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

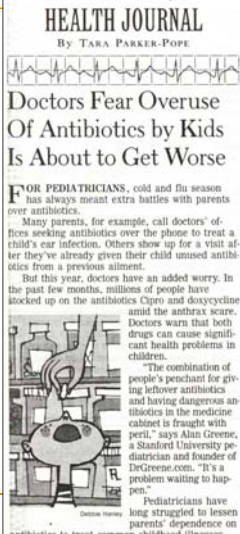1

Recap/Outline

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

- *Knowledge Engineering*

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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

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Slide 4

HEALTH JOURNAL
By Tara Parker-Pope

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

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

Centers for Disease Control and Prevention, July 2019

Wall Street Journal
11/30/01

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Why This Domain

- Overuse of antibiotics

- Irrational use of antibiotics

- Maldistribution of expertise

- Domain is "small" and "isolated"

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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
```

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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
```

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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-MIRABILUS

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
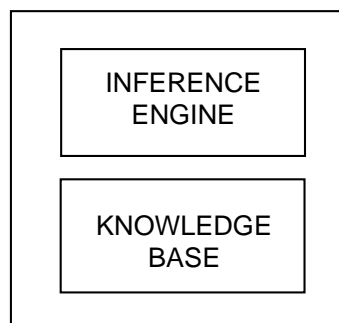   Dose:563 mg (7.5 mg.kg) q6h for 14 days
      Comments: Monitor patient's white count
Do you wish to see the next choice therapy?
**   NO

How It Worked: Architecture

```
┌─────────────────────────┐
│  ┌───────────────────┐  │
│  │     INFERENCE     │  │
│  │      ENGINE       │  │
│  └───────────────────┘  │
│  ┌───────────────────┐  │
│  │    KNOWLEDGE      │  │
│  │      BASE         │  │
│  └───────────────────┘  │
└─────────────────────────┘
```

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.
```
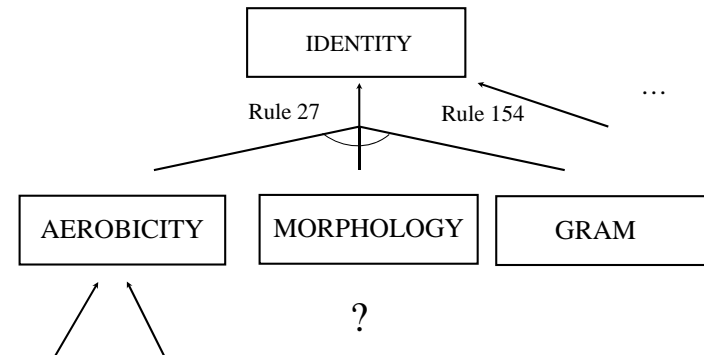
Representation

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_.

Inference Engine: Backward Chaining

IDENTITY

...

Rule 27   Rule 154

AEROBICITY   MORPHOLOGY   GRAM

?

Sample Interaction

The first significant organism from this blood culture (CULTURE-1)
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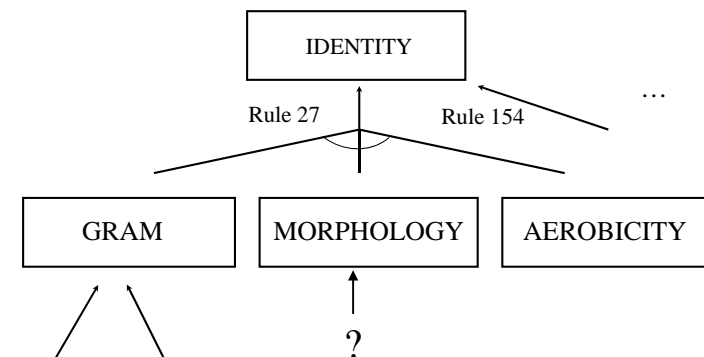**   GRAMNEG
9) HAVE THERE BEEN positive cultures yielding organisms
    about which you will NOT be seeking advice?
** YES

Inference Engine: Backward Chaining

IDENTITY

...

Rule 27   Rule 154

GRAM   MORPHOLOGY   AEROBICITY

?

Control Structure

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

  - Forward-chaining (chain from facts to goals)

Control Structure

- Dr. Backward Chaining

- Dr. Forward Chaining

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]

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).

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:

** 9

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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Gold Star Ideas

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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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