

## Rule-Based Systems and The Focus on Knowledge

### Gold Star Ideas

- ★ Where's the power? / Why does it work?
- ★ Simon's ant metaphor
- ★ Separate what to know from how to use it
- ★ Knowledge engineering
  - Work from specific cases
  - Attend to unexplained variations
  - Failures are enormously informative
- ★ Knowledge engineering yourself


### Recap/Outline

- Models of problem solving
  - Generate and test
  - Problem reduction (integration)
  - *Rule chaining: backward; Mycin*
  - *Rule chaining: forward*
- *Knowledge Engineering*

### MYCIN: An Early Knowledge Based System

- The task
  - Medical diagnosis and therapy selection for bacterial infections of the blood
- Why this domain?
  - Overuse of antibiotics

**HEALTH JOURNAL**  
By TARA PARKER-POPE



**Doctors Fear Overuse Of Antibiotics by Kids Is About to Get Worse**

**F**OR PEDIATRICIANS, cold and flu season has always meant extra battles with parents over antibiotics. Many parents, for example, call doctors' offices seeking antibiotics over the phone to treat a child's ear infection. Others show up for a visit after they've already given their child unused antibiotics from a previous ailment.

But this year, doctors have an added worry. In the past few months, millions of people have stocked up on the antibiotics Cipro and doxycycline amid the anthrax scare. Doctors warn that both drugs can cause significant health problems in children.

The combination of people's penchant for giving leftover antibiotics and having dangerous antibiotics in the medicine cabinet is fraught with peril," says Alan Greene, a Stanford University pediatrician and founder of DrGreene.com. "It's a problem waiting to happen."

Pediatricians have long struggled to lessen parents' dependence on antibiotics to treat common childhood illnesses.

**Wall Street Journal**  
11/30/01

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Antibiotic resistance is: *"one of the world's most pressing public health problems."*

Centers for Disease Control and Prevention, July 2019

## Why This Domain

- Overuse of antibiotics
- Irrational use of antibiotics
- Maldistribution of expertise
- Domain is "small" and "isolated"

## Sample Interaction

-----PATIENT-248-----

- 1) Patient's name: (first-last)  
\*\* CR
- 2) Sex:  
\*\* MALE
- 3) Age:  
\*\* 52
- 4) Have you been able to obtain positive microbiological information about a possible infection of C.R.?  
\*\* YES

-----INFECTION-----

- 5) What is the infection?  
\*\* ENDARTERITIS

## Sample Interaction (cont'd)

The first significant organism from this blood culture (CULTURE-1) will be referred to as:

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

- 6) Enter the identity of ORGANISM-1  
\*\* UNKNOWN
- 7) Is ORGANISM-1 a rod or coccus (etc.):  
\*\* ROD
- 8) The gram stain of ORGANISM-1  
\*\* GRAMNEG
- 9) HAVE THERE BEEN positive cultures yielding organisms about which you will NOT be seeking advice?  
\*\* YES

## Sample Interaction: Diagnosis

INFECTION-1 is ENDARTERITIS with BACTEREMIA

- <Item 1> E. COLI
- <Item 2> SALMONELLA (species unknown)
- <Item 3> KLEBSIELLA-PNEUMONIAE
- <Item 4> PSEUDOMONAS-AERUGINOSA
- <Item 5> ENTEROBACTER
- <Item 6> PROTEUS-NON-MIRABILIS

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## Sample Interaction: Therapy

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

In order to cover for Items <1 3 4 5 6 >:

Give: GENTAMICIN

Dose: 128 mg (1.7. Mg/kg) q8h IV (or IM) for 10 days

Comments: Modify dose in renal failure

In order to cover for Item <2>:

Give: CHLORAMPHENICOL

Dose: 563 mg (7.5 mg.kg) q6h for 14 days

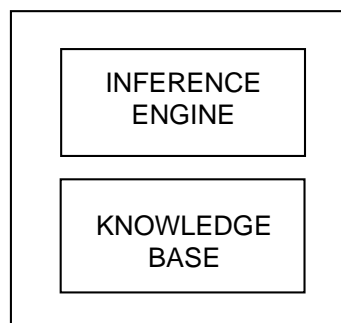
Comments: Monitor patient's white count

Do you wish to see the next choice therapy?

\*\* NO

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## How It Worked: Architecture



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## Knowledge Base

Rule 27

If:

- 1) the gram stain of the organism is gram negative, and
- 2) the morphology of the organism is rod, and
- 3) the aerobicity of the organism is anaerobic,

Then:

There is evidence that the identity of the organism is Bacteriodes.

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## Representation

Rule 27

If:

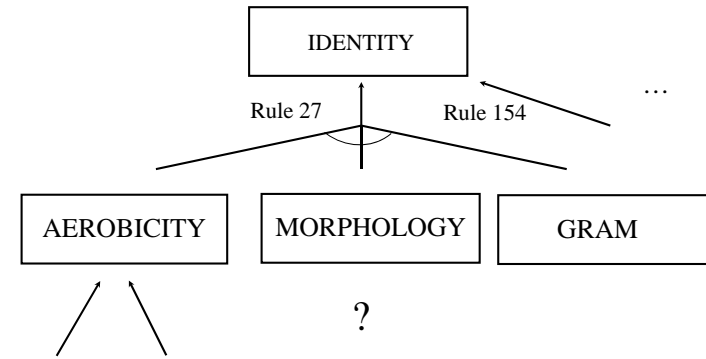
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## Inference Engine: Backward Chaining



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## Sample Interaction

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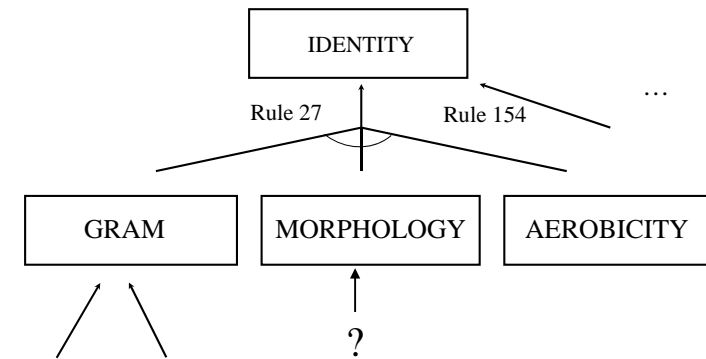
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\*\* YES

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## Inference Engine: Backward Chaining



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## Control Structure

- What kind of search?
  - Depth-first
  - Backward-chaining (chain from goals to facts)
  - Forward-chaining (chain from facts to goals)

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Photo by [Shireah Ragnar](#) on [Unsplash](#)

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## Control Structure

- Dr. Backward Chaining
- Dr. Forward Chaining

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## Sample Interaction: Explanation

Is the patient's illness with ORGANISM-1 a hospital-acquired infection?  
\*\* WHY  
[i.e. WHY is it important to determine whether or not the infection with ORGANISM-1 was acquired while the patient was hospitalized]  
[2.0] This will aid in determining the identity of ORGANISM-1.  
It has already been established that  
[2.1] the morphology of ORGANISM-1 is rod  
[2.2] the gram stain of ORGANISM-1 is gramneg  
[2.3] the aerobicity of ORGANISM-1 is facul  
Therefore, if  
[2.4] the infection with ORGANISM-1 was acquired while the patient was hospitalized  
then  
there is evidence that the identity of ORGANISM-1 is pseudomonas [RULE050]

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## Explanation

\*\* HOW DID YOU DECIDE THAT ORGANISM-1 WAS AN E.COLI?

I used rule084 to conclude that the identity of ORGANISM-1 is e.coli. This gave a cumulative c.f. of (.51).

I used rule003 to conclude that the identity of ORGANISM-1 is e.coli. This gave a cumulative c.f. of (.43).

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## Explanation

\*\* WHY DIDN'T YOU THINK THAT ORGANISM-1 WAS NEISSERIA?

The following rules could have been used to determine that the identity of ORGANISM-1 is neisseria: 9.

However, none of these succeeded in the context of ORGANISM-1. If you would like an explanation for why any of these rules failed, please enter their numbers:

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Clause 2 of rule009 ["the morphology of the organism is coccus"] was already known to be false for ORGANISM-1, so the rule was never tried.

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## Successful?

- Appropriate task: Narrow domain, heuristic knowledge, articulate experts, etc.
- The match of knowledge and representation:
  - Knowledge about of how the body works, vs.
  - Knowledge about how to diagnose it
- Answer was a ranked list, not a single result
- Perhaps most important:  
Having the right abstractions, the right language

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## The Right Abstraction

If ...  
the organism is gram-negative, and  
the portal of entry is skin-wound,  
Then the organism is likely to be ...

- It's an abstraction
- It's the right abstraction for this task
- Where did it come from?

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## Contributions

- Existence proof of adequacy of rule-based systems
- Knowledge can be captured as a set of mostly independent rules
- Experts can be debriefed
  - Specific cases
  - Subtle differences
  - Failures are wonderful, and revealing
  - You can usefully do this to yourself

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