

Among the virtues of production rules<sup>6</sup> are (1) their modularity allows easy addition and modification of inferential knowledge and (2) they can be written in such a way that their grain size seems appropriate for explanation systems. As we move toward hierarchical reasoning methods the grain size of individual production rules seems too small for coherent explanations. Just as the reasoning methods work with abstractions to reduce the combinatorics, explanations of this should also be abstract.

At present, the problem of factoring knowledge is an opaque art. When a frame-structured representation is used, a knowledge engineer makes decisions about what facts to group together. This decision takes into account indexing during problem solving and the interactions among items in the knowledge base. In hierarchical reasoning methods knowledge is viewed with a varying grain size; it starts with an abstract conceptualization at the beginning of problem solving and moves toward finer detail as the solution proceeds. Although we have some understanding of how to organize a body of knowledge hierarchically, much work remains to be done to make the best use of that organization during knowledge acquisition and problem solving.

#### Matching representation methods to problems

In our current systems, a knowledge engineer must learn the particulars about a problem and then pick or develop an appropriate representation. We would like to extend current AI ideas in the design of a system which takes more responsibility for choice of representation. Such a system will select or modify its representations combining the knowledge of the limits and advantages of representations with the knowledge of its own needs.

#### IV.C.2. Reasoning

In Section IV.B.2.} we traced our research on methods of reasoning from the Generate-and-Test paradigm (DENDRAL, GAL), to backwards chaining (MYCIN, EMYCIN, PUFF), to the cooperative knowledge sources model (CRYALIS, HASP, AGE-1). In this section we discuss core issues related to these reasoning models as well as some ideas for new models.

#### Incomplete Reasoning

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<sup>6</sup>See [16] for a discussion of different ways of using this formalism.

One of the themes in all of our methods of reasoning is the treatment of inexact and incomplete knowledge. One of the difficulties which we have perceived in MYCIN's simple CF model is that the representation is inadequate for discriminating between (1) absence of evidence and (2) evidence of absence. This example illustrates how the needs of the reasoning program have to influence the fundamental representations used in the system.

#### Reasoning with Abstractions

The availability of the Unit Package [52] has broadened our capabilities for representing abstractions. For example, an organism can be variously described as "a bacterium", "E.coli K-12", "a bacterium that is grampositive", or even "a bacterium with a vector which has the rat-insulin gene". A reasoning program can use the descriptions available in the Unit Package as abstractions in its reasoning process. We are currently using this idea in the MOLGEN project for reasoning about experiment planning.

#### Orthogonal Planning

One of the themes in our representation work is to make knowledge explicit for general processing. We have carried this theme into an experimental framework for reasoning being developed currently in the MOLGEN project. The idea is to make the reasoning operations, which are carried out by a planner, explicit in the knowledge base. These operators then implicitly define an abstract "planning space". Our hope is that this will provide a computer with a planning method more powerful and flexible than previous hierarchical planning methods. The feasibility of this approach is currently being tested.

#### Matching Reasoning Methods to Problems

One of our long term goals in developing and understanding reasoning methods is to develop a theory for matching reasoning methods to problems. Such a program would combine knowledge of the limitations of available reasoning frameworks with the needs of an application to aid in the design of a knowledge based system. We have started on this problem with the research of the AGE project within the HPP.

### IV.C.3. Knowledge Acquisition and Management

In Section IV.B.3., we traced our work on knowledge acquisition from the DENDRAL program, where knowledge was acquired by a knowledge engineer and then programmed into the system, to the PUFF example where the EMYCIN package greatly accelerated the creation of a consultation system for pulmonary function diagnosis.

#### Three Phases of Knowledge Acquisition

As a result of our recent experiences with the SACON program [3], we have found it useful to characterize the knowledge acquisition process as occurring in three distinct phases. We have done the most research on the third phase and plan to work our way towards the first phase.

- (1) Framework Identification. The first phase corresponds to making initial decisions about the typical advice the consultant will give and the major reasoning steps the consultant will use.
- (2) Acquisition of Fundamental Concepts. This is followed by an extended period of defining parameters and objects. These objects form the fundamental vocabulary of the domain. Using this initial domain vocabulary, a substantial portion of the rule base is developed. This process, captures enough domain expertise to allow the consultation system to give advice on the large number of common cases.
- (3) Acquisition in a Well-Developed Knowledge Base. In the final phase, further interactions with the expert tend to refine and adjust the established rule base, primarily to handle more obscure or complicated cases. In this phase, the system can draw on examples from the knowledge base to guide the acquisition process.

Previous work on the TEIRESIAS program [15], which explored one possible method for handling the "final phase", will provide the basis for our research in knowledge acquisition. This phase of the acquisition task utilizes the large body of knowledge to set the appropriate context for understanding new facts.

#### Consistency

Developing an understanding of the automatic management of knowledge during and after its acquisition is an important aspect of our research aims. The knowledge base consists of the totality of concepts and relations between concepts that have been presented to the program. We will investigate methods for determining the consistency of the aggregate knowledge base.

The quality of the knowledge base is improved through experimentation. Cases are run (for medical domains) by selecting a diverse set of patients and comparing the results to the conclusions of our expert. When the results don't match, the knowledge base must be updated to account for those changes. Two operations are important for this process: (1) the ability to determine the piece or pieces of knowledge that must be changed and (2) determining that changing the knowledge to correct the results on one patient will not produce incorrect results when applied to another patient.

Another possibility is to identify and, in effect, live with inconsistency, just as people apparently do. Predominantly rational behavior may be evinced by a system which does not satisfy consistency requirements. The key test is whether the elimination of any "inconsistent" rule makes the system behave better or worse in the long run. This is closely tied to consensus-formation, as discussed in the next section.

#### IV.C.4. Multiple Uses of a Knowledge Base

We are exploring many additional uses of the knowledge base beyond the performance aspects for which we acquired the knowledge. Three areas are of interest: using the knowledge for explanation of the reasoning steps of the program, using the knowledge for intelligent teaching about the domain, and using the knowledge base as a vehicle for building consensus among experts.

##### Explanation

The use of explicit inference rules in a knowledge base has made it possible to generate an explanation of the program's reasoning steps. While this has been achieved in the "backwards chaining" reasoning model, it is more difficult in the reasoning methods which reason hierarchically. We will examine methods for modifying the level of explanation based on the abstractions used by the program and a model of the user.

### Tutoring

The act of explaining the knowledge has led to the problem of using the knowledge base for tutoring purposes. Our initial experiment with this in the MYCIN framework [12] demonstrates the potential educational value of this use of the knowledge base. Under another proposal (pending to ONR & ARPA) we will be exploring strategies for presenting the contents of a knowledge base represented as a set of rules. Here we propose to extend those methods for relating to the user the contents of knowledge bases stored in other representations.

### Consensus Building

We propose to investigate approaches for building consensus among experts. Because the strength of consultation programs will in large part lie with their ability to pool knowledge from several sources, it is important to recognize apparent differences of opinion among experts and to assist, when possible, with arriving at a consensus. This represents another version of the consistency checking problem: comparing the ramifications of multiple versions of knowledge and providing the capability to guide an interaction in which such differences are "ironed out". Of course there may be times when both versions of the knowledge may need to be stored and appropriately flagged so that users can select which experts' opinion they will follow during a consultation. The experts may wish to select a style of reasoning (e.g., empirical vs theoretical), rather than a particular individual's set of rules. Ultimately, the system itself may be able to choose from differing advice in its knowledge base.

All of these areas require some augmentation to the knowledge base to provide the causal reasoning steps upon which the knowledge is tied. This allows a program to explain why a particular rule was written in addition to telling how the rule was used to make a particular conclusion. Similar needs have been shown in the use of a rule base for tutoring and for determining consensus among experts [37]. Often, a rule will be put into the system cast in a much more specific form than that to which the knowledge truly applies. One task to investigate is how to generalize to just the proper level. More complex still are the subtle changes that accompany a rule as it is generalized (e.g., changing certainty factors).

IV.D. Significance

The significance of this work is twofold:

1. Understanding how to represent inexact and incomplete knowledge symbolically so that a system can perform complex intelligent processes — like diagnosis and explanation. This work expands the boundaries of what we understand how to do with computers.
2. Investigating the fundamental questions that underlay the development of domain-independent tools of AI discussed elsewhere in this proposal.

One of our ultimate goals is to understand the techniques employed in building such programs. It has always been difficult to determine if a particular problem-solving method used in a particular knowledge-based program is domain-specific or whether it can generalize easily to other domains. In current knowledge-based programs, the domain knowledge and the manipulation of it using AI techniques are often so intertwined that it is difficult to uncouple them, to make a program useful for another domain. This long range goal, then, is to isolate AI techniques that are general, to determine the conditions for their use; to build up a knowledge base about AI techniques themselves. We will carry out our research with this question in mind: what are the criteria determining whether a particular problem-solving framework and representation system is suitable for a particular application?

V. FACILITIES AVAILABLEV.A. Hardware

All computing work will be carried out initially on the SUMEX facility, a dual processor DEC KI-10 system running TENEX. The system is located at Stanford, but is supported by NIH under grant RR-0785 as a national resource for the study of applications of artificial intelligence to problems in biology and medicine. It has available a wide variety of advanced programming languages (e.g., INTERLISP, SAIL), and support programs (e.g., text editors), as well as powerful file handling and storage management capabilities. Resources available at no cost to this program include CPU usage and disk storage, while access is via local dial-up lines and three networks (TYMNET, TELENET, and ARPANET).

Within the next 18 months the SUMEX installation is also scheduled to receive a PDP-20/20 system that will be interfaced with the currently existing PDP-10. The new machine is intended for service-related applications of artificial intelligence to medicine, and some of our programs, once operational, would most appropriately be run on this machine. The machine will be used by other projects, however, and may occasionally be scheduled for sole use by one of these. Thus SUMEX can make no commitment to provide scheduled service to medical personnel wishing to use the programs routinely. The PDP-20/20 hence will function as a prototype for the kind of dedicated small machine that may eventually operate in the clinic.

V.B. Software and Personnel

Our proposal is to build on the knowledge representation and control techniques developed during work on the MYCIN, Molgen, PUFF, and AGE systems in the Heuristic Programming Project. New programs and data structures will, of course, be required. Starting with existing software packages, however, is a considerable advantage over developing the software - and design experience - de novo. The base language will continue to be INTERLISP.

In addition to the computing power and the large collection of existing software, access to the SUMEX system also offers the

benefit of being a part of the SUMEX-AIM community. The SUMEX user community includes a wide range of researchers in artificial intelligence united by a number of common interests. We have found our interchanges with them in the past to be very useful, and expect this to continue.

VI. COLLABORATIVE ARRANGEMENTS

Formal collaboration with Dr. Lindberg's group at the University of Missouri is the natural result of many years of informal exchange. The formal arrangement between the two institutions is that Dr. Lindberg's project will be funded as a subcontract from Stanford, with budget as indicated in the budget section.

There is a long history of successful collaboration between the Stanford Medical School and the Computer Science Department. The SUMEX Computer Facility is a physical demonstration of this collaboration, while the large number of interdisciplinary research publications is more evidence. In part, this is due to the physical proximity of the two groups; but more importantly, it is due to common interests and common goals. The SUMEX facility itself has removed many of the communication barriers which often halt interdisciplinary research.

Sec. VII.

P.I. Assurance

VII. PRINCIPAL INVESTIGATOR ASSURANCE

The undersigned agrees to accept responsibility for the scientific and technical conduct of the research project and for provision of required progress reports if a grant is awarded as the result of this application.

Jan. 30, 1979  
Date

Edward A. Feigenbaum  
Principal Investigator

VIII. APPENDICES

VIII.A. APPENDIX A -- Annotated MYCIN Typescript

In the following pages we have included many detailed examples of the MYCIN program in operation. These exemplify both the accomplishments and the limitations of the work we have done so far. Although we are not proposing expansion of the program's infectious disease knowledge at this time, these examples should help illustrate the kinds of capabilities that we intend to develop in a system for oncology protocol management.

The examples in this appendix include the following:

Section I - A sample production rule, translated into English.

Section II - Instructions printed for new users if they request assistance when trying MYCIN for the first time.

Section III - Free-text case summary that may be entered by a physician for purposes of case identification in the future.

Section IV - Detailed example of a consultation session for a patient with meningitis; the WHY and HOW commands of the reasoning-status checker (RSC) are also demonstrated.

Section V - Interactive session with the general question answerer (GOA) regarding the consultation session in Section IV.

Section VI - Example of MYCIN's ability to assist with antibiotic dosage modification in renal failure patients; note that the program can also explain its decisions at this specialized task.

Section VII - Example of a graphical option we have developed which permits interested physicians to display a chart estimating the steady state blood levels of an antibiotic at a variety of regimens for modified dose or dosing interval.

Section VIII - Example of a subsystem of MYCIN in which the user can circumvent much of the extensive consultation session demonstrated in Section IV. If a physician is relatively certain of the infection and organisms to be treated, he may specify these as shown and MYCIN will simply assist with therapy selection.

Section IX - Example of MYCIN's ability to rerun previously stored patients and to interact with an expert when a problem in performance is identified. Note that MYCIN and the expert have a "discussion" in which a missing rule is identified. The physician tells MYCIN the missing rule (in English) and the program translates it into its internal LISP representation. The case is then run again to see if the performance improves with the new rule in place.

## I. Sample Rule with Additional Stored Information

RULE300

[This rule applies to all cultures and suspected infections, and is tried in order to find out about the organisms (other than those seen on cultures or smears) which might be causing the infection]

- If: 1) The infection which requires therapy is meningitis, and  
2) The patient does have evidence of serious skin or soft tissue infection, and  
3) Organisms were not seen on the stain of the culture, and  
4) The type of the infection is bacterial

Then: There is evidence that the organisms (other than those seen on cultures or smears) which might be causing the infection is staphylococcus-coag-pos (.75) streptococcus-group-a (.5)

Author: YU

Literature: G. Karalazin "Sickle-cell anemia - CLINICAL MANIFESTATIONS IN 100 PATIENTS" AmJMedSci 269:51 1975.

E. Barret-Connor "Acute pulmpnary disease and sickle-cell anemia" ARRD 104:159 Aug 1971.

M. Robinson "Pneumococcal meningitis in sickle-cell anemia"NEJM 274:1006 1966.

II. Instructions for Users at the Start of  
Infectious Disease Consultation (Optional)

MYCIN 3-Jun-78 ...

Special options (type ? for help):

\*\*

Instructions? (Y or N)

\*\* YES

This is a computer program named MYCIN that has been designed to advise you regarding an appropriate choice of infectious disease therapy. It is understood that you have a patient who may have an infection. Please answer the following questions, terminating each response with RETURN. To correct typing errors, use the DELETE key to delete single characters, <ctrl>W to delete a word, and <ctrl>C to delete the whole line.

If you are not certain of your answer, you may modify the response by inserting a certainty factor (a number from 1 to 10) in parentheses after your response. Absolute certainty (10) is assumed for every unmodified answer. It is likely that some of the following questions can not be answered with certainty.

You may change an answer to a previous question in two ways. If the program is waiting for a response from you (that is, has typed "\*\*\*"), enter CHANGE followed by the number(s) of the question(s) whose answers will be altered. You may also change a previous answer at any time (even when the program is not waiting for a response from you) by typing <ctrl>F (Fix), which will cause the program to interrupt its computation and ask what you want to change. (If the response to <ctrl>F is not immediate, try typing the RETURN key in addition.) Try to avoid going back because the process requires reconsidering the patient from the beginning and therefore may be slow.

Note that you may also enter UNK (for UNKNOWN) if you do not know the answer to a question, ? if you wish to see a more precise definition of the question or some examples of recognized responses, ?? if you want to see all recognized responses, the word RULE if you would like to see the decision rule which has generated the question being asked, the word WHY if you would like to see a more detailed explanation of the question, or the letters QA if you would like to interrupt the consultation in order to ask questions regarding the decisions made so far in the consultation. If you are ever puzzled about what options are available to you during a consultation, enter the word HELP and a list of options will be listed for you.

Sample Response [user input follows the "\*\*\*"]

Does the patient have a risk factor for tuberculosis?

\*\*?

One or more of the following are considered risk factors for tb:

a) positive PPD (STU), b) history of close contact with a

person having active tb, c) household member with a past history of active tb, d) chest X-ray showing apical scarring, e) granulomas seen on biopsy of any organ tissue.

expected responses are: YES NO  
Enter HELP for user options.  
\*\* YES

## SUMMARY:

(type ctrl-O to abort printout)  
UNK - answer not known  
? - Rephrases the question and gives examples of recognized responses  
?? - prints a list of all recognized responses  
RULE - prints the current decision rule  
QA - program enters question-answering mode  
CHANGE - go back and re-request answer to question number  
COMMENT - enter comments about any aspect of the system's performance. Your comments will be forwarded to those in charge of the MYCIN program.  
WHY - gives high-level explanation of the current reasoning chain that provoked this question.  
HOW - explains HOW the system will achieve a goal referred to by number in a previous explanation.  
EXPLAIN - provides a more detailed explanation of a previous answer given by a WHY command.  
FORGET - resets the explanation of the reasoning chain back to the lowest level, as if you never used the WHY/EXPLAIN commands.  
STOP - Halts the program without completing the consultation.  
SAVE - Halts the program, saving the current patient on a disk file, retrievable at a later date.  
HELP - Prints this list

## III. User's Description of Patient

This will be patient 538

If you would care to enter a brief summary of PATIENT-538's case, to be used for easy future reference to this file, please do so now (type as many lines as required, terminate with a control-Z):

\*\* 34 yr old white male with severe burn. After 15 days  
\*\* of hospitalization pt became disoriented and febrile. On 16th  
\*\* hospital day LP performed. PMN 100, PMN%99, Pro 280, Glu 5 (periph  
\*\* blood glu unk). WBC 1900 with 88% PMN and 5% bands. Pt had drug-  
\*\* induced aplastic anemia. Current med at time of LP: Cephalothin.  
\*\* Final org: Pseudomonas-aeruginosa. Correct Rx: Ideal would have been  
\*\* Carb + Tobra (or Genta). Same as pt 504 except gram stain of CSF  
\*\* omitted.  
Z  
\*\*

IV. Infectious Disease Consultation Session  
 [User's responses follow double asterisks]

-----PATIENT-538-----

1) Patient's name:

\*\* PT538

2) Age:

\*\* 34 YEARS

3) Sex:

\*\* MAEL

=MALE

4) Race:

\*\* WHY

[i.e. WHY is it important to determine the race of PATIENT-538?]

[1.0] The race of a patient is one of the 5 standard parameters that identify a patient.

This may be useful later in the consultation. For example, it is relevant in determining the organisms (other than those seen on cultures or smears) which might be causing the infection.

[back to question 4...]

\*\* CAUCASIAN

Please supply one answer under each heading. If your response is not understood, you will be prompted by the standard questioning method. (enter ? for normal prompting, \* for questions that are not applicable).

Please enter the results of positive cultures using the following table.

site	culture number	date collected	date  positive	method  of collection [urine,sputum only]
5)**	DONE			

Please enter the results of pending cultures in the following table.

site	culture number	date collected	stain  examined	method of  collection [urine,sputum only]
6)**	CSF	1234	30-Jan-77	YES

stain of morph|

smear

[type DONE if no organism was seen on the smear]

7)\*\*

site	cul	date coll.	smear examined?	coll. method
8)**	DONE			

Please enter negative cultures in the following table.

site	culture number	date  collected	method of  collection [urine,sputum only]
9)**DONE			
10) Do you suspect Pt538 may have an infection at a site from which you have not obtained culture specimens?			
** NO			

Please enter information on current antimicrobials.

drug name	route of administration	date  started
11)** CEPHALOTHIN	IV	23-Jan-77
12)**DONE		

Please enter information on prior antimicrobials.

drug name	route of administration	date started	date  stopped
13)**DONE			

[Considering organisms (other than those isolated from cultures) which might be present...]

- 14) Has Pt538 recently had symptoms of persistent headache or other abnormal neurologic symptoms (dizziness, lethargy, etc.)?  
\*\* YES
- 15) Has Pt538 recently had objective evidence of abnormal neurologic signs (nuchal rigidity, coma, seizures, etc.) documented by physician observation or examination?  
\*\* YES

The CSF cultures will be considered to be associated with MENINGITIS.

- 16) Please give the date on which clinical evidence (symptoms, signs, or laboratory tests) of the meningitis first appeared.  
\*\* 29-Jan-77 22:15
- 17) Does Pt538 have an abnormal chest X-ray?  
\*\* NO
- 18) Does Pt538 have one or more of the following risk factors for tb: a) positive intermediate strength PPD, b) history of close contact with a person with active tb, c) a household member with a past history of active tb, d) apical scarring on chest xray, e) history of granulomas on biopsy of liver, lymph node, or other organs.?  
\*\* NO
- 19) Does Pt538 have any cutaneous lesions or rash on physical examination?  
\*\* NO
- 20) Does Pt538 have evidence of ocular nerve dysfunction?  
\*\* NO
- 21) Is Pt538 a compromised host (e.g. alcoholic, sickle-cell-disease, immunosuppressed)?  
\*\* YES
- 22) Is Pt538 immunosuppressed (e.g. corticosteroid therapy, cytotoxic drug

therapy, radiation therapy, leukemia, lymphoma)?

\*\* NO

23) For how many days has Pt538 had abnormal neurologic signs?

\*\* 7.2 HOURS

24) For how many days has Pt538 had neurologic symptoms?

\*\* 1 DAYS

25) Has Pt538 had recent evidence of tender or enlarged salivary glands?

\*\* NO

26) Has Pt538 been exposed to any contagious disease recently (e.g. meningococcal disease, mumps) ?

\*\* NO

Please enter CSF findings in the following table

	CSF WBC	Percent PMN	Protein	CSF Glucose	Peripheral Glucose
27)**	100	99	280	5	UNKNOWN

28) Do you know the results of a recent CBC of Pt538?

\*\* YES

Please enter CBC results in the following table

	WBC in 1000's	Percent PMN	Percent BANDS
29)**	1.9	UNKNOWN	UNKNOWN

30) Has Pt538 had any injury or insult to, or defect in the central-nervous-system (excluding neurosurgery)?

\*\* NO

31) Has Pt538 ever undergone any type of surgery?

\*\* YES

32) Does Pt538 have a history of NEUROSURGERY?

\*\* NO

33) Does Pt538 live in a crowded environment?

\*\* NO

34) Do you suspect recent alcoholic history in Pt538?

\*\* NO

35) Is meningitis a hospital-acquired infection?

\*\* WHY

[i.e. WHY is it important to determine whether the infection was acquired while the patient was hospitalized?]

[2.0] This will aid in determining the organisms (other than those seen on cultures or smears) which might be causing the infection.

It has already been established that

[2.1] the infection which requires therapy is meningitis, and

[2.2] organisms were not seen on the stain of this pending csf culture, and

[2.3] the type of the infection is bacterial, and

[2.4] neurosurgery is not one of the relevant items from the history of pt538, and

[2.5] the age of pt538 is greater than 10 days

Therefore, if

[2.6] the infection was acquired while the patient was hospitalized

then

there is evidence that the organisms (other than those seen on cultures or smears) which might be causing the infection is e.coli (.75) staphylococcus-coag-pos (.3) pseudomonas-aeruginosa (.3) klebsiella-pneumoniae (.5)

Author: Yu  
[RULE545]

[back to question 35...]  
\*\* HOW 2.3

[i.e. HOW was it established that the type of the infection is bacterial?]

The following rules concluded about:  
the likelihood that the type of the infection is bacterial

	Rule	Yes	No
[2.7]	RULE148	(.19)	
[2.8]	RULE500	(.51)	
[2.9]	RULE501	(.95)	
[3.0]	RULE502	(.97)	
[3.1]	RULE526	(.98)	
[3.2]	RULE504	(.97)	
[3.3]	RULE524	(.98)	

Thus, is has been established that the type of the infection is bacterial.

[back to question 35...]  
\*\* HOW 2.5

[i.e. HOW was it established that the age of pt538 is greater than 10 days?]

In answer to question 2 you said that the age of pt538 is 34 years

Thus, it has been established that the age of pt538 is greater than 10 days.

[back to question 35...]  
\*\* Y

36) Is Pt538's clinical history consistent with EPIGLOTTITIS?

\*\* NO

37) Is Pt538's clinical history consistent with OTITIS-MEDIA?

\*\* NO

38) Has Pt538 ever undergone splenectomy?

\*\* NO

39) Is Pt538 a burn patient?

\*\* WHY

[i.e. WHY is it important to determine whether PATIENT-538 has been seriously burned?]

[4.0] This will aid in determining the organisms (other than those seen on cultures or smears) which might be causing the infection.

It has already been established that  
 [4.1] the infection which requires therapy is meningitis, and  
 [4.2] organisms were not seen on the stain of this pending csf culture,  
 and  
 [4.3] the type of the infection is bacterial  
 Therefore, if  
 [4.4] pt538 has been seriously burned  
 then  
 there is suggestive evidence (.5) that pseudomonas-aeruginosa is one  
 of the organisms (other than those seen on cultures or smears)  
 which might be causing the infection

Author: Yu

[RULE578]

[back to question 39...]

\*\* WHY

[i.e. WHY is it important to determine the organisms (other than those seen  
 on cultures or smears) which might be causing the infection?]

[5.0] ... in order to determine the therapeutic regimen of PATIENT-538.

If

[5.1] information has been gathered about organisms isolated from the  
 patient, organisms noted on smears of the patient, negative  
 cultures of the patient, suspected infections without  
 microbiological evidence, current drugs of the patient and  
 prior drugs of the patient, and

[5.2] an attempt has been made to deduce the organisms which require  
 therapy, and

[5.3] You have given consideration to organisms (other than those  
 seen in cultures or smears) which might be present, and found  
 at least one organism which requires therapy.

then

determine the best therapy recommendation from among the drugs likely  
 to be effective against the significant organisms

[RULE092]

[back to question 39...]

\*\* Y

I have found evidence (RULE545 RULE557) that treatment should cover for E.coli  
 causing meningitis.

I have found evidence (RULE545 RULE557 RULE578) that treatment should cover  
 for Pseudomonas-aeruginosa causing meningitis.

I have found evidence (RULE545 RULE557) that treatment should cover for  
 Klebsiella-pneumoniae causing meningitis.

I have found evidence (RULE507) that treatment should cover for Diplococcus-  
 pneumoniae causing meningitis.

40) Does Pt538 have focal neurological signs?

\*\* UNKNOWN

[Determining which drugs are desirable for use against the E.coli...]

[Determining which drugs are desirable for use against the Pseudomonas-  
 aeruginosa...]

[Determining which drugs are desirable for use against the Klebsiella-  
 pneumoniae...]

[Determining which drugs are desirable for use against the Diplococcus-pneumoniae...]

My therapy recommendations will be designed to treat for organisms that either are very likely or, although less likely, would have a significant effect on therapy selection if they were present. It is important to cover for the following probable infection(s) and associated organism(s):

INFECTION-1 is MENINGITIS

- + <ITEM-1> E.COLI [from clinical evidence only]
  - + <ITEM-2> PSEUDOMONAS-AERUGINOSA [from clinical evidence only]
  - + <ITEM-3> KLEBSIELLA-PNEUMONIAE [from clinical evidence only]
  - + <ITEM-4> DIPLOCOCCUS-PNEUMONIAE [from clinical evidence only]
- 41) Does Pt538 have a clinically significant allergic reaction to any antimicrobial agent?

\*\* NO

[Considering AMPICILLIN-AND-GENTAMICIN for use against INFECTION-1...]

- 42) Do you have reason to suspect that Pt538 may have impaired renal function?

\*\* NO

- 43) Pt538's weight in kilograms (or <number> POUNDS):

\*\* 70

[REC-1] My preferred therapy recommendation is as follows:

In order to cover for Items <1 2 3 4>:

Give the following in combination:

1) AMPICILLIN

Dose: 3.5g (28.0 ml) q4h IV [calculated on basis of 50 mg/kg]

2) GENTAMICIN

Dose: 119 mg (3.0 ml, 80mg/2ml ampule) q8h IV [calculated on basis of 1.7 mg/kg] plus consider giving 5 mg q24h Intrathecal

Comments: Monitor serum concentrations

Since high concentrations of penicillins can inactivate aminoglycosides, do not mix these two antibiotics in the same IV bottle.

Do you wish to see the next choice therapy?

\*\* YES

Which, if any, of the above drugs do you wish eliminated from consideration?

\*\* AMPICILLIN

[Considering GENTAMICIN for use against INFECTION-1...]

[Considering PENICILLIN for use against INFECTION-1...]

[REC-2] Next best therapy recommendation:

In order to cover for Items <1 2 3>:

Give: GENTAMICIN

Dose: 119 mg (3.0 ml, 80mg/2ml ampule) q8h IV [calculated on basis of 1.7 mg/kg] plus consider giving 5 mg q24h Intrathecal

Comments: Monitor serum concentrations

In order to cover for Item <4>:

Give: PENICILLIN

Dose: 3.5 million units (7.0 ml) q4h IV [calculated on basis of 50000 units/kg]

RECOMMENDATION-2 is equivalent to RECOMMENDATION-1.

Would you like to see details of this comparison?

\*\* YES

Looking at the coverage of the most likely items, we see that:

RECOMMENDATION-1 consists of 1 first choice drug (AMPICILLIN for ITEM-1 and ITEM-4) and 1 third choice drug (GENTAMICIN for ITEM-1, ITEM-2 and ITEM-3)

RECOMMENDATION-2 consists of 1 first choice drug (PENICILLIN for ITEM-4) and 1 third choice drug (GENTAMICIN for ITEM-2, ITEM-1 and ITEM-3)

ORGANISMS	RECOMMENDATION-1	RECOMMENDATION-2
most likely'	Drug -- Choice Ranking	Drug -- Choice Ranking
ITEM-1	AMPICILLIN-AND-GENTAMICIN -- 1st	
		GENTAMICIN -- 3rd
ITEM-2	GENTAMICIN -- 2nd	GENTAMICIN -- 2nd
ITEM-3	GENTAMICIN -- 3rd	GENTAMICIN -- 3rd
ITEM-4	AMPICILLIN -- 1st	PENICILLIN -- 1st

(The desirability of a drug is defined to be its lowest ranking for the items it covers.)

Do you wish to see the next choice therapy?

\*\* NC

V. Answers to User's Questions about this Consultation and  
About the Knowledge Base

Please ask any simple-English questions regarding the above consultation session or the overall knowledge of the consultation system. When discussing the consultation above, please refer to organisms, cultures, etc. by their numeric names (eg. ORGANISM-1). Questions which were asked during the consultation may be specified by the numbers that preceded them above, (e.g., 'WHY DID YOU ASK QUESTION 1?'). Control-O will abort type-out, or 'cancel' the current question. Type HELP for a list of the options available. Enter the word STOP when you have no further questions.

Type HELP for the list of question options.

\*\* HELP

QA-OPTIONS:

(Type ctrl-O to abort printout)

ADVICE - prints suggestions for using the QA system effectively  
 QT - prints examples of question types recognized by the system  
 EQ <numbers> - prints an explanation of the specified question(s) from the consultation, e.g., EQ 8 13  
 LP <object type> - prints list of attributes associated with object type, e.g., LP CULTURE. (Object types are patient, infection, culture, organism, and drug.)  
 PR <numbers> - prints specified rule(s), e.g., PR 373 49 87 2  
 EXPLTHER - prints a short description of the therapy program  
 REC - prompts user for alternative therapy RECommendation and compares it to mycin's recommendation  
 RX <infection> <organism identities> - prints treatment lists for specified organisms causing the indicated infection, e.g., RX MENINGITIS ENTEROCOCCUS  
 JUSTIFICATION - when rules are printed out, include their justifications  
 LITERATURE - when rules are printed out, include their literature references  
 NOJUST - stop giving justification and/or literature with rules  
 TERSE - print rules in terse format  
 VERBOSE - turns off terse printing of rules  
 STOP - escape from QA-module  
 HELP - prints this list

\*\* JUSTIFICATION

\*\* LITERATURE

\*\* WHY DID YOU TREAT E.COLI?

ITEM-1 is E.coli associated with meningitis. I decided to treat ITEM-1 on the basis of clinical evidence only.

The following rules concluded about:

the likelihood that e.coli is one of the organisms (other than those

seen on cultures or smears) which might be causing the infection

RULE545 was used to conclude that e.coli is one of the organisms (other than those seen on cultures or smears) which might be causing the infection (.74). The last question asked before the conclusion was made was 35.  
 RULE557 was used to conclude that e.coli is one of the organisms (other than those seen on cultures or smears) which might be causing the infection (.93). The last question asked before the conclusion was made was 37.

The parameters most frequently used in these rules were:  
 the infection which requires therapy  
 whether a smear of the culture was examined  
 whether organisms were seen on the stain of the culture  
 the type of the infection

Would you like a summary of ALL the parameters used by these rules? \*\* YES

Parameter (rules with this parameter)

the white count from the patient's peripheral CBC (in thousands) (557)  
 whether the results of a recent CBC of the patient are available (557)  
 whether the infection was acquired while the patient was hospitalized (545)  
 the age of the patient (545)  
 the relevant items from the history of the patient (545)  
 the type of the infection (545, 557)  
 whether organisms were seen on the stain of the culture (545, 557)  
 whether a smear of the culture was examined (545, 557)  
 the infection which requires therapy (545, 557)

\*\* WHY DIDN'T YOU GIVE TETRACYCLINE FOR E.COLI IN REC-1?

Shall I describe the therapy algorithm for you? \*\* YES

DESCRIPTION OF THERAPY SELECTION

[Type cntrl-0 to abort printout]

MYCIN is designed to provide optimal therapy recommendations. The program uses the following three steps:

The first step ranks the drugs for each organism that requires therapy. Rules for doing this take into account invitro (lab) sensitivities and the patient's response to prior and current therapies. In the absence of other information, default lab sensitivities are used. Preference is given to current therapies if certain criteria are satisfied.

Next, 1 or 2 drugs are selected to cover for the organisms which are most likely to be causing the infection. As many of the "less likely" organisms as possible are treated, but they are disregarded altogether if 3 or more drugs are necessary. Throughout, preference is given to drugs that appear higher in the treatment lists. (These lists can be examined via the RX option.)

Finally, the set of drugs is tested for patient factors that preclude their administration, such as allergies, age, and renal function.

TETRACYCLINE was not prescribed for ITEM-1

TETRACYCLINE was not prescribed for ITEM-1 in RECOMMENDATION-1 because: