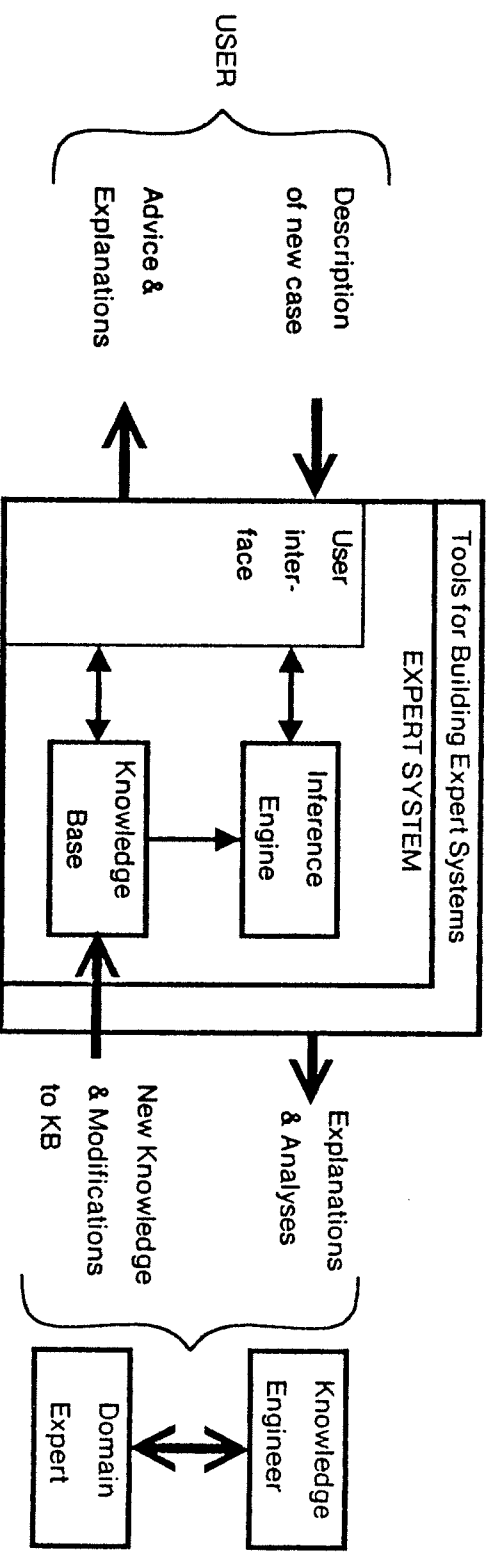
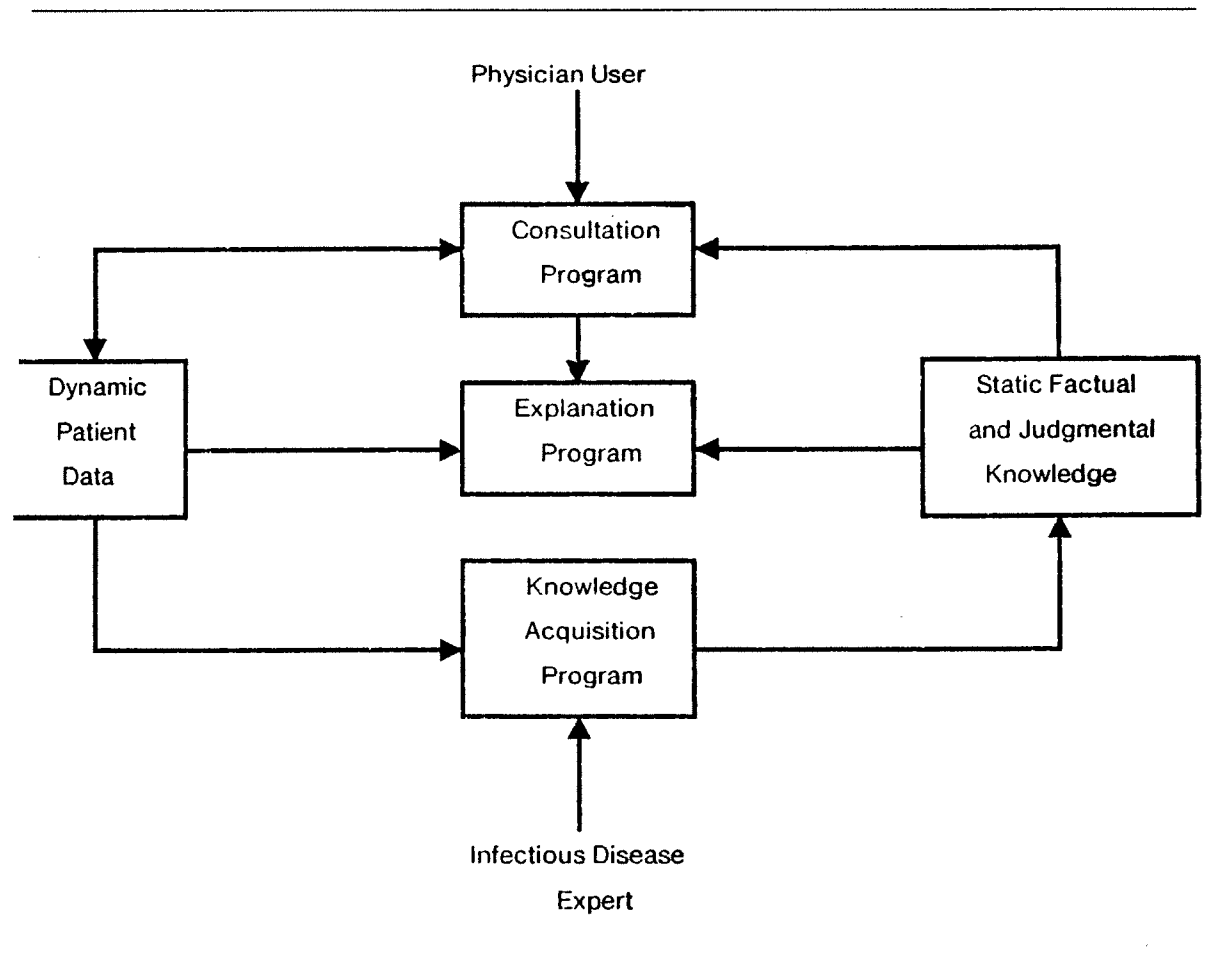


**FIGURE 1-1** Major parts of an expert system. Arrows indicate information flow.



**FIGURE 1-2** Interaction of a knowledge engineer and domain expert with software tools that aid in building an expert system. Arrows indicate information flow.



**FIGURE 4-1** Organization of the MYCIN system. Arrows denote information flow between modules, knowledge base, and users.

**RULE037**

IF: 1) The identity of the organism is not known with certainty, and  
2) The stain of the organism is gramneg, and  
3) The morphology of the organism is rod, and  
4) The aerobicity of the organism is aerobic  
THEN: There is strongly suggestive evidence (.8) that the class of the organism is enterobacteriaceae

**RULE145**

IF: 1) The therapy under consideration is one of: cephalothin clindamycin erythromycin lincomycin vancomycin, and  
2) Meningitis is an infectious disease diagnosis for the patient  
THEN: It is definite (1) the therapy under consideration is not a potential therapy for use against the organism

**RULE060**

IF: The identity of the organism is bacteroides  
THEN: I recommend therapy chosen from among the following drugs:

1 - clindamycin	(.99)
2 - chloramphenicol	(.99)
3 - erythromycin	(.57)
4 - tetracycline	(.28)
5 - carbenicillin	(.27)

1) Patient's name: (first-last)

**\*\* FRED BRAUN**

2) Sex:

**\*\* M**

3) Age:

**\*\* 55**

4) Are there any cultures for Fred Braun which may be related to the present illness, and from which organisms have been grown successfully in the microbiology laboratory?

**\*\* Y**

-----CULTURE-1-----

5) From what site was the specimen for CULTURE-1 taken?

**\*\* BLOOD**

= BLOOD

(System corrects typing error.)

6) Please give the date and time when CULTURE-1 was obtained.

(mo/da/yr time)

**\*\* JUN 20, 1977**

The first organism isolated from the blood culture of 20-JUN-77

(CULTURE-1) will be referred to as:

-----ORGANISM-1-----

7) Enter the laboratory-reported identity of ORGANISM-1:

**\*\* UNKNOWN**

(Typically identity is not yet known.)

8) The stain (gram or Ziehl-Neelsen acid-fast) of ORGANISM-1:

**\*\* NEG**

(Preliminary lab results give some clues.)

9) Is ORGANISM-1 rod or coccus (etc.):

**\*\* ROD**

10) What is the form of the individual organisms (e.g. lancet-shaped for cocci, fusiform for rods, etc.):

**\*\* FUSIFORM**

*skip 12 questions* (... more questions follow in order to gather sufficient information to infer the identity and significance of the infecting organisms ...)

23) What is the suspected portal of entry of the gramneg rod from the blood culture of 20-JUN-77 (ORGANISM-1) into this sterile site?

**\*\* GI (6)**

(User indicates the uncertainty of his response.)

24) Is Fred Braun a burn patient?

**\*\* N**

25) Is Fred Braun a compromised host (e.g. alcoholic, sickle-cell-disease, immunosuppressed)?

**\*\* N**

26) Is Fred Braun febrile?

**\*\* Y**

*skip another 25 questions!* (... after about 50-60 questions, MYCIN prints the diagnostic hypotheses on which therapy will be based ...)

My therapy recommendations will be designed to treat for organisms that are either 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 BACTEREMIA

<ITEM-1> E.COLI [ORGANISM-1]

<ITEM-2> KLEBSIELLA [ORGANISM-1]

<ITEM-3> ENTEROBACTER [ORGANISM-1]

<ITEM-4> KLEBSIELLA-PNEUMONIAE [ORGANISM-1]

*R explanation*

FIGURE 4-2 Excerpts from a MYCIN consultation. (Comments in italics are not part of the actual interaction.)

*initial history*  
*rough overview of system*

*happy!*

*(... questions follow to evaluate possible therapy choices, and finally MYCIN prints its therapy recommendations ...)*

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

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

Give: GENTAMICIN

Dose: 119 mg (6.0 ml) q8h IV for 10 days [calculated on basis of 1.7 mg/kg]

Comments: Modify dose in renal failure.

*(One drug covers 4 possible identities.)*

**FIGURE 4-2 continued**

IF: There is evidence that A and B are true,  
THEN: Conclude there is evidence that C is true.

---

**RULE035**

PREMISE: (\$AND (SAME CNTXT GRAM GRAMNEG)  
(SAME CNTXT MORPH ROD)  
(SAME CNTXT AIR ANAEROBIC))

ACTION: (CONCLUDE CNTXT IDENTITY BACTEROIDES TALLY .6)

IF: 1) The gram stain of the organism is gramneg, and  
2) The morphology of the organism is rod, and  
3) The aerobicity of the organism is anaerobic

THEN: There is suggestive evidence (.6) that the identity  
of the organism is bacteroides

---

**FIGURE 4-3** A MYCIN rule, in both its internal (LISP) form and English translation. The term CNTXT appearing in every clause is a variable in MYCIN that is bound to the current context, in this case a specific organism (ORGANISM-2), to which the rule may be applied.

**\*\* IS ORGANISM-1 A STREPTOCOCCUS?**

No. The identity of ORGANISM-1 is e.coli (.74) bacteroides (.7)  
klebsiella-pneumoniae (.4) pseudomonas-aeruginosa (.22) enterobacter  
(.21) proteus-non-mirabilis (.19) serratia (.03) salmonella (.02)

**\*\* WHY DID YOU RULE OUT STREPTOCOCCUS AS A POSSIBILITY FOR ORGANISM-1?**

RULE033 could have been used to determine that the identity of ORGANISM-1 is streptococcus. However, clause 2 of RULE033 ["the morphology of the organism is coccus"] was already known to be false for ORGANISM-1, so the rule was never tried.

**\*\* HOW DO YOU KNOW THAT CULTURE-1 WAS FROM A STERILE SOURCE?**

Used RULE189 to conclude that this blood culture was taken from a sterile source. This gave a cumulative CF of (1.0). The last question asked before the conclusion was made was 7.

**\*\* WHAT DOES GU MANIPULATION TELL YOU ABOUT THE IDENTITY OF AN ORGANISM?**

The rules listed below use:

whether the patient has had a genito-urinary manipulative procedure  
to conclude about:  
the identity of the organism

156, 163, 190

Which do you wish to see?

**\*\* 156**

**RULE156**

IF: 1) The site of the culture is blood, and  
2) The gram stain of the organism is gramneg, and  
3) The morphology of the organism is rod, and  
4) The portal of entry of the organism is urine, and  
5) The patient has not had a genito-urinary manipulative procedure,  
and  
6) Cystitis is not a problem for which the patient has been treated  
THEN: There is suggestive evidence (.6) that the identity of the  
organism is e.coli

**\*\* IS BLOOD A STERILE SITE?**

Yes. Blood is one of those sites that is normally sterile.

**\*\* WHAT ARE THE NONSTERILE SITES?**

Those sites that are normally nonsterile are: CERVIX, CUTANEOUS-ULCER, LOCHIA, NOSE, SKIN, STOOL,  
THROAT, URETHRA, VAGINA.

**\*\* IS BACTEROIDES AEROBIC?**

No, the aerobicity of bacteroides is anaerobic.

**FIGURE 4-4 Interaction with the QA Module. The user's questions follow the double-asterisk prompt.**

→ system can explain its reasoning  
→ use rules of inference to do so!

---

34) Was penicillinase added to this blood culture (CULTURE-1)?

**WHY**

[i.e. WHY is it important to determine whether penicillinase was added to CULTURE-1?]

[3.0] This will aid in determining whether ORGANISM-1 is a contaminant.

It has already been established that

[3.1] the site of CULTURE-1 is blood, and

[3.2] the gram stain of ORGANISM-1 is grampos

Therefore, if

[3.3] penicillinase was added to this blood culture

then

there is weakly suggestive evidence (.4) that ORGANISM-1 is a contaminant [RULE039]

**WHY**

[i.e. WHY is it important to determine whether ORGANISM-1 is a contaminant?]

[4.0] . . . In order to determine whether there is significant disease associated with this occurrence of ORGANISM-1.

It has already been established that

[4.1] this blood culture was taken from a sterile source

Therefore, if

[4.2] ORGANISM-1 is not a contaminant

then

there is strongly suggestive evidence (.9) that there is significant disease associated with this occurrence of ORGANISM-1

[RULE032]

**WHY**

[i.e. WHY is it important to determine whether there is significant disease associated with this occurrence of ORGANISM-1]

[5.0] . . . In order to determine the organisms which require therapy.

It has already been established that

[5.1] the infection is known, and

[5.2] the identity of ORGANISM-1 is known

Therefore, if

[5.3] there is significant disease associated with this occurrence of ORGANISM-1

then

it is definite (1.0) that ORGANISM-1 is one of the organisms which require therapy

[RULE090]

**HOW 5.2**

[i.e. HOW was it established that the identity of ORGANISM-1 is known?]

Question 9 was asked, but you weren't sure; so the following was used:

[5.5] RULE084 was used to conclude that the identity of ORGANISM-1 is streptococcus-group-a (.29).

---

**FIGURE 4-5 Use of the Reasoning Status Checker during the consultation to explain MYCIN's line of reasoning.**

To inspect the system reasoning  
A use as learning tool!

---

**\*\* WHY DIDN'T YOU SUGGEST PENICILLIN IN REC-1 FOR STAPH-COAG+ ?**

PENICILLIN was not prescribed for ITEM-1 in RECOMMENDATION-1:

PENICILLIN was discounted for ITEM-1 because it is NOT DEFINITE that the item is sensitive to this drug. There are other potential therapies under consideration which are much more desirable, viz., current therapies or drugs to which the item is definitely sensitive.

Would you like to see some details? **\*\* YES**

The drugs to which the staphylococcus-coag-pos is sensitive are: cephalothin (1.0) vancomycin (1.0) gentamycin (1.0) tobramycin (1.0) erythromycin-and-tetracycline (1.0) chloramphenicol-and-erythromycin (1.0) [RULE098 RULE445]

Would you like to know about the history of PENICILLIN in the decision process up to this point? **\*\* YES**

-- PENICILLIN is a treatment of choice for staphylococcus-coag-pos in meningitis. But as explained above, PENICILLIN was discounted.

---

**FIGURE 6-6 Question concerning why a drug was *not* prescribed.**

→ scope of explanations is very broad!

---

Do you wish to see the next choice therapy?

**\*\* YES**

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

**\*\*CHLORAMPHENICOL**

[REC-2] Next best therapy recommendation:

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

Give: GENTAMICIN

In order to cover for Item <1>:

Give: METHICILLIN

RECOMMENDATION-2 is substantially inferior to RECOMMENDATION-1 (because it requires more drugs or drugs that are not as good).

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 (CHLORAMPHENICOL for ITEM-2 and ITEM-3) and 1 second choice drug (GENTAMICIN for ITEM-3 and ITEM-1)

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

Do you wish to see the next choice therapy?

**\*\* NO**

---

**FIGURE 6-8 Comparing alternative recommendations.**

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

AMPICILLIN-AND-GENTAMICIN was not prescribed for ITEM-2 in RECOMMENDATION-1:

AMPICILLIN-AND-GENTAMICIN is a plausible choice for e.coli in meningitis, and was not explicitly rejected for use against ITEM-2 in RECOMMENDATION-1. However, the best therapy did not include AMPICILLIN-AND-GENTAMICIN.

If you would like to suggest therapy which includes AMPICILLIN-AND-GENTAMICIN, your regimen will be compared to MYCIN's. Would you like to do this? **\*\* YES**

For each item in turn, enter the drug you would have prescribed in RECOMMENDATION-1.

In order to minimize the number of drugs in your recommendation, you may not want to prescribe therapy for every item. Items which represent the most likely organisms are indicated with a plus sign (+).

- + ITEM-1 -- the staphylococcus-coag-pos **\*\* GENTAMICIN**
- + ITEM-2 -- the e.coli **\*\* AMPICILLIN GENTAMICIN**
- + ITEM-3 -- the klebsiella-pneumoniae **\*\* GENTAMICIN**
- + ITEM-4 -- the pseudomonas-aeruginose **\*\***

[Checking for contraindications . . .]

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

[No contraindications found . . .]

[Now comparing your prescription to MYCIN's . . .]

Perhaps you did not realize that one of the drugs you prescribed, GENTAMICIN, will cover for ITEM-4, an item for which you did not prescribe therapy. I have changed your prescription accordingly.

ORGANISMS	Your regimen Drug -- Choice	MYCIN's regimen Drug -- Choice
"most likely"		
ITEM-3	GENTAMICIN -- 3rd	CHLORAMPHENICOL-AND-GENTAMICIN -- 1st
ITEM-2	AMPICILLIN-AND-GENTAMICIN -- 1st	CHLORAMPHENICOL -- 1st
ITEM-1	GENTAMICIN -- 2nd	GENTAMICIN -- 2nd
"less likely"		
ITEM-4	GENTAMICIN -- 2nd	GENTAMICIN -- 2nd

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

Both prescriptions include fewer than 3 drugs, so we must look at how highly ranked each prescription is for the most likely organism(s).

Your prescription of 1 first choice drug (AMPICILLIN for ITEM-2) and 1 third choice drug (GENTAMICIN for ITEM-3) is not as good as MYCIN's prescription of 1 first choice drug (CHLORAMPHENICOL for ITEM-2 and Item-3) and 1 second choice drug (GENTAMICIN for ITEM-1).

[You may refer to your regimen as RECOMMENDATION-2 in later questions.]

**FIGURE 6-9 Evaluating a user's choice of therapy.**

*• consulting the physician.*

*→ Can you do this for common sense?*