISP reference manual, Xerox Palo Alto Research Center, Palo Alto, California, 1978.

Tennant H, Experience with the evaluation of natural language question answerers, in Proceedings Sixth International Conference on Artificial Intelligence, 1979, pp 874-876.





Thompson BH, Thompson FB, Rapidly extendable natural language, in Proceedings of 1978 Annual Conference, Association for Computing Machinery, New York, 1978, pp 173-182.

Tukey JW, Exploratory Data Analysis, Addison-Wesley, Reading, Massachusetts, 1977.

Walker DE, Automated language processing, in Annual review of Information Science and Technology, volume 8, eds. CA Cuadra, AW Luke, American Society for Information Science, Washington DC, 1973, pp 69-119.

Waltz DL, An english language question answering system for a large relational database, Communications of the ACM, vol 21, no 7, pp 526-539, July 1978.

Weinstein MC, Fineberg HV, Clinical Decision Analysis, WB Saunders, Philadelphia, Pennsylvania, 1980.

Weiss S, Kulikowski CA, Amarel S, Safir A, A model-based method for computer-aided medical decision-making, Artificial Intelligence, vol 11, no 1/2, pp 145-172, August 1978.

Wong RL, Platt R, Baldwin A, Hain T, Experience on a surgical pathology data base and a lexicon compiled from locally derived medical english, Proceedings of the Second Annual Symposium on Computer Applications in Medical Care, IEEE, New York, 1978, pp 314-317.

Woods WA, Transition network grammars for natural language analysis, Communications of the ACM, vol 13, no 10, pp 591-606, October 1970.

Woods WA, Semantics and quantification in natural language question answering, in Advances in Computers, vol 17, ed. M Yovits, Academic Press, New York, 1978, pp 1-87.

Woodyard M. MEDQUEL: Practical natural language comprehension in a medical environment, MS thesis, Department of Computer Science, Vanderbilt University, July 1979.

Wortman PM. Medical Diagnosis: An information processing approach, Computers and Biomedical Research, vol 5, pp 315-328, 1972.

Wortman PM, Kleinmuntz B, The role of memory in information-processing models of problem solving, manuscript, Northwestern University, Evanston, Illinois, 1972.

Wulff HR, Rational Diagnosis and Treatment, Oxford, Blackwell Scientific Publications, 1976.

Zuckerman AE, Stenn HM, A general purpose report generator for the computer stored ambulatory record: A tool for use by physicians to monitor their practice, in Proceedings First Annual Symposium on Computer Applications in Medical Care, IEEE Computer Society, 1977, pp 165-167.



REFERENCES ON MALIGNANT MELANOMA

Ames FC, Sugarbaker EV, Ballantyne AJ, Analysis of survival and disease control in stage 1 melanoma of the head and neck, American Journal of Surgery, vol 132, pp 484-491, October 1976.

Balch CM, Soong SJ, Murad TM, et al., A multifactorial analysis of melanoma. II. Prognostic factors in patients with stage I (localized) melanoma, Surgery, vol 86, no 2, pp 343-351, August 1979.

Balch CM, Wilkenson JA, Murad TM, et al., The prognostic significance of ulceration of cutaneous melanoma, Cancer, vol 45, no 12, pp 3012-3017, June 15 1980.

Breslow A, Thickness, cross-sectional areas and depth of invasion in the prognosis of cutaneous melanoma, Annals of Surgery, vol 172, no 5, pp 902-908, November 1970.

Breslow A, Tumor thickness, level of invasion and node dissection in Stage I cutaneous melanoma, Annals of Surgery, vol 182, no 5, pp 572-575, November 1975.

Breslow A, Cascinelli N, van der Esch EP, Morabito A, Stage I melanoma of the limbs: assessment of prognosis by levels of invasion and maximum thickness, Tumori, vol 64, pp 273-284, 1978.

Clark WH, Goldman LI, Mastrangelo MJ (eds.), Human Malignant Melanoma, Grune and Stratton, New York, 1979.

Clark WH, Mastrangelo MJ, Ainsworth AM, et al., Current concepts of the biology of human cutaneous melanoma, in Advances in Cancer Research, vol 24, eds. G. Klein and S. Weinhouse, Academic Press, New York, 1977, pp 267-338.

Clark WH, From L, Bernardino EA, Mihm MC, The histogenesis and biological behavior of primary human malignant melanoma of the skin, Cancer Research, vol 29, pp 705-726, March 1969.

Clark WH, Schoenfeld RJ, Walton RG, Spotting changes that signal melanoma, Patient Care, August 1974.

Clark WH, Ainsworth AM, Bernardino EA et al., The developmental biology of primary tumor malignant melanoma, Seminars in Oncology, vol 2, no 2, pp 83-103, June 1975.

Cohen MH, Ketcham AS, Felix EL, et al., Prognostic factors in patients undergoing lymphadenectomy for malignant melanoma, Annals of Surgery, vol 186, no 5, pp 632-642, November 1977.

Comis RL, DTIC in malignant melanoma: a perspective, Cancer Treatment Reports, vol 60, no 2, pp 165-176, February 1976.



Cox EB, Laszlo J, Freiman A, Classification of cancer patients beyond TNM, Journal American Medical Association, vol 242, no 24, pp 2691-2695, December 14 1979.

Davis NC, Cutaneous melanoma: The Queensland experience, Current Problems in Surgery, vol 12, no 5, pp 1-63, May 1976.

Drepper H, Lindemann M, Obst D, A new classification of malignant melanoma proposed according to the TNM System, Journal of Cancer Research and Clinical Oncology, vol 96, pp 223-229, 1980.

Eilber FR, Townsend CM, Morton DL, Results of BCG adjuvant immunotherapy for melanoma of the head and neck, American Journal of Surgery, vol 132, pp 476-479, October 1976.

Eldh J, Boeryd B, Peterson LE, Prognostic factors in cutaneous malignant melanoma in Stage I, Scandinavian Journal of Plastic and Reconstructive Surgery, Vol 12, pp 243-255, 1978.

Elwood JM, Lee JAH, Recent data on the epidemiology of malignant melanoma, Seminars in Oncology, vol 2, no 2, pp 149-154, June 1975.

Everall JD, Dowd PM, Diagnosis, prognosis and treatment of melanoma, Lancet, pp 286-289, August 6, 1977.

Gromet MA, Epstein WL, Blois MS, The regressing thin malignant melanoma, Cancer, vol 42, pp 2282-2292, November 1978.

Gutterman JU, Mavligit G, Reed R, et al., Immunology and immunotherapy of human-malignant melanoma: historic review and perspectives for the future, Seminars in Oncology, vol 2 no 2, pp 155-174, June 1975.

Holmes EC, Clark W, Morton DL, Eilber FR, Bochow AJ, Regional lymph node metastases and the level of invasion of the primary melanoma, Cancer, vol 37, no 1, pp 199-201, January 1976.

Kapelanski DP, Block GE, Kaufman M, Characteristics of the primary lesion of malignant melanoma as a guide to prognosis and therapy, Annals of Surgery, vol 189, no 2, pp 225-235, February 1979.

Knutson CO, Hori JM, Spratt JS, Melanoma, Current Problems in Surgery, pp 1-55, December 1971.

Kopf AW, Bart RS, Rodriguez-Sains RS, Ackerman AB, Malignant Melanoma, Masson Publishing USA, New York, 1979.

Mackie RM, Carfue DC, Cochran AJ, Assessment of prognosis in patients with malignant melanoma, Lancet, pp 455-456, September 2, 1972.

Manual for Staging of Cancer 1977, American Joint Committee for Cancer Staging and End Results Reporting, Chicago, Illinois, 1977.

McGovern VJ, Shaw HM, Milton GW, Farago GA, Prognostic significance of the histologic features of malignant melanoma, Cancer, in press, 1980.



McGovern VJ, The classification of melanoma and its relationship with prognosis, Pathology, vol 2, pp 85-98, April 1970.

Mihm MC, Fitzpatrick TB, Brown NM et al., Early detection of primary cutaneous malignant melanoma, New England Journal of Medicine, vol 289, pp 989-996, November 8, 1973.

Polk HC, Linn BS, Selective regional lymphadenectomy for melanoma, a mathematical aid to clinical judgment, Annals of Surgery, vol 174, no 3, pp 402-413, September 1971.

Schmoeckel C, Braun-Falco O, Prognostic index in malignant melanoma, Archives of Dermatology, vol 114, pp 871-873, June 1978.

Sober AJ, Fitzpatrick TB, Mihm MC et al., Early recognition of cutaneous melanoma, Journal American medical Association, vol 242, no 25, pp 2795-2799, December 21, 1979.

Spitler LE, Sagebiel R, A randomized trial of levamisole versus placebo as adjuvant therapy in malignant melanoma, New England Journal of Medicine, vol 303, no 20, pp 1143-1147, November 13, 1980.

Sugarbaker EV, McBride CM, Melanoma of the trunk: the results of surgical excision and anatomic guidelines for predicting nodal metastases, Surgery, vol 80, no 1, pp 22-30, July 1976.

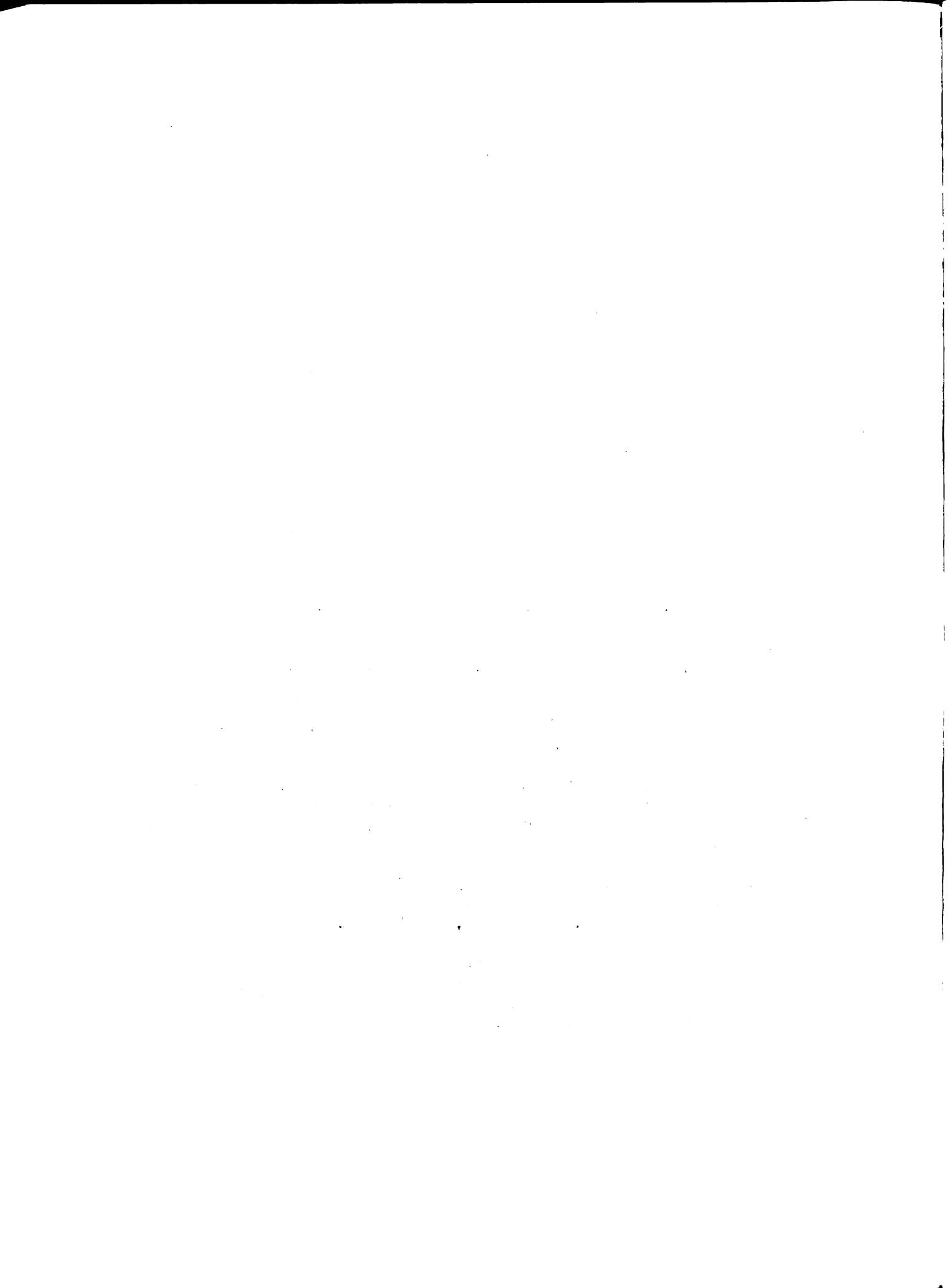
Terry WD, Immunotherapy of malignant melanoma, New England Journal of Medicine, vol 303, no 20, pp 1174-1175, November 13, 1980.

Veronesi U, et al., Inefficacy of immediate node dissection in Stage 1 melanoma of the limbs, New England Journal of Medicine, vol 297, no 12, pp 627-630, September 22, 1977.

Wanebo HJ, Fortner JG, Woodruff J, Maclean B, Binkowski E, Selection of optimal surgical treatment of Stage I melanoma by depth of microinvasion, Annals of Surgery, vol 182, no 3, pp 302-315, September 1975.

Wanebo HJ, Woodruff J, Fortner JG, Malignant melanoma of the extremities: a clinicopathologic study using levels of invasion (microstage), Cancer, vol 35, pp 666-676, March 1975.

Young JL, Asire AJ, Pollack ES (eds.), SEER Program: Cancer incidence and mortality in the United States 1973-1976, Biometry Branch, Division of Cancer Cause and Prevention, National Cancer Institute, DHEW Publication no. (NIH) 78-1837, 1978.





## Appendix A

DATA FORMS USED IN MEDINQUIRY

This appendix includes the forms used to collect the data for the prototype MEDINQUIRY system. On the clinical form (Appendix A.1), the attributes included in the prototype MEDINQUIRY system are starred. The other attributes were not included in the prototype data base for the reasons discussed in Section 4.1. The data for initial therapy (Appendix A.2) were extracted from the original initial therapy form, while the follow up data were completely redone using the form in Appendix A.4. The pathology form was redesigned for use in this study and all the pathology data were collected on this form included in Appendix A.3.

**A.1 Clinical Form**

Card No.  
6

Form No.

**MELANOMA CLINICAL COOPERATIVE GROUP  
CLINICAL FORM ON PRIMARY TUMOR  
(Supported by the National Institutes of Health)**

FORM FILLED IN BY \_\_\_\_\_

(Please Print)

**HISTORY: I. PERSONAL DATA**

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<p><b>PATIENT'S ADDRESS</b></p> <p>Street _____</p> <p>City _____ State _____ Zip Code _____</p>	<p><b>PATIENT'S TELEPHONE NO.</b></p> <p>Area Code _____ Number _____</p>																																																																				
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39	40	41	42	43	44																																																																
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Card No.  
6

Form No.   
1 2 3 4 5

**HISTORY: II. FAMILY DATA**

**FAMILY PHYSICAL CHARACTERISTICS:**

**HOW MANY GRANDPARENTS ARE KNOWN TO HAVE:** (Record number 0 to 4)

Yes	No	Unknown	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Blond Hair
7	8	9	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Red Hair
10	11	12	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Freckles
13	14	15	

**HOW MANY PARENTS ARE KNOWN TO HAVE:** (Record number 0 to 2)

	Yes	No	Unknown
Blond Hair	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	16	17	18
Red Hair	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	19	20	21
Freckles	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	22	23	24

**HOW MANY SIBLINGS DO YOU HAVE?**

25 26

**HOW MANY SIBLINGS ARE KNOWN TO HAVE:**

<input type="text" value=""/> <input type="text" value=""/>	Blond Hair
27 28	
<input type="text" value=""/> <input type="text" value=""/>	Red Hair
29 30	
<input type="text" value=""/> <input type="text" value=""/>	Freckles
31 32	

**HOW MANY CHILDREN DO YOU HAVE?**

33 34

**HOW MANY CHILDREN HAVE:**

Blond Hair	<input type="text" value=""/> <input type="text" value=""/>
	35 36
Red Hair	<input type="text" value=""/> <input type="text" value=""/>
	37 38
Freckles	<input type="text" value=""/> <input type="text" value=""/>
	39 40

**FAMILY HISTORY OF DISEASE:**

- |               |                 |
|---------------|-----------------|
| 1 Yes         | 5 More than one |
| 2 No          | 8 Other         |
| 3 No siblings | 9 Unknown       |
| 4 No children |                 |

	Vitiligo	Any other pigmentary disturbance (state)	Melanoma	A malignant skin tumor (state)	Any other malignant tumors (specify)
* Did your father ever have:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	41	42	43	44	45
* Did your mother ever have:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	46	47	48	49	50
* Has any sibling ever had:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	51	52	53	54	55
* Has any child ever had:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	56	57	58	59	60

\* HAVE ANY OTHER BLOOD RELATIONS EVER HAD MELANOMA?

1 Yes    3 Uncertain    9 Unknown  
61    2 No    8 Other \_\_\_\_\_ If yes or uncertain, state \_\_\_\_\_

IF ANY RELATIVES HAD MELANOMA, AT WHAT HOSPITAL(S) WAS IT TREATED (Name and Address)?

\_\_\_\_\_  
\_\_\_\_\_

3 Card No.  
6

Form No       
1 2 3 4 5

**HISTORY: III. PATIENT'S BACKGROUND**

<p><b>BIRTHPLACE</b></p> <p>_____</p>	<p><b>PLACES LIVED IN (Greater than 2 years)      DURATION</b></p> <p>_____</p> <p>_____</p> <p>_____</p> <p>(Continue on Supplemental Sheet)</p>
<p><b>WHERE ARE (WERE) YOU WHEN YOU PERFORM(ED) YOUR DOMINANT LIFETIME JOB?</b></p> <p><input type="checkbox"/> 7</p> <p>1 Mostly indoors 2 Mostly outdoors 3 Half indoors and half outdoors 8 Other _____ 9 Unknown</p>	<p><b>WHERE ARE YOU WHEN YOU ENGAGE IN RECREATIONS?</b></p> <p><input type="checkbox"/> 8</p> <p>1 Mostly indoors 2 Mostly outdoors 3 Half indoors and half outdoors 8 Other _____ 9 Unknown</p>
<p><b>* SUNBURN</b></p> <p><input type="checkbox"/> 9</p> <p>1 Rarely in sun 2 Practically none 3 Some redness only 4 Moderate burn 5 Painful burn 8 Other _____ 9 Unknown</p>	<p><b>* TAN</b></p> <p><input type="checkbox"/> 10</p> <p>1 Practically none 2 Light tan 3 Average tan 4 Deep tan 8 Other _____ 9 Unknown</p>
<p><b>* PATIENT SUN EXPOSURE</b></p> <p><input type="checkbox"/> 11</p> <p>1 Practically none 2 Little 3 Moderate 4 Much 8 Other _____ 9 Unknown</p>	<p><b>* LESION SUN EXPOSURE</b></p> <p><input type="checkbox"/> 12</p> <p>1 Practically none 2 Little 3 Moderate 4 Much 8 Other _____ 9 Unknown</p>

**HISTORY OF SKIN DISEASES**

**MELANOCYtic DISORDERS**

**NON-MELANOCYtic DISORDERS**

Answers: 1 Yes 2 No 3 Uncertain 8 Other 9 Unknown

Have you ever had:

- 13 \* Freckle
- 14 \* Vitiligo
- 15 \* Giant Hairy or "Garment" Nevus
- 16 \* Any other congenital nevus
- 17 \* Previous melanoma
- 18 \* Other pigmented lesion  
State \_\_\_\_\_

Have you ever had:

- 19 \* Basal Cell Carcinoma
- 20 \* Squamous Cell Carcinoma
- 21 \* Other Skin Cancer; Type, if known \_\_\_\_\_
- 22 \* Solar Keratosis
- 23 \* Cancer other than skin  
Site \_\_\_\_\_
- 24 Other \_\_\_\_\_

Card No.

Form No.

**HISTORY: III. PATIENT'S BACKGROUND (Continued)**

WHEN DID YOU LAST HAVE A GENERAL MEDICAL EXAMINATION?

years  months ago State reason \_\_\_\_\_

HOW MANY TIMES HAVE YOU BEEN PREGNANT? (GRAVIDA)?

HOW MANY CHILDREN HAVE RESULTED (PARA)?

\* MENSTRUAL STATUS

33  
 1 Premenstrual  
 2 Menstrual  
 3 Menopausal  
 4 Postmenopausal  
 8 Other \_\_\_\_\_  
 9 Unknown

BIRTHDATE OF OLDEST CHILD \_\_\_\_\_

BIRTHDATE OF YOUNGEST CHILD \_\_\_\_\_

\* HAVE YOU EVER TAKEN ORAL CONTRACEPTIVES (BIRTH CONTROL PILLS)?  35

1 Yes 8 Other \_\_\_\_\_  
 2 No 9 Unknown

\* DURING THE YEAR PRIOR TO THE TIME YOU BECAME AWARE OF THE LESION OR THE TIME YOU FIRST NOTED CHANGE IN IT WERE YOU PREGNANT, OR DID YOU TAKE ORAL CONTRACEPTIVES OR ESTROGEN?

34  
 1 Yes 8 Other \_\_\_\_\_  
 2 No 9 Unknown

Age started \_\_\_\_\_ Age stopped \_\_\_\_\_

Total duration of use.

years  months  
 36 37 38 39

ENDOCRINE

\* HAVE YOU HAD GONADAL SURGERY (OOPHORECTOMY - FEMALES) (ORCHIECTOMY - MALES)?

40  
 1 Yes 8 Other \_\_\_\_\_  
 2 No 9 Unknown

HAVE YOU EVER TAKEN THE FOLLOWING HORMONES.

1 Yes 8 Other  
 2 No 9 Unknown  
 41 \* Estrogens (Female hormone)  
 42 \* Androgens (Male hormone)  
 43 \* Steroids (Cortisone)  
 44 \* Thyroid  
 45 Other hormone \_\_\_\_\_

HAVE YOU TAKEN THE FOLLOWING MEDICATIONS:

1 Yes 8 Other  
 2 No 9 Unknown  
 L-DOPA  46  
 Psoralens  47  
 Sulfonamides, thiazide diuretics, or other sulfa derivative  48  
 \* Phenothiazines (Major tranquilizers)  49  
 Immunosuppressives  50  
 \* Other medications  51

Card No.  
6

Form No.   
1 2 3 4 5

**HISTORY: IV. PRIMARY LESION**

\* PRE-EXISTENT LESION

7  
1 Yes  
2 No  
8 Other \_\_\_\_\_  
9 Unknown \_\_\_\_\_  
Describe \_\_\_\_\_  
\_\_\_\_\_

DURATION OF MELANOMA

and/or   
8 9 10 11  
Years Months

If pre-existing lesion, time from first change.  
If de novo, time from first awareness.

\* COLORS OF SUSPICIOUS LESION WHEN FIRST NOTED (dominant color in top box)

12 1 Red  
2 Blue  
3 Black  
4 Brown  
 13 5 Tan  
6 Grey  
7 White  
 14 8 Other \_\_\_\_\_  
9 Unknown \_\_\_\_\_

\* SIZE (largest diameter) WHEN FIRST NOTED

15 1 Pinhead  
2 Pencil eraser  
3 Dime  
4 Nickel  
5 Quarter  
6 Half dollar  
7 Larger than half dollar  
8 Other \_\_\_\_\_  
9 Unknown \_\_\_\_\_

\* ELEVATION WHEN FIRST NOTED

16 1 Flat  
2 Elevated  
3 Both  
8 Other \_\_\_\_\_  
9 Unknown \_\_\_\_\_

\* DID THE LESION HAVE EXCESS HAIR?

17 1 Yes  
2 No  
8 Other \_\_\_\_\_  
9 Unknown \_\_\_\_\_

DID THE PATIENT CONSIDER THE LESION UGLY?

18 1 Yes  
2 No  
8 Other \_\_\_\_\_  
9 Unknown \_\_\_\_\_

CAN THE PATIENT BRING IN ANY OLD PHOTOGRAPHS WHICH VISUALIZE THE SITE OF LESION?

19 1 Yes  
2 No  
8 Other \_\_\_\_\_  
9 Unknown \_\_\_\_\_

4 Card No.

Form No.

**HISTORY: IV. PRIMARY LESION (Continued)**

\* WAS THERE ANY CHANGE IN THE LESION SINCE THE TIME OF FIRST APPEARANCE?

<input type="checkbox"/>	1 Yes	8 Other _____	* Months Since Change First Noted
20	2 No	9 Unknown	
	3 Uncertain		
			REMARKS
<input type="checkbox"/>	* SIZE	1 Increase	8 Other _____
21		2 No change	9 Unknown
		3 Decrease	<input type="checkbox"/> <input type="checkbox"/>
			22 23
<input type="checkbox"/>	* ELEVATION	1 Increase	8 Other _____
24		2 No change	9 Unknown
		3 Decrease	<input type="checkbox"/> <input type="checkbox"/>
			25 26
<input type="checkbox"/>	* COLOR	1 Yes	8 Other _____
27		2 No	9 Unknown
			<input type="checkbox"/> <input type="checkbox"/>
			28 29
<input type="checkbox"/>	* BLEEDING	1 Yes	8 Other _____
30		2 No	9 Unknown
			<input type="checkbox"/> <input type="checkbox"/>
			31 32
<input type="checkbox"/>	* ULCERATION	1 Yes	8 Other _____
33		2 No	9 Unknown
			<input type="checkbox"/> <input type="checkbox"/>
			34 35
<input type="checkbox"/>	* ITCHING	1 Yes	8 Other _____
36		2 No	9 Unknown
			<input type="checkbox"/> <input type="checkbox"/>
			37 38
<input type="checkbox"/>	* TENDERNESS	1 Yes	8 Other _____
39		2 No	9 Unknown
			<input type="checkbox"/> <input type="checkbox"/>
			40 41

\* HAS THERE BEEN ANY TRAUMA TO THE SITE OF THE PRIMARY LESION?

42

1 Yes, once  
 2 Yes, more than once  
 3 Chronic \_\_\_\_\_  
 4 None  
 8 Other \_\_\_\_\_  
 9 Unknown

PATIENT ACCURACY

43

1 Good  
 2 Average  
 3 Fair  
 8 Other \_\_\_\_\_  
 9 Unknown

HOW WAS LESION FIRST DISCOVERED?

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

HOW DID THE PATIENT ENTER THE STUDY?

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

\* IN THE EXAMINER'S OPINION, AFTER CAREFUL QUESTIONING ABOUT A PRE-EXISTING LESION, ITS NATURE AND DURATION, THE MELANOMA AROSE

44

1 In association with a mole  
 2 From a Hutchinson's melanotic freckle  
 3 De novo  
 4 Cannot determine  
 8 Other \_\_\_\_\_  
 9 Unknown

Remarks: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Card No.  
6

Form No.

**PHYSICAL EXAMINATION: I. PRIMARY LESION**

LOCATION OF LESION  
(refer to Lesion Location Form)

State: \_\_\_\_\_

SKETCH OF LESION  
Surface from Above

Cross Section at Point of  
Highest Elevation

1. Primary Seen  
 2. Previously Excised  
Date of Excision \_\_\_\_\_

LESION SHAPE (Viewed from Above)

1 Disciform



2 Annular (ring shaped)



3 Arciform



4 Reniform (kidney shaped)



5 Irregular

6 Completely excised

8 Other \_\_\_\_\_

9 Unknown

\* SIZE

•  cm X   •  cm

\* ELEVATION (if measureable; flat = 0)

mm

\* BORDER REGULARITY

- 1 Regular
- 2 Moderately irregular
- 3 Very irregular
- 8 Other \_\_\_\_\_
- 9 Unknown

\* BORDER ELEVATION

- 1 Elevated – visible only
- 2 Elevated – palpable only
- 3 Elevated – visible and palpable
- 4 Flat
- 5 Indeterminate
- 8 Other \_\_\_\_\_
- 9 Unknown

\* TOPOGRAPHY

- 1 Flat
  - 2 Papular
  - 3 Flat-papular
  - 4 Plaque-like
  - 5 Nodular
  - 6 Sessile
  - 7 Pedunculated
  - 8 Other \_\_\_\_\_
  - 9 Unknown
- If there is more than one pattern, list predominant pattern first.



5 Card No.

Form No.

**PHYSICAL EXAMINATION: I. PRIMARY LESION (Continued)**

**SURFACE CHARACTERISTICS:**

Answers: 1 Yes 2 No 8 Other \_\_\_\_\_ 9 Unknown

\* Ulcerated  
27

\* Verrucous  
28

\* Hair  
29

\* Scaly  
30

\* Smooth  
31

\* Excess Hair  
32

**Skin Markings**

33  
1 Present throughout  
2 Absent throughout  
3 Absent in any part

8 Other \_\_\_\_\_  
9 Unknown

**COLOR: Answer for each color (avoid fluorescent light)**

Answers:

- \* 1 Most dominant color
- \* 2 Second most dominant (if > 25%)
- \* 3 Third most dominant (if > 25%)

- 4 Present, but less than 25%
- 5 Absent
- 8 Other
- 9 Unknown

Red  
34

Grey  
35

Brown  
36

White  
37

Blue  
38

Black  
39

Light Brown  
40

**\* COLOR PATTERN**

41  
1 Uniform  
2 Variegated  
8 Other \_\_\_\_\_  
9 Unknown

**\* ERYTHEMATOUS HALO**

1 Present, complete  42  
2 Present, partial  
3 Absent  
8 Other \_\_\_\_\_  
9 Unknown

**\* HYPOPIGMENTED HALO**

43  
1 Regular  
2 Irregular  
3 Absent  
8 Other \_\_\_\_\_  
9 Unknown

**EXAMINED WITH WOOD'S LIGHT**

1 Yes  
2 No  45  
8 Other \_\_\_\_\_  
9 Unknown

44  
1 Concentric  
2 Eccentric  
3 Absent  
8 Other \_\_\_\_\_  
9 Unknown

**HYPOPIGMENTATION AWAY FROM LESION SITE**

1 Yes, State (size, shape, location):  46  
2 No \_\_\_\_\_  
8 Other \_\_\_\_\_  
9 Unknown

**\* SATELLITES (Any suspicious (palpable or visible) cutaneous lesion with 5 cm of border of lesion).**

47  
1 Yes, State \_\_\_\_\_  
2 No  
8 Other \_\_\_\_\_  
9 Unknown

**\* MULTIPLE PRIMARIES**

1 Yes  50  
2 Suspicious  
3 No  
8 Other \_\_\_\_\_  
9 Unknown

↓ How many?  
48 49

If yes, fill out history, physical, and pathology forms for each lesion.

6  
6

Card No.

Form No.

1	2	3	4	5
---	---	---	---	---

**PHYSICAL EXAMINATION: II. PATIENT**

**WEIGHT**

7	8	9

lbs.

**HEIGHT**

10	11 12
Feet	Inches

\* **HAIR COLOR (as young adult)**

- 1 Blond
- 2 Red
- 3 Light Brown
- 4 Brown
- 5 Black
- 8 Other \_\_\_\_\_
- 9 Unknown

13
----

\* **EYE COLOR**

14
----

- 1 Blue
- 2 Green
- 3 Grey
- 4 Light Brown
- 5 Dark Brown
- 6 Black
- 8 Other \_\_\_\_\_
- 9 Unknown

\* **SKIN COLOR (Unexposed buttock)**

- 1 Pale
- 2 Medium
- 3 Dark
- 8 Other \_\_\_\_\_
- 9 Unknown

15
----

\* **FRECKLING**

16
----

- 1 None
- 2 One to 25
- 3 26 to 100
- 4 More than 100
- 8 Other \_\_\_\_\_
- 9 Unknown

\* **MOLE COUNT (estimated)**

- 1 None
- 2 One to 25
- 3 26 to 100
- 4 More than 100
- 8 Other \_\_\_\_\_
- 9 Unknown

18
----

**EXAMINED WITH WOOD'S LIGHT**

17
----

- 1 Yes
- 2 No
- 8 Other \_\_\_\_\_
- 9 Unknown

\* **SOLAR DAMAGE AT LESION SITE (As evidenced by solar keratoses, telangiectasis, wrinkling, yellow papules, solar lentigo)**

- 1 Absent
- 2 Moderate
- 3 Severe
- 8 Other \_\_\_\_\_
- 9 Unknown

19
----

**TUMOR SPREAD:**

**DISTANT METASTASES:**

20
----

\* Liver

21
----

\* Spleen

22
----

\* Skin metastases

23
----

\* Other \_\_\_\_\_

**Answers:**

- 1 Positive
- 2 Suspicious
- 3 Clinically negative
- 8 Other \_\_\_\_\_
- 9 Unknown

\* **IN TRANSIT TYPE: (Cutaneous, subcutaneous nodules between primary site and regional nodes and 5 or more cm from primary tumor)**

- 1 Present
- 2 Absent
- 3 Uncertain
- 8 Other \_\_\_\_\_
- 9 Unknown

24
----

\* **REGIONAL LYMPH NODES:**

- 1 Clinically positive
- 2 Suspicious
- 3 Clinically negative
- 8 Other \_\_\_\_\_
- 9 Unknown

25
----

A.2 Initial Therapy Record

## Type of Initial Biopsy Procedure

1. None
2. Punch
3. Incisional
4. Excisional, close margins
5. Excisional, wide margins
6. Other \_\_\_\_\_
7. Unknown

## Type from Biopsy

1. LMM
2. SSM
3. NM
4. Indeterminate
5. Malignant Melanoma
6. Metastatic
7. Other

## Level from Biopsy

1. I
2. II
3. III
4. IV
5. V
6. Other \_\_\_\_\_
7. Unknown

Date Of Initial Definitive  
Therapy of Primary Lesion ... ..  
mo da yr

## Type of Initial Definitive Therapy

1. No treatment, primary known
2. No treatment, primary unknown
3. Punch biopsy only (tumor not removed)
4. Incisional biopsy only (tumor not removed)
5. Tumor partially removed (some tumor remains)
6. Excision without graft (include total excisional biopsy)
7. Excision with flap
8. Excision with split thickness skin graft
9. Excision with full thickness skin graft



10. Partial amputation of digit
11. Amputation of entire digit
12. Partial or total limb amputation
13. Fore or hind quarter amputation

Initial Definitive Treatment of Primary Lesion

1. At MCCG institution
2. At another institution
3. Other
4. Unknown

Did the Initial Definitive Excision  
Specimen Contain Tumor

1. No
2. Yes
3. No definitive excision
4. Other
5. Unknown

Distance from Tumor Edge to Resection Edge  
At Time of Initial Definitive Treatment \_\_\_\_\_ mm.

Definitive Diagnostic Type

1. LMM
2. SSM
3. NM
4. Indeterminate
5. Malignant melanoma
6. No residual tumor
7. Metastases
8. Other
9. Unknown

Definitive Diagnostic level

1. I
2. II
3. III
4. IV
5. V
6. Other
7. Unknown

Immunotherapy at Time of Initial Therapy and/or Lymph Node  
Dissection Within First Two Months

1. No
2. Yes
3. Other \_\_\_\_\_
4. Unknown

A.3 Pathology Data Form

Patient Name

Surgical Pathology Number

Hospital Unit Number

MCCG Number

Age

Sex

Date of Biopsy of Primary Lesion

Site of Primary

Head & Neck	Front	Back	Thigh	Foot	Arm & Hand	Calf
Other _____		Modifier _____				

Type    SSM        NM        LMM    UNCLASSIFIED

Level    II    III    IV    V

Tumor Thickness \_\_\_\_\_ mm.

Mitotic Rate            Few        Moderate        Many        NS

Cell Type	Nevoid small	Nevoid large	Pagetoid
	Spindle	Pleomorphic	Mixed
	NS		

Risk Factor            LRP        IRP        HRP        Indeterminate

Clonism                Mono        Poly        Unclear    NS

Regression            Present        Absent        NS

Lymphocytes            Few        Moderate        Many        Incomplete

Macrophages            Few        Moderate        Many

Angioneogenesis        Absent        Moderate        Prominent    NS

Plasma-cells            Absent        Moderate        Prominent    NS

Nevus                    Present        Absent        NS







## Appendix B

CLASSIFICATION SYSTEMS FOR MALIGNANT MELANOMAB.1 Staging System For Malignant Melanoma

## Stage I

## Local Disease

- Stage IA Primary lesion alone  
 IB Primary and satellites within 5 cm.  
 IC Local recurrence within 5 cm. of primary site  
 ID Spread more than 5 cm. from primary site but within primary lymphatic drainage area  
 IE Possible regional lymph node involvement; clinically positive, histology not done  
 IF Regional nodes histologically negative

## Stage II

Nodal Disease  
(regional draining nodes)

- Stage IIA Probable regional lymph node involvement; clinically positive, histology not done  
 IIB Regional lymph nodes; clinically negative, histology positive  
 IIC Regional lymph nodes; clinically positive, histology positive

## Stage III

## Disseminated Disease

- Stage IIIA Remote cutaneous/subcutaneous melanoma  
 IIIB Remote nodal involvement only  
 IIIC Both Stage IIIA and Stage IIIB  
 IIID Visceral spread

Note that for visceral spread, supporting evidence may be either clinical (derived from physical examination, x-ray, or tomograms) or histologic.



**B.2 TNM Classification for Malignant Melanoma****T- Primary Tumor**

T1: level 2 and/or tumor thickness less than .75 mm.

T2: level 3 and/or tumor thickness .75 to 1.5 mm.

T3: level 4 and/or tumor thickness 1.51. to 3.0 mm.

T4: level 5 and/or tumor thickness greater than 3.0 mm.

T1a, T2a, T3a or T4a: satellites within immediate or regional area  
of the primary

T2a, T2b, T3b or T4b: intransit metastases directed toward primary  
lymph node draining basin

**N- Regional Lymph Nodes**

N0: No regional lymph node involvement

N1: Regional lymph node involvement of regional draining nodes

N2: Lymph node involvement other than regional draining nodes

**M- Distant Metastases**

M0: No distant metastases

M1: metastases to skin only

M2: visceral metastases

## Appendix C

DATA ATTRIBUTES IN PROTOTYPE MELANOMA DATA BASE

AGE (AT DIAGNOSIS)  
ANDROGENS  
ANGIONEogenesis  
AVERAGE LESION SIZE (CM.)

BASAL CELL CARCINOMA  
BIOPSY TYPE  
BIOPSY LEVEL  
BIOPSY DATE  
BLEEDING OF LESION  
BLOOD RELATIVES MELANOMA  
BORDER REGULARITY  
BORDER ELEVATION

CELL TYPE  
CHANGE IN SIZE OF LESION  
CHANGE IN ELEVATION OF LESION  
CHANGE IN COLOR OF LESION  
CHANGE IN LESION  
CHILD VITILIGO  
CHILD OTHER PIGMENTARY DISEASES  
CHILD OTHER MALIGNANT TUMOR  
CHILD MELANOMA  
CHILD MALIGNANT SKIN TUMOR  
CLINICAL STATUS OF NODES  
CLONISM  
COLOR PATTERN  
COLORS FIRST NOTED

DEFINITIVE PATHOLOGICAL TYPE  
DEFINITIVE PATHOLOGICAL LEVEL  
DEFINITIVE TREATMENT TYPE  
DEFINITIVE TREATMENT LEVEL  
DIAGNOSTIC TYPE (FROM BIOPSY)  
DIAGNOSTIC LEVEL (FROM BIOPSY)  
DOMINANT COLOR

ELEVATION- FIRST NOTED  
ERYTHEMATOUS HALO  
ESTROGENS  
EXCESS SURFACE HAIR  
EXCESS HAIR  
EYE COLOR

FATHER VITILIGO  
FATHER OTHER PIGMENTARY DISEASES  
FATHER OTHER MALIGNANT TUMOR

FATHER MELANOMA  
FATHER MALIGNANT SKIN TUMOR  
FOLLOW UP DATES  
FRECKLES

GIANT HAIRY NEVUS OR GARMENT NEVUS  
GONADAL SURGERY

HAIR COLOR  
HYPOPIGMENTED HALO CONTINUITY  
HYPOPIGMENTED HALO CONCENTRICITY

ID  
IMMUNOTHERAPY  
INITIAL THERAPY FORM  
INITIAL THERAPY  
INITIAL BIOPSY PROCEDURE  
INITIAL THERAPY DATE  
INTRANSIT MELANOMA  
ITCHING OF LESION

LESION SUN EXPOSURE  
LESION ELEVATION (MM.)  
LEVEL  
LIVER METASTASES  
LN PROCEDURE DATE  
LNP TYPE

MENSTRUAL STATUS  
MITOSES  
MONTHS SINCE INITIAL THERAPY  
MOTHER VITILIGO  
MOTHER OTHER PIGMENTARY DISEASES  
MOTHER OTHER MALIGNANT TUMOR  
MOTHER MELANOMA  
MOTHER MALIGNANT SKIN TUMOR  
MULTIPLE PRIMARIES

NEVUS  
NUMBER OF SATELLITES  
NUMBER OF MOLES  
NUMBER OF FRECKLES  
NUMBER OF LYMPH NODE PROCEDURES  
NUMBER OF MONTHS- ULCERATION  
NUMBER OF MONTHS- TENDERNESS  
NUMBER OF MONTHS- CHANGE IN SIZE  
NUMBER OF MONTHS- ITCHING  
NUMBER OF MONTHS- ELEVATION CHANGE  
NUMBER OF MONTHS- COLOR CHANGE  
NUMBER OF MONTHS- BLEEDING  
NUMBER OF MACROPHAGES  
NUMBER OF LYMPHOCYTES  
NUMBER OF LYMPH NODES POSITIVE  
NUMBER OF LYMPH NODES FOUND

ORAL CONTRACEPTIVE  
ORIGIN OF PRIMARY  
OTHER SKIN CANCER  
OTHER PIGMENTED LESION  
OTHER METASTATIC DISEASE  
OTHER MEDICATIONS  
OTHER CONGENITAL NEVUS  
OTHER CANCER

PATHOLOGIC STAGE  
PATIENT SUN EXPOSURE  
PHENOTHIAZINES  
PLACE FOR DEFINITIVE TREATMENT OF PRIMARY  
PLASMA CELLS  
PRE-EXISTING LESION  
PREGNANT OR TOOK ORAL CONTRACEPTIVES  
PREVIOUS MELANOMA  
PRIOR THERAPY

REGRESSION OF THE PRIMARY  
RELATIVE VITILIGO  
RELATIVE OTHER PIGMENTARY DISEASES  
RELATIVE OTHER MALIGNANT TUMOR  
RELATIVE MELANOMA  
RELATIVE MALIGNANT SKIN TUMOR  
RESECTION MARGIN  
RISK FACTOR

SATELLITES  
SCALY SURFACE  
SECOND DOMINANT COLOR  
SEX  
SIBLING VITILIGO  
SIBLING OTHER PIGMENTARY DISEASES  
SIBLING OTHER MALIGNANT TUMOR  
SIBLING MELANOMA  
SIBLING MALIGNANT SKIN TUMOR  
SITE OF PRIMARY  
SITE OF LYMPH NODE PROCEDURE  
SIZE (LARGEST DIAMETER) WHEN FIRST NOTED  
SKIN METASTASES  
SKIN MARKINGS  
SKIN COLOR (UNEXPOSED BUTTOCK)  
SMOOTH SURFACE  
SOLAR KERATOSIS  
SPLEEN METASTASES  
SQUAMOUS CELL CARCINOMA  
STATUS  
STEROIDS  
STUDY POPULATION  
SOLAR DAMAGE (AT LESION SITE)  
SUNBURN  
SURFACE HAIR  
SURGICAL PATH NUMBER

TAN  
TENDERNESS OF LESION  
THERAPY SUGGESTED  
THIRD DOMINANT COLOR  
THYROID  
TIME TO NEXT VISIT (MONTHS)  
TOPOGRAPHY  
TRAUMA TO SITE OF LESION  
TUMOR PRESENT  
TUMOR THICKNESS (MM.)  
TYPE

ULCERATED SURFACE  
ULCERATION OF LESION

VERRUCOUS SURFACE  
VITILIGO



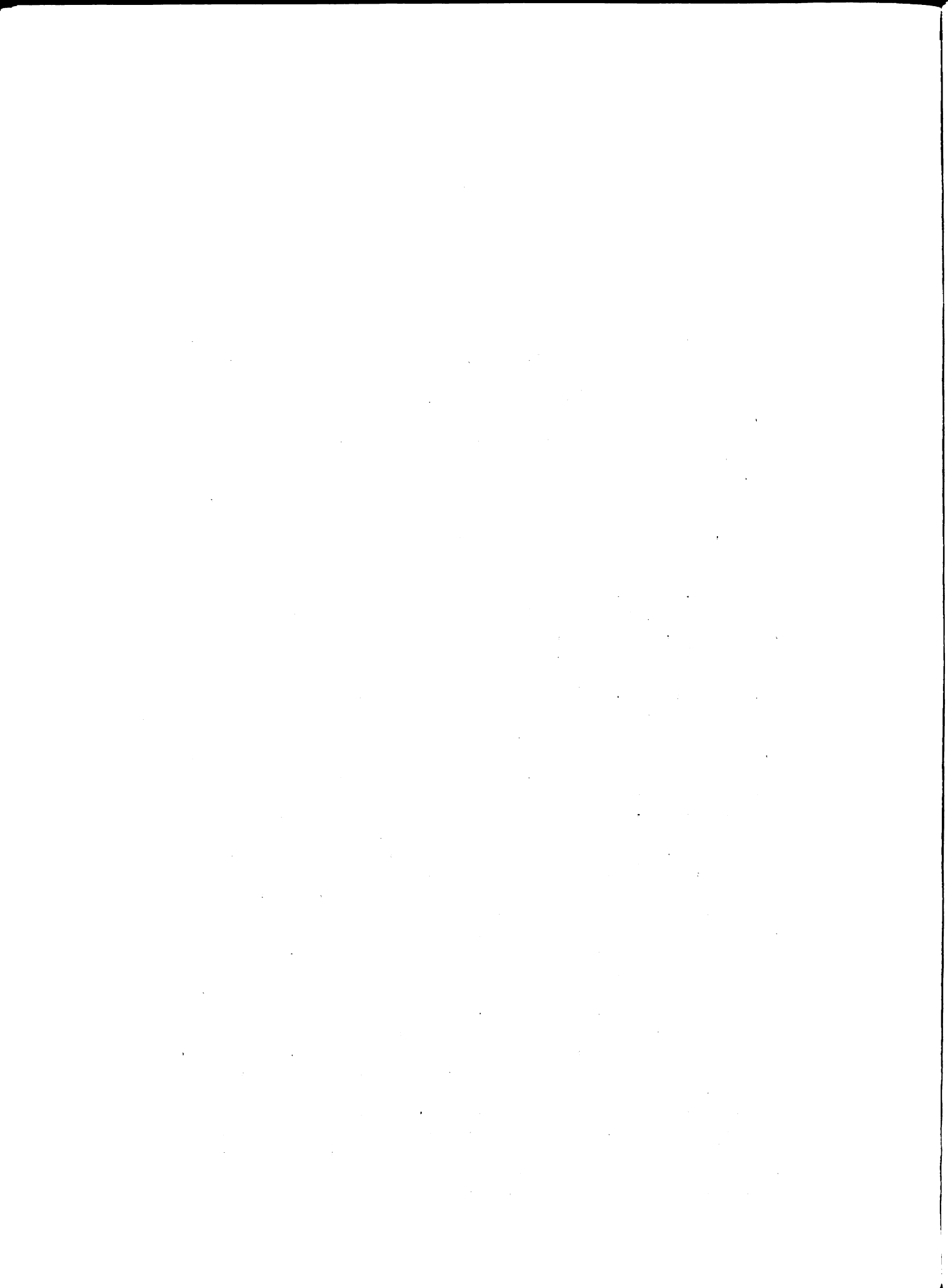
## Appendix D

ITEMS IN APPLICATION VOCABULARY AND WORD CLASSES IN GRAMMAR

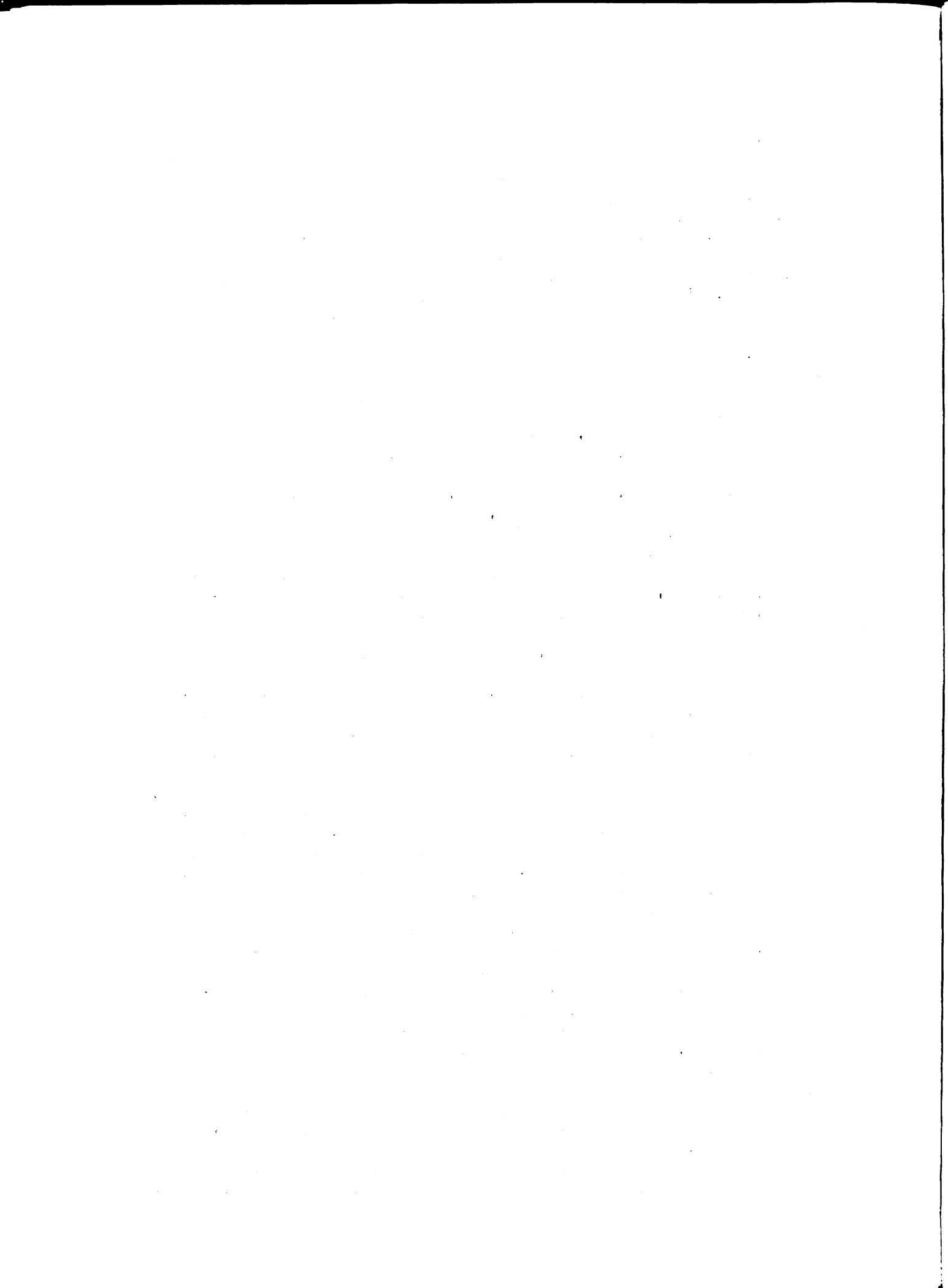
The number of unique types in the application vocabulary is 866.

The items are:

%, &, +, -, 1-25, 1A, 1B, 1C, 1D, 1F, 1ST, 26-100, 2A, 2B, 2C, 2ND, 3A, 3B, 3C, 3D, 3RD, 4TH, 5TH, <, =, >, A, ABOUT, ABSENCE, ABSENT, ACCEPTABLE, ACTIVITY, ADMISSIBLE, ADVISED, AFTER, AGE, AGENTS, AGES, ALL, AMOUNT, AMPUTATION, AMT, AN, ANATOMIC, ANATOMICAL, AND, ANDROGEN, ANDROGENS, ANGIOGENESIS, ANOTHER, ANY, APPEARANCE, APPEARED, APPEARING, APPLIED, ARE, AREAS, ARISE, ARISING, ARM, AROSE, ARRANGE, ARRANGED, AS, ASSIGNED, ASSOCIATED, ASSOCIATION, AT, ATTRIBUTE, ATTRIBUTES, AVAILABLE, AVAILED, AVERAGE, AXILLARY, BACK, BACKGROUND, BASAL, BASE, BE, BEEN, BEFORE, BEHIND, BETWEEN, BIOPSIES, BIOPSY, BIRTH, BLACK, BLED, BLEEDING, BLOND, BLOOD, BLUE, BODY, BORDER, BORDERS, BOTH, BREAK, BROKEN, BROWN, BURN, BUT, BX, BY, CA, CALCULATE, CALF, CAN, CANCER, CARCINOMA, CASE, CASES, CELL, CELLS, CELLULAR, CERVICAL, CHANGE, CHANGES, CHARACTERISTICS, CHARACTERIZED, CHARACTERIZING, CHEMOTHERAPY, CHEMOTHERAPEUTIC, CHILD, CHILDBEARING, CHILDREN, CHRONIC, CITE, CLASSES, CLASSIFIED, CLINICAL, CLINICAL-PATHOLOGIC, CLINICALLY, CLINICO, CLONAL, CLONISM, CLOSE, CM, COLLECTED, COLOR, COLORS, COMMENTS, COMPLETE, COMPUTE, COMPUTER, CONCENTRIC, CONCERNING, CONFIRMED, CONGENITAL, CONTRACEPTIVE, CONTRACEPTIVES, CONTROL, COUNT, COURSE, CURRENTLY, CUTANEOUS, DAMAGE, DARK, DATA, DATABANK, DATABASE, DATE, DATES, DB, DE, DEAD, DECREASE, DEEP, DEFINE, DEFINED, DEFINITE, DEFINITION, DEFINITIVE, DEGREE, DEMONSTRATE, DEMONSTRATED, DEMONSTRATING, DENOVO, DEPTH, DESCRIBE, DESCRIBED, DESCRIPTION, DETERMINE, DIAGNOSIS, DIAGNOSTIC, DIAMETER, DID, DIED, DIGIT, DIME, DISEASE, DISORDER, DISORDERS, DISPLAY, DISPLAYED, DISSECTION, DISSECTIONS, DISSEMINATED, DISTANCE, DISTRIBUTION, DO, DOD, DOES, DOLLAR, DOMINANT, DONE, DOWN, DRUGS, DURATION, DURING, EACH, ECCENTRIC, EDGE, EFFECT, ELAPSED, ELECTIVE, ELEMENTS, ELEVATED, ELEVATION, ELIMINATE, ELND, ELNP, EMPLOYED, ENCOUNTERS, END, ENGLISH, ENTIRE, ENTITIES, ENTITY, EPITHELIOD, EQUAL, EQUIVALENT, ERASER, ERYTHEMATOUS, ESTROGEN, ESTROGENS, EVER, EVERY, EVIDENCE, EXAM, EXAMINATION, EXCESS, EXCISION, EXCISIONAL, EXCLUDE, EXHIBIT, EXHIBITED, EXHIBITING, EXIST, EXISTED, EXISTING, EXPERIENCED, EXPIRED, EXPLAIN, EXPOSED, EXPOSURE, EXTENT, EXTREMITIES, EXTREMITY, EYE, EYED, EYES, FACTOR, FAMILIAL, FAMILY, FATHER, FATHERS, FEATURE, FEATURES, FEMALE, FEMALES, FEW, FEWER, FIFTH, FIGURES, FILE, FIND, FINDINGS, FINISHED, FIRST, FIVE, FLAP, FLAT, FOLK, FOLKS, FOLLOW, FOLLOW-UP, FOLLOWED, FOLLOWING, FOLLOWS, FOOT, FOR, FORE, FORMATION, FORMED, FOUND, FOUR, FOURTH, FRACTION, FRECKLE, FRECKLES, FRECKLING, FREE, FREQUENCY, FROM, FRONT, FTSG, FULL, GARMENT, GET, GIANT, GIVE, GIVEN, GONADAL, GRAFT, GREATER, GREATEST, GREEN, GREY, GROIN, GROUP, GROUPED, H1, HAD, HAIR, HAired, HAIRY, HALF, HALO, HAND, HAS, HAVE, HAVING, HEAD, HEMMORHAGE, HEMMORHAGING, HI, HIGH, HIGHEST, HIND, HIST, HISTOGENIC, HISTOLOGIC, HISTOLOGICAL, HISTOLOGICALLY, HISTOLOGY, HISTORY, HORMONES, HOST, HOW, HRP, HRP1, HUTCHINSON'S, HYPOPIGMENTED, I, IA, IB, IC, ID, IDENTIFICATION, IE, IF, II, IIA, IIB, IIC, III, IIIA,



IIIB, IIIC, IIID, IMMUNOTHERAPY, IN, INCISIONAL, INCLUDE, INCOMPLETE, INCREASE, INDETERMINATE, INDEX, INDIVIDUAL, INDIVIDUALS, INFILTRATION, INFO, INFORMATION, INGUINAL, INITIAL, INSTANCE, INSTANCES, INSTEAD, INSTITUTION, INTERMEDIATE, INTERPRETATION, INTERPRETATIONS, INVADING, INVASION, INVASIVE, INVOLVEMENT, IRP, IRRADIATION, IRREGULAR, IS, IT, ITCHED, ITCHING, ITEMS, IV, KERATOSIS, KNEE, LACK, LARGE, LARGER, LARGEST, LATERAL, LEAST, LEAVE, LEFT, LEG, LENTIGO, LESION, LESIONS, LESS, LET, LEVEL, LEVELS, LIGHT, LIKE, LIMB, LIMBS, LIMITS, LIST, LISTED, LITTLE, LIVER, LMM, LN, LND, LNP, LO, LOCAL, LOCATED, LOCATION, LOCATIONS, LOGOFF, LOGOUT, LONGER, LOW, LOWER, LOWEST, LRP, LYMPH, LYMPHADENECTOMIES, LYMPHADENECTOMY, LYMPHOCYTES, LYMPHOCYTIC, MACROPHAGES, MAKE, MALE, MALES, MALIGNA, MALIGNANCY, MALIGNANT, MAN, MANY, MARGIN, MARGINS, MARKINGS, MAX, MAXIMUM, MCCG, ME, MEAN, MEANING, MEASURED, MEDIAN, MEDICATIONS, MEDIUM, MELANOCYTIC, MELANOMA, MELANOMAS, MELANOTIC, MEN, MENOPAUSAL, MENSTRUAL, METASTASES, METASTATIC, MICROSCOPIC, MICROSCOPICALLY, MIN, MINIMAL, MINIMUM, MISSING, MITOSES, MITOSIS, MITOTIC, MM, MO, MODAL, MODE, MODERATE, MODERATELY, MOLE, MOLES, MONO, MONOCLONAL, MONOCLONISM, MONTH, MONTHS, MORE, MORE.THAN.100, MOS, MOST, MOTHER, MOTHERS, MUCH, MULTIPLE, NAMES, NAVAIL, NECK, NED, NEGATIVE, NEOPLASM, NEOPLASMS, NEVI, NEVOID, NEVUS, NICKEL, NM, NO, NOD, NODAL, NODE, NODES, NODULAR, NODULES, NON-MELANOCYTIC, NONE, NOT, NOTED, NOTICED, NOVO, NS, NUMBER, NUMBERS, OBSERVED, OCCURRENCE, OCCURRENCES, OF, OLDER, OLDEST, OMIT, ON, ONE, ONES, ONLY, OR, ORAL, ORDER, ORDERED, ORGANIZE, ORGANIZED, ORIGIN, ORIGINATED, ORIGINATING, OTHER, OUT, OUTCOME, OUTPUT, OVER, OVERALL, PAGETOID, PAINFUL, PALE, PALPABLE, PAPULAR, PARAMETERS, PARAPHRASE, PARAPHRASES, PART, PARTIAL, PAST, PATH, PATHOLOGIC, PATHOLOGICAL, PATHOLOGICALLY, PATHOLOGY, PATIENT, PATIENT'S, PATIENTS, PATTERN, PE, PEDUNCULATED, PENCIL, PEOPLE, PERCENT, PERCENTAGE, PERFORMED, PERSON, PERSONAL, PERSONS, PHENOTHIAZINES, PHYSICAL, PIGMENTARY, PIGMENTED, PILLS, PINHEAD, PLACE, PLAQUE, PLASMA, PLASMA-CELLS, PLEASE, PLEOMORPHIC, POLY, POLYCLONAL, POLYCLONISM, POPLITEAL, POPULATION, POSITIVE, POSSIBLE, POST, POST-MENOPAUSAL, POSTMENOPAUSAL, PRACTICALLY, PRE-EXISTING, PRECEEDING, PREDOMINANT, PREEXISTING, PREGNANCY, PREGNANT, PREMENSTRUAL, PREPROCESSOR, PRESENCE, PRESENT, PRESENTED, PRESENTING, PREVIOUS, PREVIOUS.THERAPY, PRIMARIES, PRIMARY, PRINT, PRINTED, PRIOR, PRIORQUERY, PROCEDURE, PROCEDURES, PROGNOSIS, PROMINENT, PROPERTIES, PROPHYLACTIC, PROPORTION, PROPOSED, PROVED, PROVEN, PROVIDE, PT, PTS, PUNCH, QUANTITY, QUARTER, RANGE, RANGES, RARELY, RATE, RECALL, RECOMMENDED, RECORDED, RECUR, RECURRED, RECURRENCE, RECURRENCES, RECURRENT, RED, REDNESS, REFERENCED, REFERRED, REGION, REGIONAL, REGRESSION, REGULAR, REGULARITY, RELAPSE, RELAPSED, RELATIONS, RELATIVE, RELATIVES, REMOVAL, RESECTION, RESPECT, RESPONSE, RESULTS, RETRIEVE, REVIEW, RISK, RLND, ROUND, SAME, SATELLITES, SCALY, SEARCH, SECOND, SEEN, SELECT, SESSILE, SEVERE, SEX, SHAPED, SHOULDER, SHOW, SHOWED, SIBLING, SIBLINGS, SIGNIFICANT, SIMILAR, SINCE, SITE, SITES, SITUATED, SIZE, SKIN, SKINED, SMALL, SMOOTH, SOLAR, SOME, SPECIFIED, SPECIMEN, SPINDLE, SPLEEN, SPLIT, SPREAD, SPREADING, SQUAMOUS, SSM, STAGE, START, STATE, STATUS, STEROID, STEROIDS, STRATIFIED, STRATIFY, STSG, STUDY, SUBCUTANEOUS, SUBPAROTID, SUBSTITUTE, SUBSTITUTIONS, SUGGESTED, SUN, SUNBURN, SUNLIGHT, SUPERFICIAL, SUPRACLAVICULAR, SURFACE, SURGERY, SURGICAL, SUSPECT, SUSPECTED, SUSPICION, SUSPICIOUS, SYNTAX, TABULATE, TABULATED, TAKE, TAKEN, TAKING, TAN, TELL, TENDER, TENDERNESS, THAN, THAT, THE, THEIR, THEM, THERAPEUTIC, THERAPY, THERE, THESE, THEY, THICK,

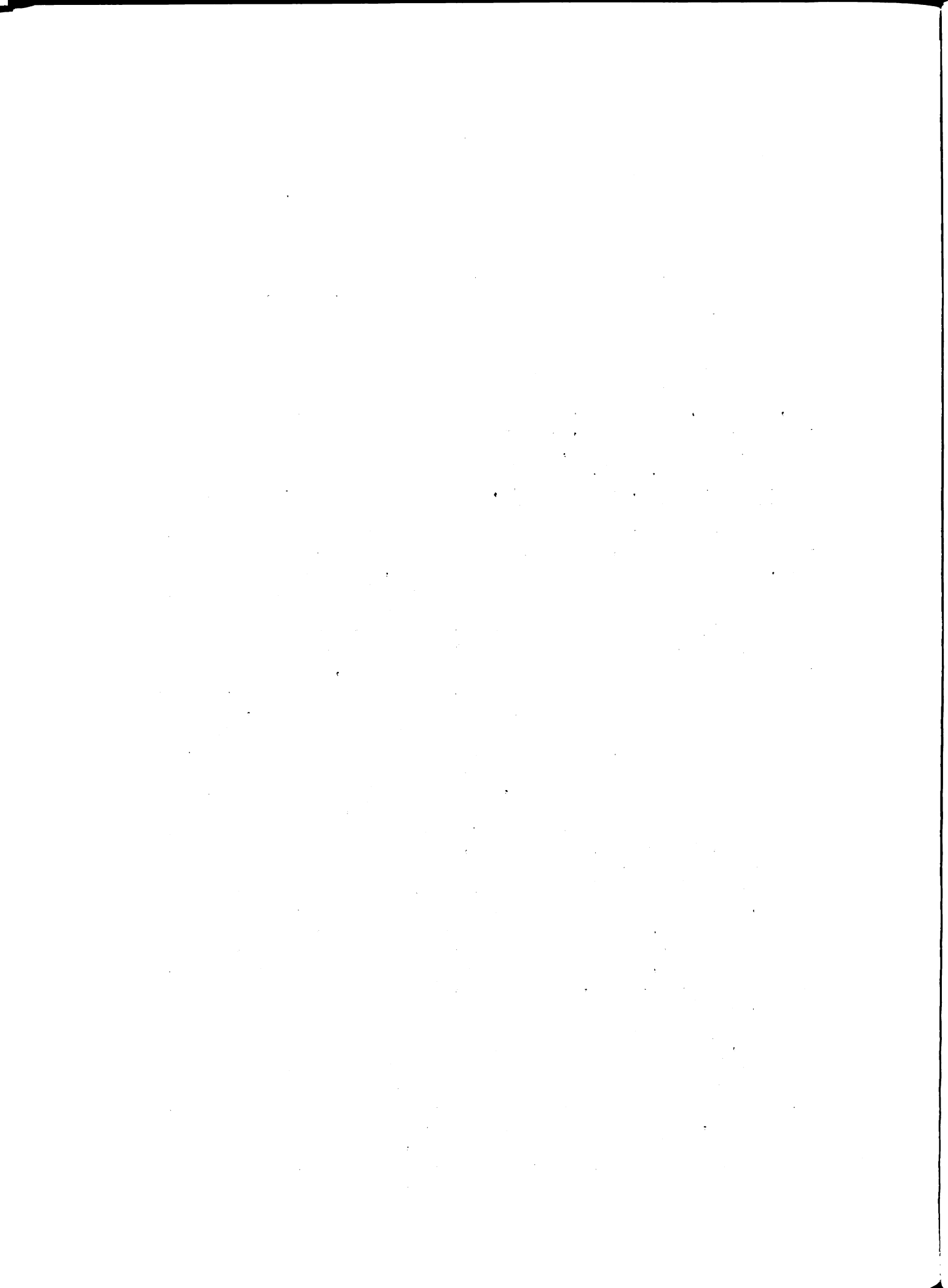


THICKER, THICKNESS, THIGH, THIN, THINNER, THIRD, THIS, THOSE, THREE, THROUGHOUT, THYROID, TIME, TLND, TO, TOOK, TOPOGRAPHY, TOTAL, TRANSIT, TRAUMA, TREATMENT, TRUE, TRUNK, TUMOR, TUMORS, TWO, TX, TYPE, TYPES, ULCERATED, ULCERATION, UNASSIGNED, UNCERTAIN, UNCLASSIFIED, UNCLEAR, UNDER, UNDETERMINED, UNIFORM, UNKNOWN, UNSPECIFIED, UP, UPON, UPPER, USE, USED, USING, UTILIZED, V, VALUES, VARIEGATED, VASCULAR, VERRUCOUS, VERTICAL, VERY, VESSEL, VISCERAL, VISIBLE, VISIT, VISITS, VITILIGO, VS, WAS, WAY, WELL, WERE, WHAT, WHEN, WHERE, WHETHER, WHICH, WHITE, WHO, WHOSE, WIDE, WITH, WITHIN, WITHOUT, WOMAN, WOMEN, WRT, X-RAY, YEAR, YEARS, YES, YOU, YOUNGER, YOUNGEST, YR, YRS

The number of word classes is 232.

The word classes are:

<AMOUNT>, <ARISE>, <ATT-COMP>, <ATTR-CLASS>, <ATTR-INFER>, <ATTR-REPEAT>, <ATTR-REPEATS>, <ATTR-TOP>, <ATTRIBUTE>, <ATTRIBUTEALL>, <ATTRIBUTES>, <AUXB-Q>, <AUXB>, <BORDER-ELEVATION>, <BORDER.REGULARITY-V>, <BY>, <CA>, <CHARACTERIZED>, <CLASS>, <CLINICAL-STATUS-NODES>, <COLOR-ATT1>, <COLOR-ATT>, <COLOR-PATT-V>, <COLOR>, <CONFIRM>, <CONSTRAINT-RESTRICT>, <CONSTRAINT1>, <CONSTRAINT>, <CREATE>, <DATA>, <DATE-OF-FOLLOW-UP-VISIT>, <DATE-OF-INITIAL-THERAPY>, <DATE-OF-LYMPHADENECTOMY>, <DATES>, <DESC-SUN-EXPOSURE>, <DET>, <DISS-V1>, <DISS-V>, <DISSECTION1>, <DISSECTION>, <DRUG>, <DRUGS>, <ELEVATION-FIRST-NOTED>, <END>, <ERYTHEMATOUS-HALO>, <EXAM>, <EXCLUDE>, <EXIST>, <EXPLAIN>, <EXTREMITY>, <F-UP>, <FAMILY-HX>, <FEATURES>, <HAVE-P>, <HAVE>, <HIST-ATT-1>, <HIST-ATT-2>, <HIST-ATT-3>, <HIST-ATT-4>, <HIST-ATT-V11>, <HIST-ATT-V1>, <HIST-ATT-V2>, <HIST-ATT-V3>, <HIST-ATT-V4>, <HISTOLOGY>, <HORMONES>, <HOW-MANY>, <HOW>, <HX-FAMILY>, <HYPOPIGMENTED-HALO1>, <HYPOPIGMENTED-HALO2>, <ID1>, <ID>, <IMMUNOTHERAPY>, <IN-TRANSIT>, <INCLUDE>, <INIT-THERAPY>, <INITIAL-THERAPY-VALUE>, <LESION-CHAR>, <LESION-CHARACTERISTICS1>, <LESION-CHARACTERISTICS2>, <LESION-MOD>, <LEVEL\*>, <LEVEL>, <LEVELN>, <LIST>, <LIT-ATT-REPEAT>, <LIT-ATT-SITE>, <LIT-DESC-SUN-EXP>, <LITERAL-ATTRIBUTE>, <LITERAL-NAMES>, <LND-SITE>, <MARGIN>, <MEDS>, <MEL-MOD>, <MEL-MODA>, <MELANOMA-AROSE>, <MELANOMA1>, <MELANOMA2>, <MELANOMA3>, <MELANOMA>, <MOD>, <MV-DIS-VAL>, <MV-DISEASE>, <NEW.STMT>, <NONE1>, <NONE>, <NOUN-FUP>, <NOUN-HIST>, <NOUN-LNODE-ALL>, <NOUN-LNODE-TIME>, <NOUN-LNODE>, <NOUN-OTHER>, <NOUN-PHRASE>, <NOUN-PROP1>, <NOUN-PROP>, <NOUN-PROPS>, <NS>, <NUM-ATT-REPEAT>, <NUM-COMP1>, <NUM-COMP2>, <NUM-COMP3>, <NUM-COMP>, <NUM1>, <NUM2>, <NUM3>, <NUM>, <NUMB>, <NUMBER-OF-LIT-VAL>, <NUMBER-OF>, <NUMERIC-ATTR-NCALC>, <NUMERIC-ATTRIBUTE>, <NUMERIC-ATTRIBUTES>, <NUMERIC-NOUN-PHRASE>, <NUMERIC-OPERATOR>, <NUMERIC-OPERATORS>, <NUMR>, <NUMS>, <OF-FOR>, <OLD.STMT>, <OLD.STMTS>, <OTHER-POST-MOD>, <P-ATT-VAL>, <P-ATTRIBUTE>, <P-DISEASE>, <PAT-PHYSICAL-EXAM>, <PAT-TEMP>, <PATH-ATTR>, <PATH-NAME>, <PATIENT-MOD>, <PATIENT-P>, <PATIENT-PRN>, <PATIENT1>, <PATIENTS>, <PE-ATTRIBUTE>, <PE-PATIENT>, <PE-PRIMARY>, <PERFORMED>, <PHYSICAL>, <PLACE>, <POSTNUM1>, <POSTNUM2>, <POSTNUM>, <PRE-PATIENTS>, <PREP>, <PRIMARY-HX>, <PROPORTION>, <QUANT1>, <QUANT>, <RANGE>, <RECURRENCE>, <REFCLAUSE>, <REL-DISEASE>, <RELATIVE>, <SAME>, <SHAPED>, <SHOW>, <SITE-MOD>, <SITE>, <SIZE-FIRST>, <SKIN-MARKING-V>, <STAGE>, <STATUS>, <STATUSN>, <STATUS-T1>, <SUBSTITUTION>, <SUGGESTED>, <SUN-DAMAGE-V>, <SUN-DAMAGE>, <SUN-EXPOSURE>, <SUNBURN>, <SWITCH-PARAMETERS>, <SYMBOL>



<TABULATE-CLAUSE>, <TABULATE>, <TABULATED>, <TAKE>, <TAN>, <THERAPY-TYPE-AT-VISIT>, <THERAPY-VALUE>, <THICKNESS-S>, <TIME-LESION-CHAR>, <TIME-FUP>, <TIME-NOTED>, <TIME-RANGE>, <TIME-SEEN>, <TIME1>, <TOPOGRAPHY-V>, <TRAUMA>, <TRUE-FALSE>, <TUMOR-PRESENT>, <TX>, <TYPE\*>, <TYPE-OF-BIOPSY-PROCEDURE>, <TYPE-OF-BIOPSY-VALUE>, <TYPE-OF-BIOPSY>, <TYPE>, <USE>, <VALUE-CLAUSE>, <VALUE-LNN>, <VALUE-LNP>, <VALUE>, <VALUES1>, <VALUES2>, <VALUES>, <WH/LIST>, <WH1>, <WH>, <WITH>, <WRT-ATTRIBUTES>, LIFER.PREPROCESSOR, LIFER.TOP.GRAMMAR





## Appendix E

EXAMPLES OF CLASSES OF REQUESTS SUPPORTED

## CLASSES OF QUESTIONS

- \* Information about contents and characteristics of the data base
- \* Information about a particular patient
- \* Counts
- \* Relations and Distributions
- \* Calculations
- \* Yes/no questions
- \* Information about the rules and application vocabulary

## INFORMATION ABOUT CONTENTS AND CHARACTERISTICS OF THE DATA BASE

Describe the data base.

What are the attributes in the melanoma db?

List the attribute classes in the melanoma data base.

What follow up information is there in the study?

Show me the data items associated with the history of the primary.

What information is there about physical examination of the primary?

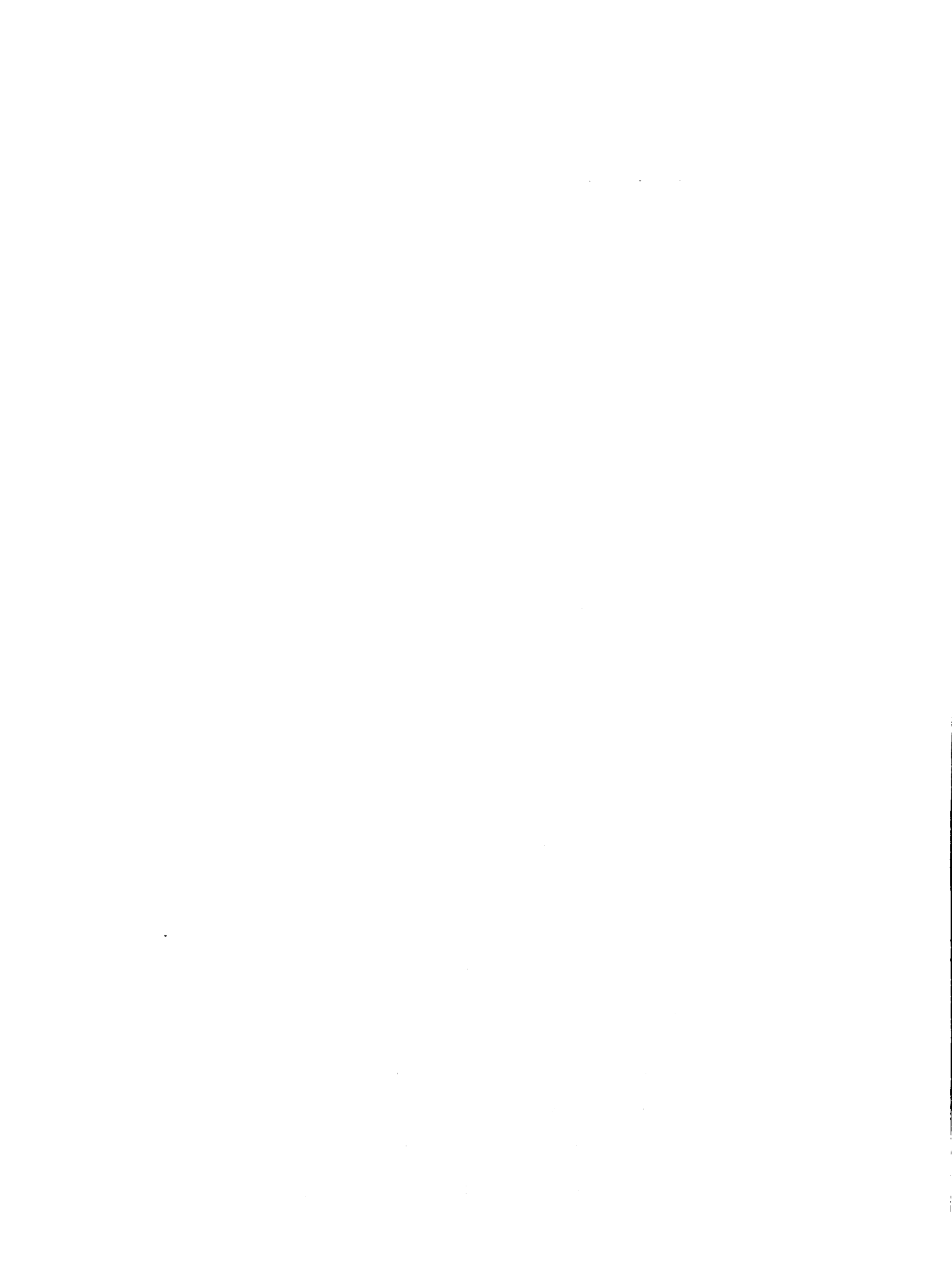
How was the existence of bleeding of the primary recorded in the data base?

List the admissible values for size first noted.

What are the recorded values in the db for current status?

What is the extent of values for tumor thickness?

Give me the range of values for lesion sun exposure.



Show me the spread of collected values in the data base for thickness of the primary in pts with ssm level 4.

How is many mitoses described?

What is the definition for stage IA?

#### INFORMATION ABOUT A PARTICULAR PATIENT

What are the outcome results for patient S-72-002?

Display the presence or absence of melanocytic disorders for S-73-005.

What are the results in the data base for pt. S-76-003?

#### COUNTS

For pts with ssm and tumor thickness greater than 1.5 mm., how many had bleeding of the primary for 1 year prior to diagnosis?

How many occurrences of individuals with trauma to the site of the primary who had no mitoses present on histologic exam of the primary?

In how many patients was level 5 disease seen?

For people with ssm 5 of the extremities, how many were males?

Did any relatives of patients with level 5 disease have other malignant tumors?

How many males with melanoma in a preexisting lesion had fathers with malignant skin tumors?

How many blond haired, blue eyed, pale skinned males with melanoma of the nodular type?

For female patients, how many were red haired, blue eyed, and pale skinned?

Count the number of patients having nodal involvement.

Display the number of individuals with ELND that were histologically positive.

Count the patients who had LNP within 4 months of diagnosis.

What was the number of people who had node dissections within 4 months since initial therapy?



How many men with melanoma of the superficial spreading type with many mitoses, and thick primaries had histologically demonstrated recurrence within 2 years following initial therapy?

How many patients with level 5 disease had no histologic recurrence within 1 year?

How many persons with level 4 or 5 and tumor thickness greater than 3.0 mm. had proven histologic recurrence in the first year?

For individuals with ssm level 4 or level 5, how many had no histologic recurrence within 24 months?

Count pts. with no evidence of disease 24 months after initial therapy.

How many individuals with level 4 or 5 were followed for 24 months?

How many people with level 4 or 5 had follow up data for more than 2 years?

How many pts with ssm of the extremities had many mitoses, and tumor thickness greater than 1.5 mm. were at risk in year one and had confirmed histologic recurrence?

Determine the number of individuals with melanoma of the extremities who had ssm and demonstrated histologic recurrence within 2 years.

How many people with tumor thickness > 3 mm. had metastatic disease?

How many pts had a lesion elevation change for 6 months before removal of the primary?

Count patients having bleeding of the primary for less than 24 months prior to excision of the primary.

Count the number of people with sex = male, age > 40, mitotic rate = many, and type = ssm.

What is the number of patients that were younger than 40?

Give me the number of people with primaries thicker than 2.5 mm.

How many entities with a high mitotic rate?

What is the number of patients who were given chemotherapeutic agents?

#### RELATIONS AND DISTRIBUTIONS

For people with ssm of the extremities, group by thickness those



with many mitoses.

List the tumor thickness for patients with ssm of the extremities arranged by mitotic rate.

How many patients had ssm invasive to level 4 ordered by site of the primary lesion?

List the tumor thickness, level of invasion, and site of the primary for patients with histologically confirmed regression of the primary.

Give the types and levels for pts with red hair and freckles, ordered by type of melanoma and level of invasion.

Stratified by site of the primary lesion, how many people had ssm followed by histologic recurrence within 1 year after initial therapy?

What are the range of values for tumor thickness in pts with level 3 or 4 arranged by level?

What were the admissible values for thickness of the primary in cases with ssm?

For patients with level 5 disease, list by sex and age those with many mitoses stratified by tumor thickness.

What is the distribution of pts. with regression of the primary arranged by tumor thickness and level of invasion?

For pts with histologic recurrence, histologically confirmed regression of the primary, and ssm, list their age, sex, tumor thickness, and mitotic rate.

How many pts had itching of the primary within 6 months of diagnosis ordered by tumor thickness?

How many patients have had an increase in the size of the primary prior to initial therapy ordered by months since size change?

Determine the number of individuals who experienced a change in lesion size ordered by months since size change.

How many women with histologically proven thick tumors broken down by menstrual status?

Tabulate people with axillary lymph node dissections by site of the primary lesion.

List the site of the primary and site of lymph node procedure for pts with ELND.

Stratify by site of the primary lesion, site of lymph node procedure and number of positive nodes found, pts who had an elective lymph node procedure with ssm, and tumor thickness less than 1.5 mm..





Output patients with number of ln dissections greater than 1.

List the follow up data for people with prophylactic lnp who had histologically + nodes.

List the data on lnp for pts dead of disease, ordered by number of dissections and depth of involvement.

What was the effect on outcome of many mitoses for people with elevated borders of the primary?

How did regression of the primary effect outcome for pts with thin tumors?

What is the effect on outcome of + elnd for pts with level 5 disease?

Who had histologic recurrence within 24 mos. of diagnosis ordered by tumor thickness?

For patients with level 5, list by sex those who had many mitoses present organized by tumor thickness.

For individuals with many mitoses and a primary melanoma on the extremities, group by level and tumor thickness those with histologic recurrence in less than 24 months.

List, arranged by level individuals with ssm who had much sun exposure.

Display by time to recurrence and status pts with ssm 3.

For people with level 5 disease who had histologically proved recurrence, output by age, sex, and by time to histologic recurrence.

Print the dominant color, and second most dominant color of the primary for patients with many mitoses, arranged by tumor thickness.

Show the presence of bleeding, itching, tenderness, and ulceration of the primary for pts with many mitoses and tumor thickness between 2 and 3 mm.

Show the dominant color of the primary for pts with tumor thickness greater than 3 mm. who had histologic recurrence.

List the histologic type for pts with no regression and few mitoses found on histologic examination of the primary.

List the histopathology results for pts with ssm 5 of the arm.

Give the personal data associated with individuals who were followed 36 months.

List the biopsy type for pts presenting with ssm 5 of the upper extremities.



How many people with ssm of the trunk arranged by biopsy type and type of initial therapy?

Display the presence of clonism for pts with level 5 disease.

Show the type of clonism for pts having ssm 5.

Using tumor thickness, tabulate pts with trauma to site of primary who had elevated borders.

Stratified by host response, list people with level 5 melanoma of the trunk.

Display organized wrt level, how many pts with melanoma arising in a preexisting lesion?

Retrieve people with ssm 3 and order them by sex.

How many relatives of patients with level 5 had other pigmentary disease?

How was lnp vs. no lnp associated in patients with ssm 5?

Display the clinical course of the disease for pts with histologic recurrence in 24 months who present with level 4 disease.

For all patients with histologic recurrence, list the disease extent and status ordered by level of invasion.

List the tumor thickness for every pt with ssm of the trunk displayed by level of invasion.

List the tumor thickness, anatomical extent, mitotic rate, and presence of regression for individuals having visceral spread.

Display the existence of a cellular host response for cases with level 5 disease ordered by thickness of the lesion.

What was the exposure to solar irradiation for females with level 4 or 5 melanoma of the lower extremities?

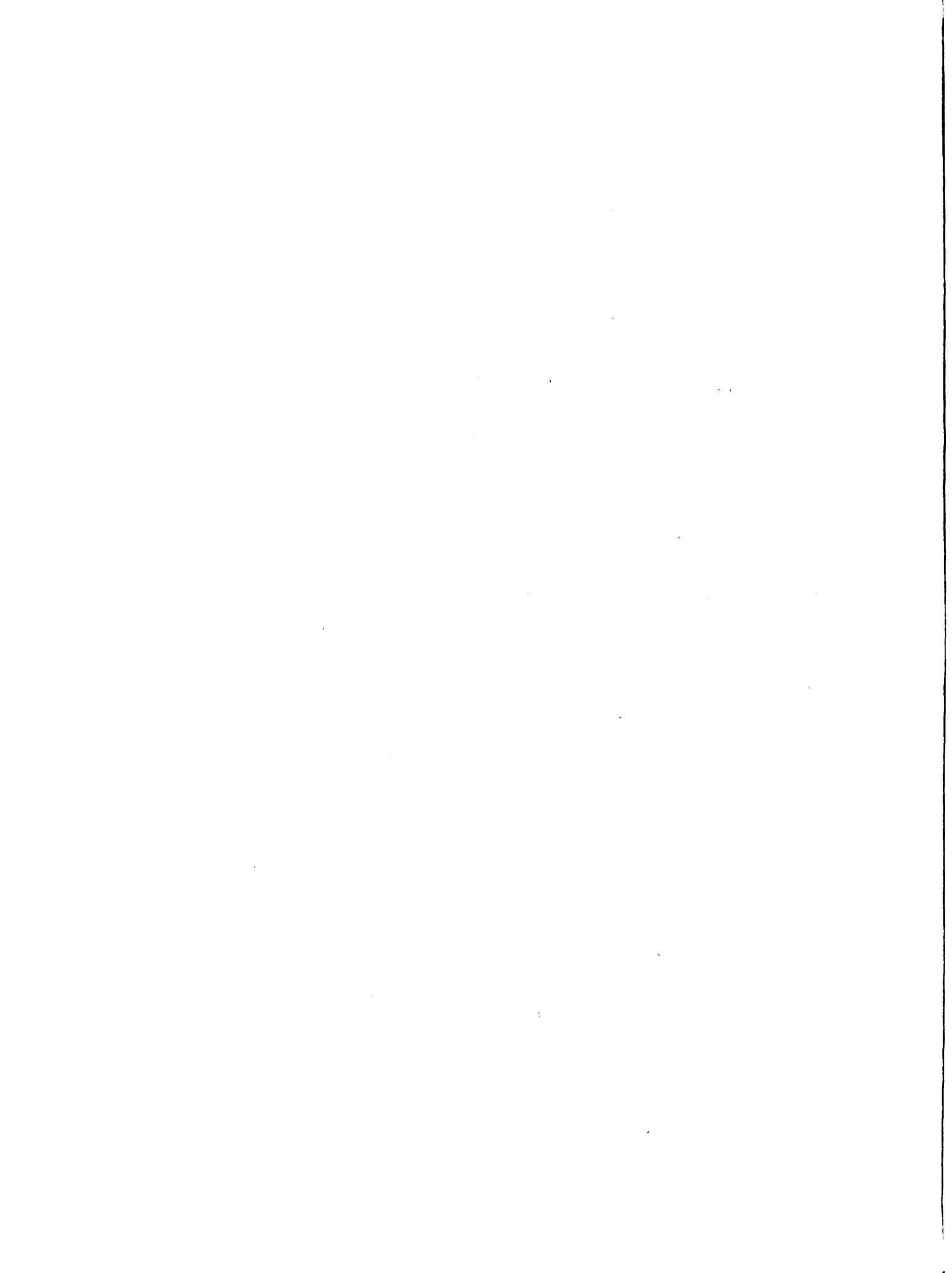
Cite changes to the primary lesion for individuals with level 5 nodular melanoma.

Select pts. with melanoma of the head or neck, and list the tumor thickness, level of invasion, and site for these people.

List patient sun exposure, lesion sun exposure, presence of sunburn, and amount of tan for people with level 5 nodular melanoma.

Tabulate by exposure to sunlight patients with tumor thickness greater than 3 mm.

What were the surface characteristics of the primary in pts with



level 4 melanoma of the upper extremities?

Show the existence of melanocytic disorders in individuals with many mitoses and tumor thickness greater than 3.5 mm.

#### CALCULATIONS

What is the minimum and maximum tumor thickness for patients with level 3 disease?

What is the average tumor thickness and age of patients with ssm organized by level of invasion?

For cases with ssm 5, what is their average age?

For patients with ssm of the extremities, calculate the minimum, maximum, and average age ordered by level.

What is the age of the oldest person with ssm?

Compute the average age for pts with ln procedures ordered by number of positive nodes found.

What is the average tumor thickness for people with histologically positive lymph nodes arranged by type of lymph node procedure?

Calculate the average tumor thickness for individuals with - nodes ordered by type of lymph node procedure.

What was the average age for individuals with ssm of the extremities who were males?

Determine for pts with melanomas that arose denovo, the mean, minimum, and maximum tumor thickness.

What is the average age and tumor thickness for individuals having melanoma of exposed sites with regression that was seen histologically who had tumor thickness more than 1.0 mm.?

Calculate the average tumor thickness for pts with level 4 having evidence of disease within 12 months.

Determine the percentage of people with ssm and thick tumors who had regression of the primary lesion.

What proportion of patients with ssm 3 had the primary in a pre-existing mole?

What fraction of people with ssm had many mitoses and regression

of the primary lesion?

Find the percentage of people who had ssm.

What was the recurrence rate for pts with ssm of the trunk?

Calculate the recurrence rate within one year of dx for individuals with tumor thickness greater than 2.5 mm. having many mitoses.

Calculate the percentage of pts with ssm who were males.

What proportion of males with thick tumors had blue eyes?

Determine the percent of people with many mitoses and histologically confirmed regression of the primary who had melanoma of the superficial spreading type.

What fraction of pts with ssm had regression of the primary?

Compute for pts with many mitoses their average and median tumor thickness grouped by type of melanoma.

#### YES/NO QUESTIONS

Did any patients have the following: ssm with confirmed regression of the primary, few mitoses, and demonstrated histologic recurrence in the first year of follow up?

Are there any pts with ssm having the following characteristics: many mitoses, tumor thickness greater than 5 mm. and proven histologic recurrence within 24 months?

Were any people followed for more than 2 years after excision of the primary?

Did any patients with level 2 have excision with STSG ordered by thickness of the primary?

#### INFORMATION ABOUT THE GRAMMAR AND APPLICATION VOCABULARY

Explain <noun-props>.

Explain <numeric-operator>.

How is <hist-att-1> referenced?

Show the paraphrase substitutions.

## DIALOGUE INTERACTIONS

Count the number of pts having nodular melanoma of the lower extremities.

What is the site of the primary and tumor thickness for these patients?

Did any of them have lymph node procedures?

Which patients?

List the follow up data for these individuals ordered by patient id.

How many people with regression of the primary grouped by level of invasion?

How many of these patients had melanoma invasive to level 4 or 5?

Tabulate them by mitotic rate and tumor thickness.

How many people with level 5 disease were followed for 24 mos.?

What percentage of them had histologic recurrence?

Display the tumor thickness for those pts with histologic recurrence.

List the tumor thickness for pts with level 5 disease who were followed for 24 months and had no histologic recurrence.

How many people with lnp had histologic recurrence?

How many of those people had stage 3 disease?

How many of these pts. had - lnp?

List them ordered by tumor thickness.

Display the follow up results for s-76-003.

Show the histology results for this patient.

Count pts in stage 3 having lnp.





Tabulated by number of positive nodes.

List those pts with histologically negative nodes.

List the follow up information for pt. s-75-015.

List the type, level, and tumor thickness for this individual.

How many cases were characterized by an increase in the size of the lesion for 6 months prior to initial therapy?

For these pts, display the tumor thickness and level ordered by time since lesion size change.

Count the number of people seen for 24 months.

How many had tumor thickness greater than 2 mm.?

Are any of them dead of disease?

Which of these patients showed regression of the primary?

For pts with ssm, how many had many mitoses?

What was their average age at diagnosis grouped wrt sex?

How many of these people had histologic recurrence within 24 months?

Which ones?

How many cases with ssm 5?

Tabulated by sex.

with ssm of the extremities.

arranged by tumor thickness.

How many people had histologic recurrence ordered by site of the primary lesion?

List the level and thickness for those people with the primary located on an extremity.

What proportion of these pts had histologic recurrence within 24 mos?

List the ones with histologic recurrence within 24 months.

What are the recorded values in the study for lesion size change?  
lesion ulceration.

bleeding of the primary?

tabulated by sex.

How is stage 1F defined?

Count the number of patients who were in stage 1F.

ordered by tumor thickness and level of invasion!

## Appendix F

A COMPLETE TRANSCRIPT OF A MEDINQUIRY SESSION

To run the current version of MEDINQUIRY, the user types MELANOMA followed by a carriage return. A transcript is retained of each MEDINQUIRY session to record the questions posed and thus gain a better understanding of information processing strategies used by experts in formulating requests. It also aids in determining gaps in the system coverage so that over time improvements can be made. What follows is a listing of an actual transcript of a session. Comments on the nature of the requests in this transcript are included in brackets prior to the request(s).

MEDINQUIRY transcript from system created 10-Jun-79 16:51:00  
 Begin transcript file Sun 10-Jun-1979 17:32:10-PDT  
 User Name: M EPSTEIN

Load Average = 1.60

Do you want information about classes of questions that can be asked and guidance on use of the system? (type FIRST LETTER of response) yes

This system provides natural language access to a data base on patients with malignant melanoma. The user can input requests in English that retrieve data for particular patients or for groups of patients satisfying certain characteristics.

The classes of questions supported to date include information about the data base, counts, tabulated groupings, tabulated counts, listings organized by specific attributes in the data base, and simple calculations (such as proportion and average). The system supports dialogue interactions; that is, the user can follow a line of inquiry to test a particular hypothesis by entering a sequence of requests that depend on each other.

Examples of questions that may be submitted are:

HOW MANY PATIENTS IN THE MELANOMA DB?

WHAT ARE THE CLASSES OF ATTRIBUTES?

LIST THE ITEMS ASSOCIATED WITH PATHOLOGY RESULTS.

DISPLAY THE PATH RESULTS FOR PATIENT S-72-002.

SHOW ME THE VALUES IN THE STUDY FOR MITOTIC RATE.

COUNT THE NUMBER OF INDIVIDUALS WHO HAD LYMPH NODE PROCEDURES.

IN HOW MANY PATIENTS WAS LEVEL 5 DISEASE SEEN?

STRATIFIED BY SITE OF THE PRIMARY, HOW MANY PEOPLE HAD SSM FOLLOWED BY HISTOLOGIC RECURRENCE WITHIN 1 YEAR OF INITIAL THERAPY?

DID ANY INDIVIDUALS WITH SSM HAVE THE FOLLOWING: REGRESSION OF THE PRIMARY, MANY MITOSES, AND THICK TUMORS?

LIST THE AGE, SEX, AND TUMOR THICKNESS FOR PEOPLE WITH SSM 5.



WHAT IS THE AVERAGE, MEDIAN, MINIMUM, AND MAXIMUM AGE AND TUMOR THICKNESS FOR PTS WITH SSM ORGANIZED BY LEVEL OF INVASION? FOR PTS. WITH LYMPH NODE PROCEDURES, HOW MANY HAD HISTOLOGICALLY POSITIVE NODES ORGANIZED BY LEVEL AND NUMBER OF + NODES? DETERMINE THE PERCENTAGE OF PEOPLE WITH LEVEL 4 OR 5 DISEASE HAVING ULCERATION OF THE PRIMARY LESION?

An example of a dialogue interaction is given by the following:  
 HOW MANY CASES WITH LEVEL 5 DISEASE WERE AT RISK IN YEAR 1?  
 DISPLAY THE AGE, SEX AND MITOTIC RATE FOR THESE PATIENTS ORDERED BY TUMOR THICKNESS.  
 HOW MANY OF THEM HAD HISTOLOGIC RECURRENCE IN THE FIRST YR?  
 LIST THE SURGICAL PATHOLOGY NUMBERS FOR THESE PATIENTS.

In this experimental system, an attempt has been made to structure recognition of requests around the concept of the patient. Thus, HOW MANY PATIENTS WITH SSM 5? is a more natural form than COUNT THE NUMBER WITH SSM 5. Requests that include more context provide useful syntactic clues to aid in recognition of requests.

For selected requests that require access to the data base, the system responds first with its understanding of the request to ensure that a proper interpretation has been assigned.

To use the system, input your request after the sequence number prompt. Terminate each request by a carriage return. Punctuation is accepted but not required. To delete a character, input (del), the delete key. <ctrl>W can be used to delete the previous word. <ctrl>D can be used to delete the entire request that has been keyboarded. Comments may be included by prefacing a question with an '\*'.  
 \*

An attempt has been made to anticipate a wide variety of questions and commands. If the system cannot process a request, it will respond with information about the problem. In the event that this information is not sufficient, try to restate the query in a different form.

— Please do not type anything until the system prompt '1\_' appears.

[questions 1 & 2: Provide information about mitotic rate as recorded in the data base.]

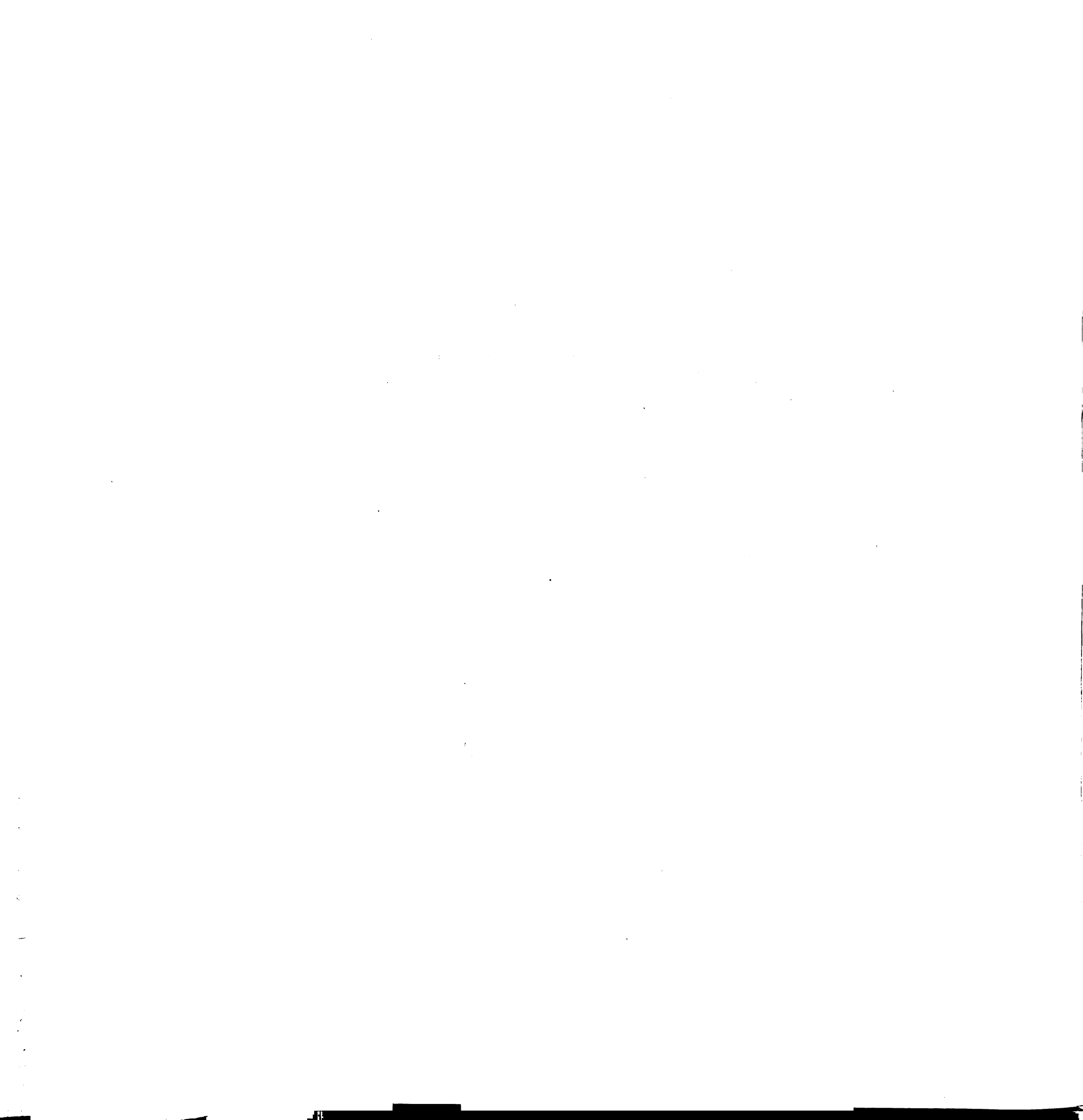
1\_show me the values for mitotic rate.

ANALYZED

MITOSES = MODERATE, FEW, MANY, NS, ABSENT, NIL

2\_how is many mitoses defined?

ANALYZED



Many mitoses is defined as more than one mitoses per high power field, or greater than 8 mitoses per square mm.

[Questions 3 & 4: Compare the distribution of tumor thickness in patients with superficial spreading melanoma and nodular melanoma.]

3\_what are the range of recorded values for tumor thickness in pts with ssm?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

How many individuals with DEFINITIVE PATHOLOGICAL TYPE equal SSM organized with respect to TUMOR THICKNESS (MM.).

TUMOR THICKNESS (MM.) = ( 0 . 0.76)  
Number of items in this category = 34

TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
Number of items in this category = 15

TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)  
Number of items in this category = 4

TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
Number of items in this category = 19

TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
Number of items in this category = 1

TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
Number of items in this category = 28

4\_nm?

Trying Ellipsis: WHAT ARE THE RANGE OF RECORDED VALUES FOR  
TUMOR THICKNESS IN PTS WITH NM

MEDINQUIRY has interpreted your request as follows:

How many individuals with DEFINITIVE PATHOLOGICAL TYPE equal NM organized with respect to TUMOR THICKNESS (MM.).

TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)  
Number of items in this category = 1





TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
 Number of items in this category = 8

TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
 Number of items in this category = 9

TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
 Number of items in this category = 5

[question 5: Display the relationship between tumor thickness and mitotic rate.]

5\_compute the average and median thickness of the primary for pts ordered by mitotic rate.

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What is the MEAN and MEDIAN TUMOR THICKNESS (MM.) for people with melanoma organized with respect to MITOSES.

-----  
 MITOSES = ABSENT

TUMOR THICKNESS (MM.)  
 5 items accepted.  
 The following items were rejected in the averaging process: NAVAIL  
 NAVAIL NS

Average is 0.46

Median value is: 0.30

-----  
 MITOSES = FEW

TUMOR THICKNESS (MM.)  
 37 items accepted.  
 The following items were rejected in the averaging process: NAVAIL  
 NAVAIL NAVAIL NAVAIL NAVAIL NS NAVAIL NAVAIL NAVAIL NS NAVAIL NAVAIL  
 NAVAIL NIL NAVAIL NIL

Average is 0.89

Median value is: 0.76

-----  
MITOSES = MANY

TUMOR THICKNESS (MM.)  
21 items accepted.

The following items were rejected in the averaging process: NAVAIL  
NAVAIL NAVAIL NAVAIL NAVAIL NAVAIL

Average is 4.55

Median value is: 2.55

-----  
MITOSES = MODERATE

TUMOR THICKNESS (MM.)  
20 items accepted.

The following items were rejected in the averaging process: NS NAVAIL  
NAVAIL

Average is 2.42

Median value is: 2.20

-----  
MITOSES = NIL

TUMOR THICKNESS (MM.)  
5 items accepted.

The following items were rejected in the averaging process: NAVAIL  
NAVAIL

Average is 4.50

Median value is: 1.70

-----  
MITOSES = NS

TUMOR THICKNESS (MM.)  
4 items accepted.

The following items were rejected in the averaging process: NAVAIL  
NAVAIL NAVAIL NAVAIL NAVAIL NAVAIL NAVAIL

Average is 0.46

Median value is: 0.50

[Question 6: Study the distribution of tumor thickness and mitotic activity in patients with histologically confirmed recurrence.]

6\_how many individuals with histologic recurrence grouped by mitotic rate and tumor thickness?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

How many individuals with STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD) organized with respect to MITOSES and TUMOR THICKNESS (MM.).

MITOSES = FEW  
TUMOR THICKNESS (MM.) = ( 0 . 0.76)  
Number of items in this category = 2

MITOSES = FEW  
TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
Number of items in this category = 2

MITOSES = FEW  
TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)  
Number of items in this category = 1

MITOSES = FEW  
TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
Number of items in this category = 2

MITOSES = FEW  
TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
Number of items in this category = 1

MITOSES = MANY  
TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)  
Number of items in this category = 1

MITOSES = MANY  
TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
Number of items in this category = 4

MITOSES = MANY  
TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
Number of items in this category = 6

MITOSES = MANY  
TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
Number of items in this category = 5

MITOSES = MODERATE

TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
 Number of items in this category = 5

MITOSES = MODERATE  
 TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
 Number of items in this category = 1

MITOSES = MODERATE  
 TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
 Number of items in this category = 1

MITOSES = NIL  
 TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
 Number of items in this category = 2

MITOSES = NS  
 TUMOR THICKNESS (MM.) = (0 . 0.76)  
 Number of items in this category = 1

MITOSES = NS  
 TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
 Number of items in this category = 2

[question 7: Study the distribution of tumor thickness and level of invasion in patients with histologically confirmed regression of the primary.]

7\_Tabulate pts with regression of the primary by depth of involvement.

ANALYZED

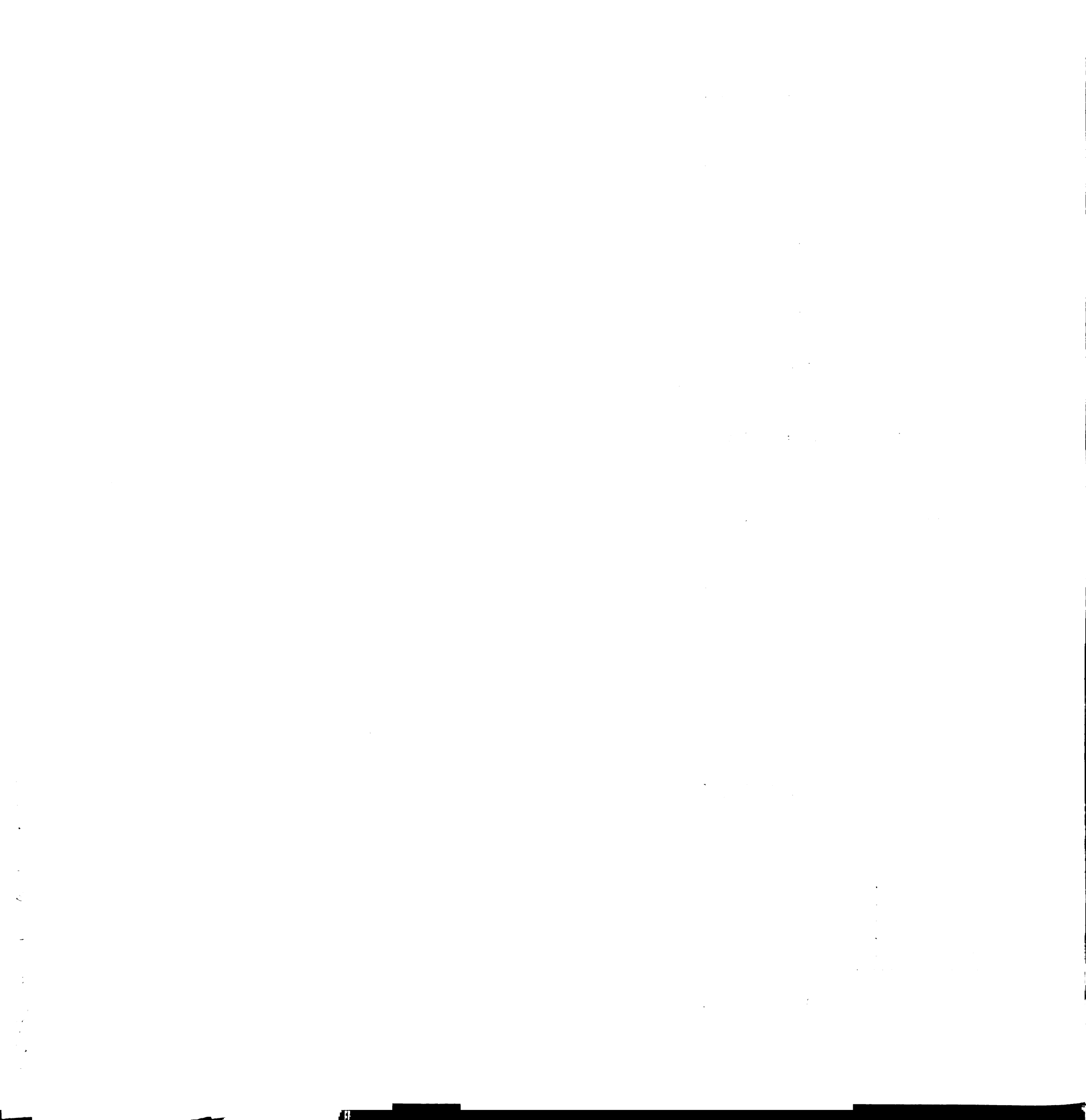
MEDINQUIRY has interpreted your request as follows:

List patients with REGRESSION OF THE PRIMARY equal PRESENT organized with respect to TUMOR THICKNESS (MM.) and DEFINITIVE PATHOLOGICAL LEVEL.

TUMOR THICKNESS (MM.) = (0 . 0.76)  
 DEFINITIVE PATHOLOGICAL LEVEL = 2

ID	TUMOR THICKNESS (MM.)	DEFINITIVE PATHOLOGICAL LEVEL
S-76-009	0.65	2
S-75-015	0.40	2
S-74-067	0.30	2
S-74-062	0.50	2
S-74-056	0.35	2

TUMOR THICKNESS (MM.) = (0 . 0.76)



DEFINITIVE PATHOLOGICAL LEVEL = 3

ID	TUMOR THICKNESS (MM.)	DEFINITIVE PATHOLOGICAL LEVEL
S-76-001	0.65	3

---

TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)  
DEFINITIVE PATHOLOGICAL LEVEL = 3

ID	TUMOR THICKNESS (MM.)	DEFINITIVE PATHOLOGICAL LEVEL
S-75-027	0.80	3
S-73-010	1.00	3

---

TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)  
DEFINITIVE PATHOLOGICAL LEVEL = 4

ID	TUMOR THICKNESS (MM.)	DEFINITIVE PATHOLOGICAL LEVEL
S-75-032	2.15	4
S-75-024	2.20	4
S-75-001	3.50	4
S-73-038	1.75	4

---

TUMOR THICKNESS (MM.) = ( 5.00 . 15)  
DEFINITIVE PATHOLOGICAL LEVEL = 5

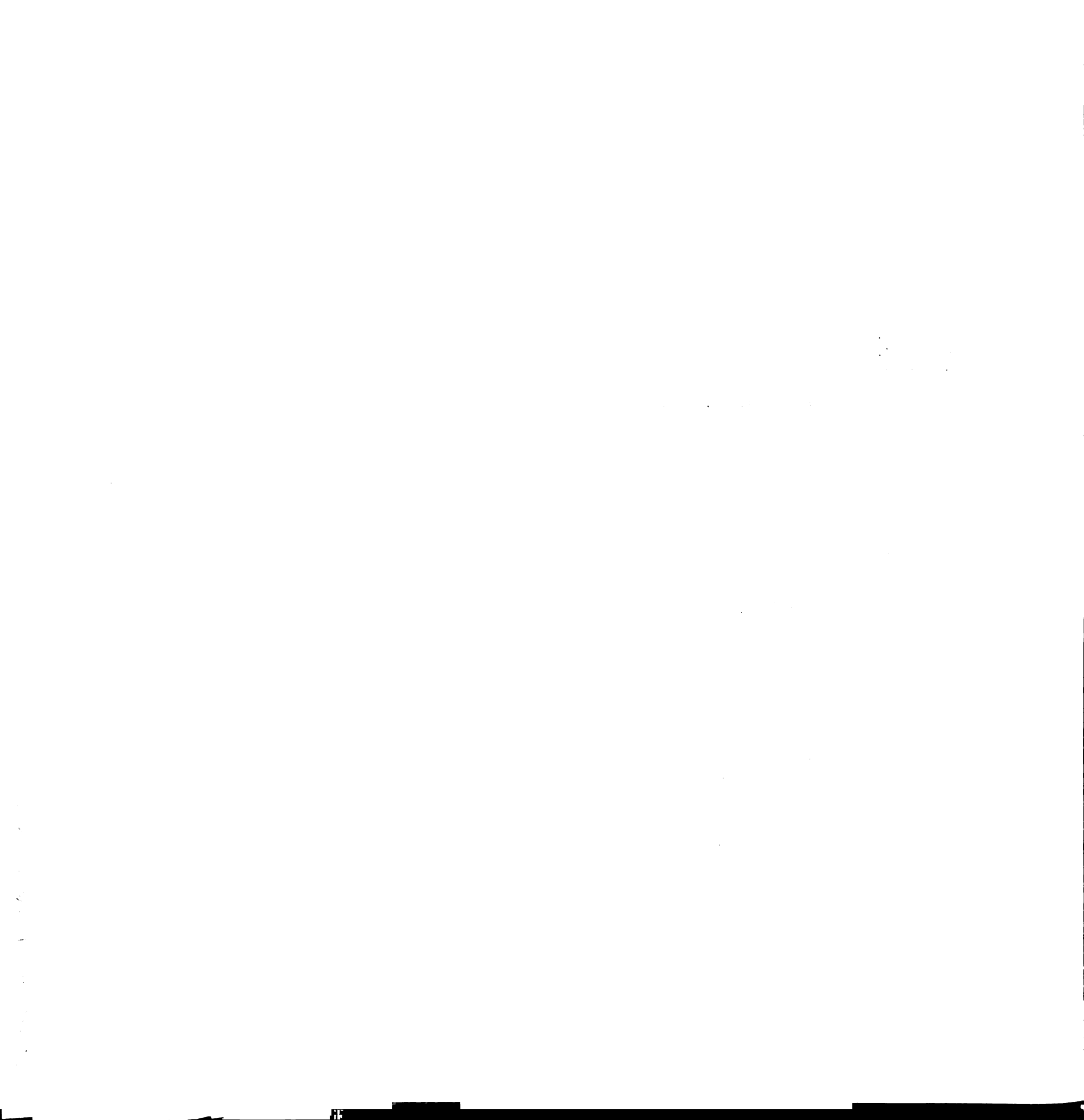
ID	TUMOR THICKNESS (MM.)	DEFINITIVE PATHOLOGICAL LEVEL
S-75-026	8.00	5

---

TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*  
DEFINITIVE PATHOLOGICAL LEVEL = 2

ID	TUMOR THICKNESS (MM.)	DEFINITIVE PATHOLOGICAL LEVEL
S-73-008	NAVAIL	2
S-72-011	NS	2

---



[Questions 8-11: Explore the possible influence of the presence/absence of regression of the primary on histologic recurrence in patients with level 2 or 3, and level 4 or 5 melanoma.]

8\_what percentage of pts with regression and level 2 or 3 had histologic recurrence?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with REGRESSION OF THE PRIMARY equal PRESENT and DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (2 3) had STATUS equal to a member of the set HISTOLOGIC.RECURRENCE DEAD).

10 case(s) were accepted  
2 case(s) satisfied the specified constraints  
0 case(s) were rejected due to missing or unspecified values.  
PERCENTAGE IS 20.00

9\_with no regression  
Trying Ellipsis: WHAT PERCENTAGE OF PTS WITH NO REGRESSION AND LEVEL 2 OR 3 HAD HISTOLOGIC RECURRENCE

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with REGRESSION OF THE PRIMARY equal ABSENT and DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (2 3) had STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD).

40 case(s) were accepted  
3 case(s) satisfied the specified constraints  
0 case(s) were rejected due to missing or unspecified values.  
PERCENTAGE IS 7.50

10\_what is the percent of cases with regression and level greater than 3 having histologic recurrence?

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with REGRESSION OF THE PRIMARY equal PRESENT and DEFINITIVE PATHOLOGICAL LEVEL greater than 3 had STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD).

5 case(s) were accepted  
3 case(s) satisfied the specified constraints





0 case(s) were rejected due to missing or unspecified values.  
PERCENTAGE IS 60.00

11\_calculate the percentage of people with level > 3 without regression who had histologic recurrence.

ANALYZED

MEDINQUIRY has interpreted your request as follows:

What proportion of patients with DEFINITIVE PATHOLOGICAL LEVEL greater than 3 and REGRESSION OF THE PRIMARY equal ABSENT had STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD).

23 case(s) were accepted  
11 case(s) satisfied the specified constraints  
1 case(s) were rejected due to missing or unspecified values.  
PERCENTAGE IS 47.83

[Question 12: Study the relationship between extent of recurrent disease and the variables type of melanoma, level of invasion, and tumor thickness.]

12\_for all pts with recurrence, list the type of melanoma, level of invasion, tumor thickness and disease extent.

ANALYZED

MEDINQUIRY has interpreted your request as follows:

List the DEFINITIVE PATHOLOGICAL TYPE and DEFINITIVE PATHOLOGICAL LEVEL and TUMOR THICKNESS (MM.) and MONTHS SINCE INITIAL THERAPY and PATHOLOGIC STAGE for people with STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEFINITE.RECURRENCE DEAD).

I have 227 answers; do you want to see them all? no

[Question 13: A more specific request than the one posed in question 12 studies the relationship between the clinical course of disease over time for patients with histologic recurrence based on the variables tumor thickness and level of invasion.]

13\_for all pts with histologic recurrence, list the disease extent ordered by level of invasion and tumor thickness.

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Stratified by DEFINITIVE PATHOLOGICAL LEVEL and TUMOR THICKNESS (MM.) display the MONTHS SINCE INITIAL THERAPY and PATHOLOGIC STAGE for people with STATUS equal to a member of the set (HISTOLOGIC.RECURRENCE DEAD).

DEFINITIVE PATHOLOGICAL LEVEL = 2  
TUMOR THICKNESS (MM.) = ( 0 . 0.76)

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-75-015	2	0.40	19	IIID
S-73-005	2	0.75	0	IIB
S-73-005	2	0.75	21	IIC

---

DEFINITIVE PATHOLOGICAL LEVEL = 3  
TUMOR THICKNESS (MM.) = ( 0 . 0.76)

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-73-033	3	0.50	5	IC

---

DEFINITIVE PATHOLOGICAL LEVEL = 3  
TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-75-010	3	1.13	0	IIB
S-73-010	3	1.00	46	IIID

---

DEFINITIVE PATHOLOGICAL LEVEL = 3  
TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-74-091	3	1.50	4	ID
S-74-091	3	1.50	5	IIC

---

DEFINITIVE PATHOLOGICAL LEVEL = 4  
TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)



ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-75-013	4	1.50	10	NOT-APPLIC

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)

I have 25 answers; do you want to see them all? yes

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-75-030	4	1.65	0	IIB
S-75-018	4	1.75	2	IIB
S-75-018	4	1.75	12	IIB
S-75-018	4	1.75	16	IIB
S-75-007	4	2.55	0	IIB
S-75-007	4	2.55	5	IIB
S-75-007	4	2.55	12	IIID
S-75-007	4	2.55	20	IIID
S-75-001	4	3.50	0	IIC
S-74-079	4	3.30	1	IIB
S-74-063	4	3.00	28	IIID
S-74-051	4	2.75	2	IIC
S-74-051	4	2.75	19	IIC
S-74-051	4	2.75	23	IIC
S-74-051	4	2.75	24	IIC
S-74-051	4	2.75	29	IIC
S-74-051	4	2.75	31	IIC
S-74-051	4	2.75	32	IIC
S-74-051	4	2.75	38	IIIA
S-73-046	4	3.50	9	IIID
S-73-046	4	3.50	14	NOT-APPLIC
S-73-038	4	1.75	2	IIC
S-73-038	4	1.75	5	NOT-APPLIC
S-72-004	4	2.20	17	IIC
S-72-004	4	2.20	48	NOT-APPLIC

DEFINITIVE PATHOLOGICAL LEVEL = 4  
 TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-75-023	4	NAVAIL	35	IIC
S-75-002	4	NAVAIL	0	IIC
S-75-002	4	NAVAIL	11	NOT-APPLIC
S-73-042	4	NAVAIL	3	NOT-APPLIC
S-73-027	4	NAVAIL	27	NOT-APPLIC



S-73-011	4	NAVAIL	0	IIB
S-73-011	4	NAVAIL	34	IIID
S-73-003	4	NAVAIL	51	NOT-APPLIC

---

DEFINITIVE PATHOLOGICAL LEVEL = 5  
 TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-74-061	5	4.50	2	IIC

---

DEFINITIVE PATHOLOGICAL LEVEL = 5  
 TUMOR THICKNESS (MM.) = ( 5.00 . 15)

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-76-022	5	9.00	0	IIC
S-76-022	5	9.00	4	IIC
S-76-003	5	7.50	9	IIID
S-75-033	5	11.00	8	IB
S-75-033	5	11.00	9	IIB
S-75-026	5	8.00	2	ID
S-75-026	5	8.00	4	IIIC
S-75-026	5	8.00	21	IIID
S-75-025	5	6.50	0	IIB
S-75-004	5	12.40	0	IIB
S-74-066	5	12	1	IIC
S-74-066	5	12	7	IIC
S-74-066	5	12	19	NOT-APPLIC
S-73-040	5	12	19	NOT-APPLIC

---

DEFINITIVE PATHOLOGICAL LEVEL = 5  
 TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-73-013	5	NAVAIL	0	IIC
S-73-013	5	NAVAIL	5	IIC
S-73-013	5	NAVAIL	7	IIID
S-73-013	5	NAVAIL	8	NOT-APPLIC
S-72-014	5	NAVAIL	5	IIID
S-72-014	5	NAVAIL	6	IIID
S-72-014	5	NAVAIL	11	NOT-APPLIC
S-72-012	5	NAVAIL	42	IIID

---





DEFINITIVE PATHOLOGICAL LEVEL = NS  
 TUMOR THICKNESS (MM.) = ( 5.00 . 15)

ID	DEFINITIVE PATHOLOGICAL LEVEL	TUMOR THICKNESS (MM.)	MONTHS SINCE INITIAL THERAPY	PATHOLOGIC STAGE
S-75-006	NS	6.50	0	IIB

-----

[Question 14: Are factors such as age, tumor thickness, mitotic rate, and change in the characteristics of the primary of value in predicting outcome for patients with high risk primaries (level 4 or 5) who had no evidence of disease within 24 months? Study these data organized by thickness of the primary. Do any of these characteristics provide clues as to why these patients did not have recurrent disease?]

14 for pts with level 4 or 5 melanoma with no evidence of disease within 24 months, display the age, tumor thickness, mitotic rate, and change in the primary organized by tumor thickness.

ANALYZED

MEDINQUIRY has interpreted your request as follows:

Count the number of patients with STATUS not equal to a member of the set (HISTOLOGIC.RECURRENCE POSSIBLE.RECURRENCE DEAD DEFINITE.RECURRENCE) and MONTHS SINCE INITIAL THERAPY less than 25.

MEDINQUIRY has interpreted your request as follows:

Stratified by TUMOR THICKNESS (MM.) display the AGE (AT DIAGNOSIS) and TUMOR THICKNESS (MM.) and MITOSES and CHANGE IN LESION and CHANGE IN SIZE OF LESION and CHANGE IN ELEVATION OF LESION and CHANGE IN COLOR OF LESION and BLEEDING OF LESION and ULCERATION and ITCHING OF LESION and TENDERNESS OF LESION and TRAUMA TO SITE OF LESION for people with DEFINITIVE PATHOLOGICAL LEVEL equal to a member of the set (4 5).

TUMOR THICKNESS (MM.) = ( 0.77 . 1.25)

ID:	S-74-048	S-75-019
TUMOR THICKNESS (MM.):	1.00	1.00
AGE (AT DIAGNOSIS):	46	36
MITOSES:	MANY	FEW
CHANGE IN LESION:	YES	YES
CHANGE IN SIZE OF LESION:	INCREASE	NO CHANGE
CHANGE IN ELEVATION OF LESION:	NO CHANGE	INCREASE
CHANGE IN COLOR OF LESION:	NO	YES
BLEEDING OF LESION:	YES	NO
ULCERATION:	YES	NO
ITCHING OF LESION:	YES	YES

TENDERNESS OF LESION: NO NO  
 TRAUMA TO SITE OF LESION: NONE NONE

-----  
 TUMOR THICKNESS (MM.) = ( 1.26 . 1.50)

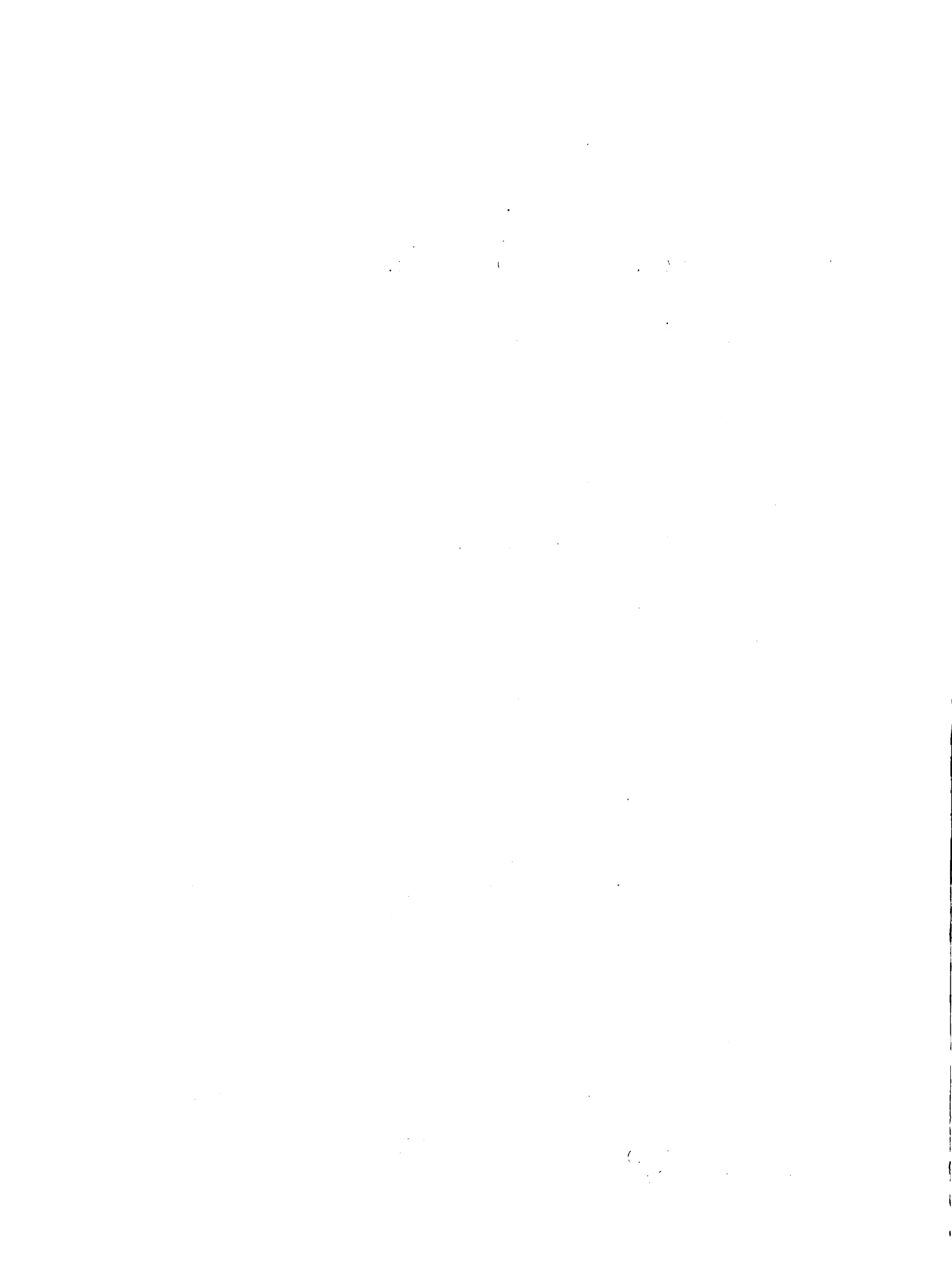
ID:	S-74-088	S-75-016
TUMOR THICKNESS (MM.):	1.50	1.35
AGE (AT DIAGNOSIS):	70	27
MITOSES:	FEW	MANY
CHANGE IN LESION:	YES	YES
CHANGE IN SIZE OF LESION:	INCREASE	INCREASE
CHANGE IN ELEVATION OF LESION:	INCREASE	INCREASE
CHANGE IN COLOR OF LESION:	NO	NO
BLEEDING OF LESION:	YES	YES
ULCERATION:	NO	NO
ITCHING OF LESION:	NO	NO
TENDERNESS OF LESION:	NO	YES
TRAUMA TO SITE OF LESION:	NONE	YES

-----  
 TUMOR THICKNESS (MM.) = ( 1.51 . 4.99)

ID:	S-74-063	S-74-087	S-74-089	S-75-008
TUMOR THICKNESS (MM.):	3	2.45	3.00	2.30
AGE (AT DIAGNOSIS):	28	28	32	37
MITOSES:	MODERATE	FEW	MANY	MANY
CHANGE IN LESION:	YES	YES	YES	YES
CHANGE IN SIZE OF LESION:	INCREASE	INCREASE	INCREASE	INCREASE
CHANGE IN ELEVATION OF LESION:	INCREASE	INCREASE	NO CHANGE	INCREASE
CHANGE IN COLOR OF LESION:	NO	YES	NO	NO
BLEEDING OF LESION:	NO	NO	YES	NO
ULCERATION:	NO	NO	YES	NO
ITCHING OF LESION:	NO	YES	YES	NO
TENDERNESS OF LESION:	NO	YES	YES	NO
TRAUMA TO SITE OF LESION:	YES(MORE)	NONE	YES(MORE)	NONE

ID:	S-75-017	S-75-024	S-75-032	S-75-034
TUMOR THICKNESS (MM.):	2.00	2.20	2.15	2.55
AGE (AT DIAGNOSIS):	66	57	61	43
MITOSES:	MANY	MANY	MODERATE	MODERATE
CHANGE IN LESION:	YES	YES	YES	YES
CHANGE IN SIZE OF LESION:	NO CHANGE	INCREASE	INCREASE	INCREASE
CHANGE IN ELEVATION OF LESION:	NO CHANGE	NO CHANGE	INCREASE	INCREASE
CHANGE IN COLOR OF LESION:	NO	YES	NO	YES
BLEEDING OF LESION:	YES	YES	YES	YES
ULCERATION:	YES	YES	YES	YES
ITCHING OF LESION:	NO	YES	YES	YES
TENDERNESS OF LESION:	NO	YES	NO	NO
TRAUMA TO SITE OF LESION:	NONE	YES(MORE)	CHRONIC	YES(MORE)

ID:	S-75-039	S-75-041
TUMOR THICKNESS (MM.):	4.00	1.90
AGE (AT DIAGNOSIS):	64	20



MITOSES:	MODERATE	MANY
CHANGE IN LESION:	YES	YES
CHANGE IN SIZE OF LESION:	INCREASE	INCREASE
CHANGE IN ELEVATION OF LESION:	INCREASE	INCREASE
CHANGE IN COLOR OF LESION:	YES	YES
BLEEDING OF LESION:	NO	YES
ULCERATION:	NO	NO
ITCHING OF LESION:	NO	NO
TENDERNESS OF LESION:	YES	NO
TRAUMA TO SITE OF LESION:	YES(MORE)	YES(MORE)

-----

TUMOR THICKNESS (MM.) = ( 5.00 . 15)

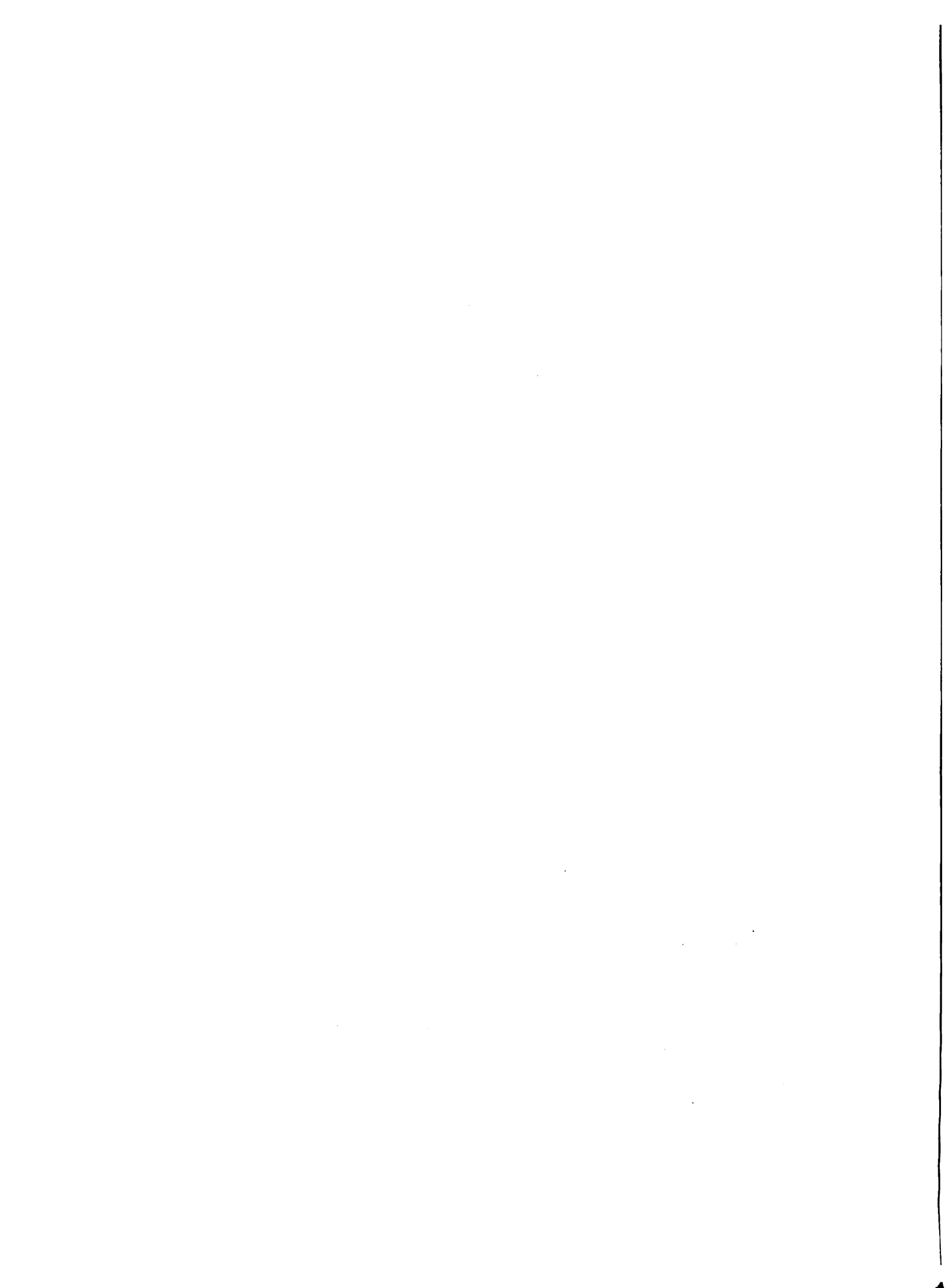
ID:	S-73-020
TUMOR THICKNESS (MM.):	6.60
AGE (AT DIAGNOSIS):	49
MITOSES:	MANY
CHANGE IN LESION:	YES
CHANGE IN SIZE OF LESION:	NO CHANGE
CHANGE IN ELEVATION OF LESION:	INCREASE
CHANGE IN COLOR OF LESION:	YES
BLEEDING OF LESION:	YES
ULCERATION:	YES
ITCHING OF LESION:	YES
TENDERNESS OF LESION:	NO
TRAUMA TO SITE OF LESION:	YES(MORE)

-----

TUMOR THICKNESS (MM.) = \*MISSING-VALUES\*

ID:	S-72-012	S-73-003	S-73-022	S-73-034
TUMOR THICKNESS (MM.):	NAVAIL	NAVAIL	NAVAIL	NAVAIL
AGE (AT DIAGNOSIS):	35	42	77	21
MITOSES:	MANY	FEW	ABSENT	FEW
CHANGE IN LESION:	YES	YES	YES	YES
CHANGE IN SIZE OF LESION:	INCREASE	INCREASE	INCREASE	INCREASE
CHANGE IN ELEVATION OF LESION:	INCREASE	NO CHANGE	INCREASE	INCREASE
CHANGE IN COLOR OF LESION:	YES	YES	NO	YES
BLEEDING OF LESION:	NO	YES	NO	NO
ULCERATION:	NO	YES	NO	NO
ITCHING OF LESION:	YES	YES	NO	NO
TENDERNESS OF LESION:	NO	YES	NO	NO
TRAUMA TO SITE OF LESION:	UNKNOWN	NONE	NONE	YES(ONCE)

ID:	S-74-052	S-74-059	S-74-077
TUMOR THICKNESS (MM.):	NS	NAVAIL	NAVAIL
AGE (AT DIAGNOSIS):	38	21	43
MITOSES:	FEW	FEW	MANY
CHANGE IN LESION:	YES	YES	YES
CHANGE IN SIZE OF LESION:	INCREASE	INCREASE	INCREASE
CHANGE IN ELEVATION OF LESION:	NO CHANGE	NO CHANGE	INCREASE
CHANGE IN COLOR OF LESION:	YES	YES	NO
BLEEDING OF LESION:	YES	NO	NO



ULCERATION:	NO	NO	NO
ITCHING OF LESION:	YES	NO	NO
TENDERNESS OF LESION:	NO	NO	YES
TRAUMA TO SITE OF LESION:	YES		
UNKNOWN	NONE		

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15 finished  
ANALYZED

End of transcript file Sun 10-Jun-1979 17:49:39-PDT



