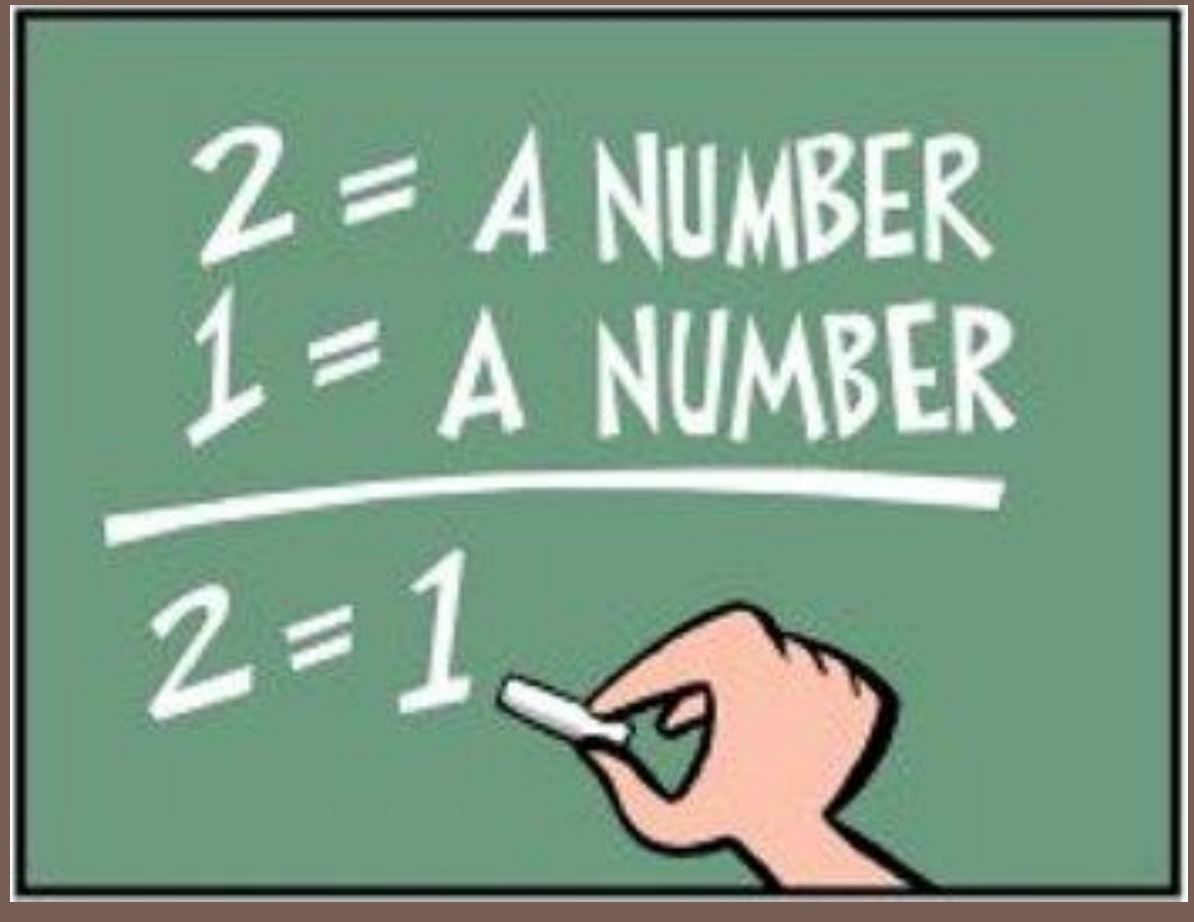
LOGIC PROGRAMMING



Chapter 1: Introduction

"What" vs "How"

Declarative vs Procedural Programming

Procedural programming

- The programmer has to specify how to get the output for the range of required inputs.
- The programmer must know the appropriate algorithm.

Declarative programming

- Requires a more descriptive style.
- The programmer must know what relationships hold between various entities.
- Prolog – the most popular logic programming language.
    - Used in Artificial Intelligence and Natural Language Processing.

Example: List Concatenation

In procedural style:

```
list procedure cat(list a,list b)
{
        list t = list u = copylist(a);
        while (t.tail != nil) t = t.tail;
        t.tail = b;
        return u;
}
```

In declarative style:

```
cat([], L, L).
cat([H|T], L, [H|Z]) :- cat(T, L, Z).
```

Contents

- Basics of PROLOG
- Facts
- Questions
- Variables
- Conjunction
- Rules

PROLOG

- Used to solve problems involving objects, and relationships between objects.
- Program can be thought of as a storehouse of facts and rules.
- Conversational Language: The user can ask questions about the set of facts and rules in the PROLOG program.

Relationships

Example

John owns the book

- The relationship: *ownership*
- The objects: *book, John*

Directional:

- John owns the book
- Not: The book owns John

PROLOG

Sisters Example:

- A rule defining sisters and the facts about the people involved.
- The user would ask:
  - **Are these two people sisters؟**
- The system would answer
  - **yes** (true) or **no** (false)

Programming in PROLOG

- Declaring Facts about objects and their relationships.
- Defining Rules about objects and their relationships.
- Asking Questions about objects and their relationships.

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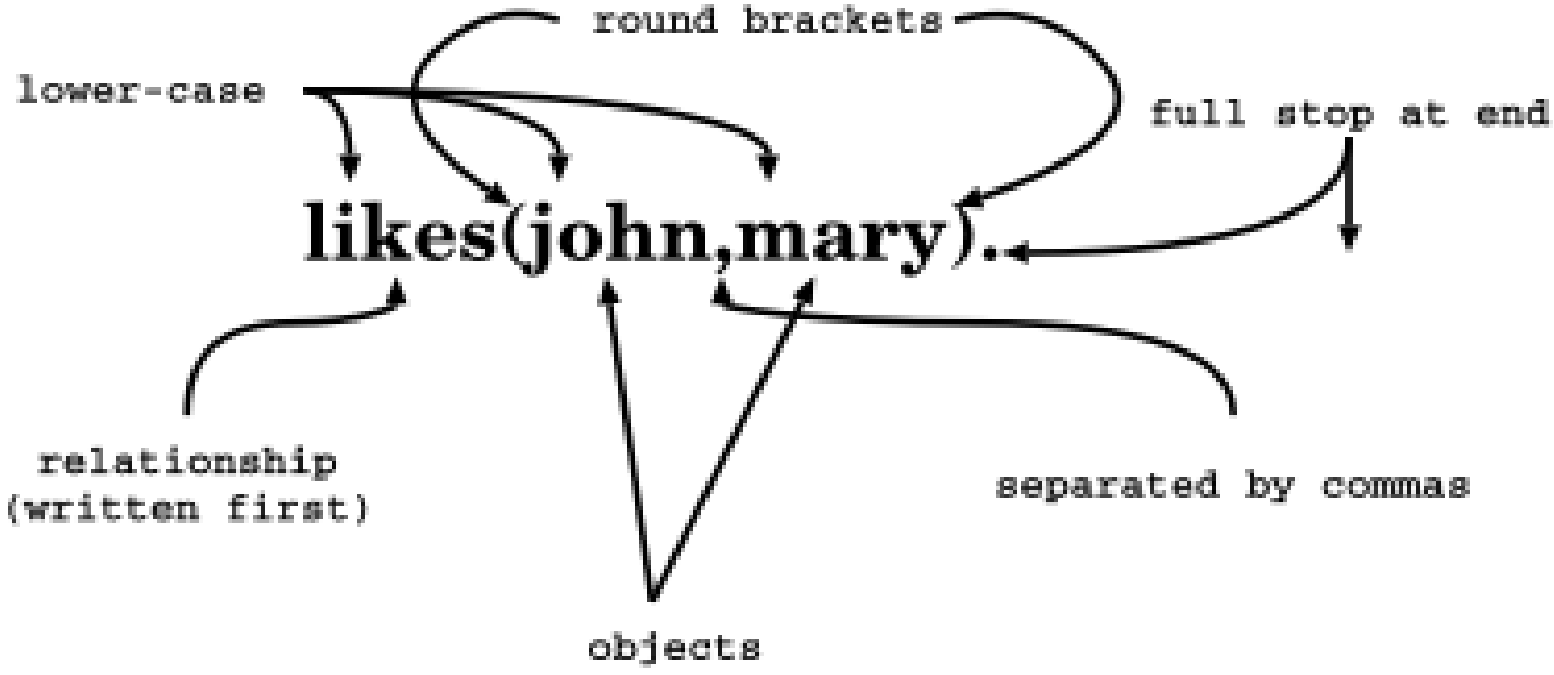
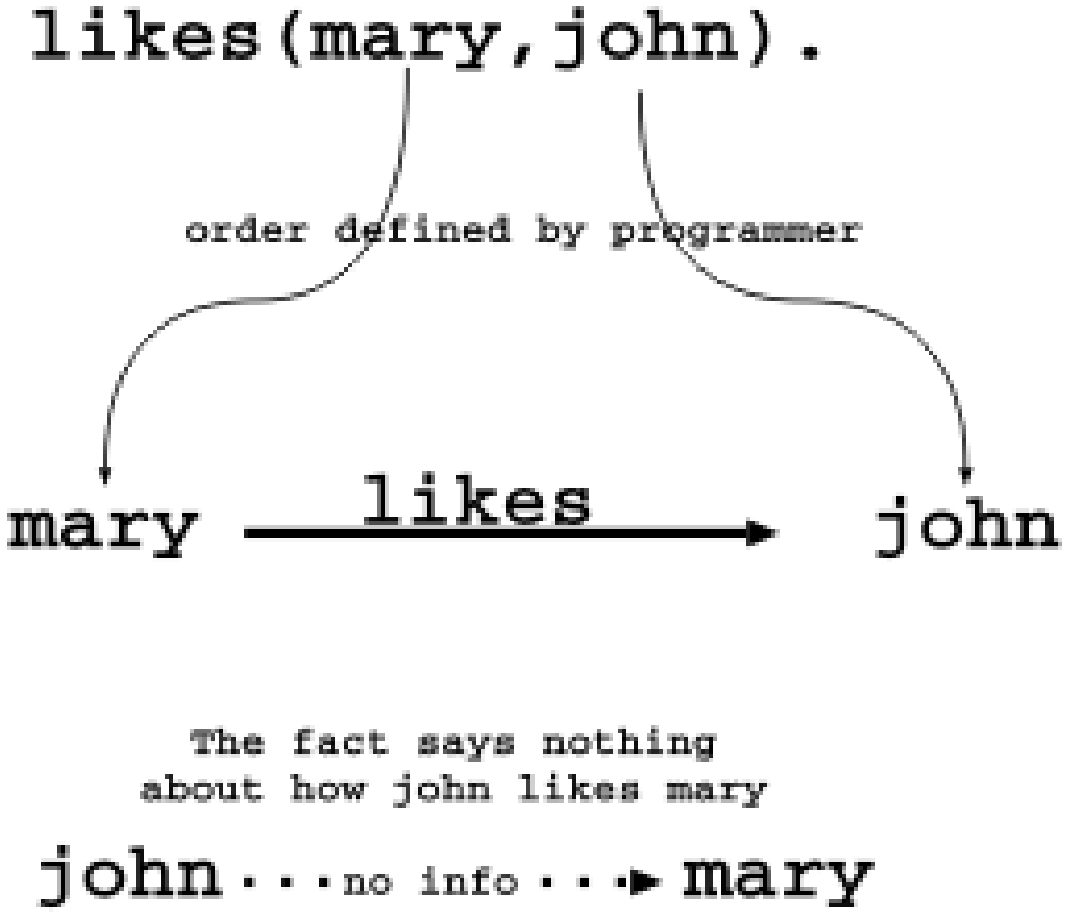
Parts of Fact



Order of Objects



Examples of Facts

Example

Gold is valuable.
valuable(gold)

Jane is a female.
female(jane)

John owns some gold.
owns(john,gold)

John is the father of Mary.
father(john,mary)

Are these expressions really facts? Is there anything missing?

Interpretation of Names

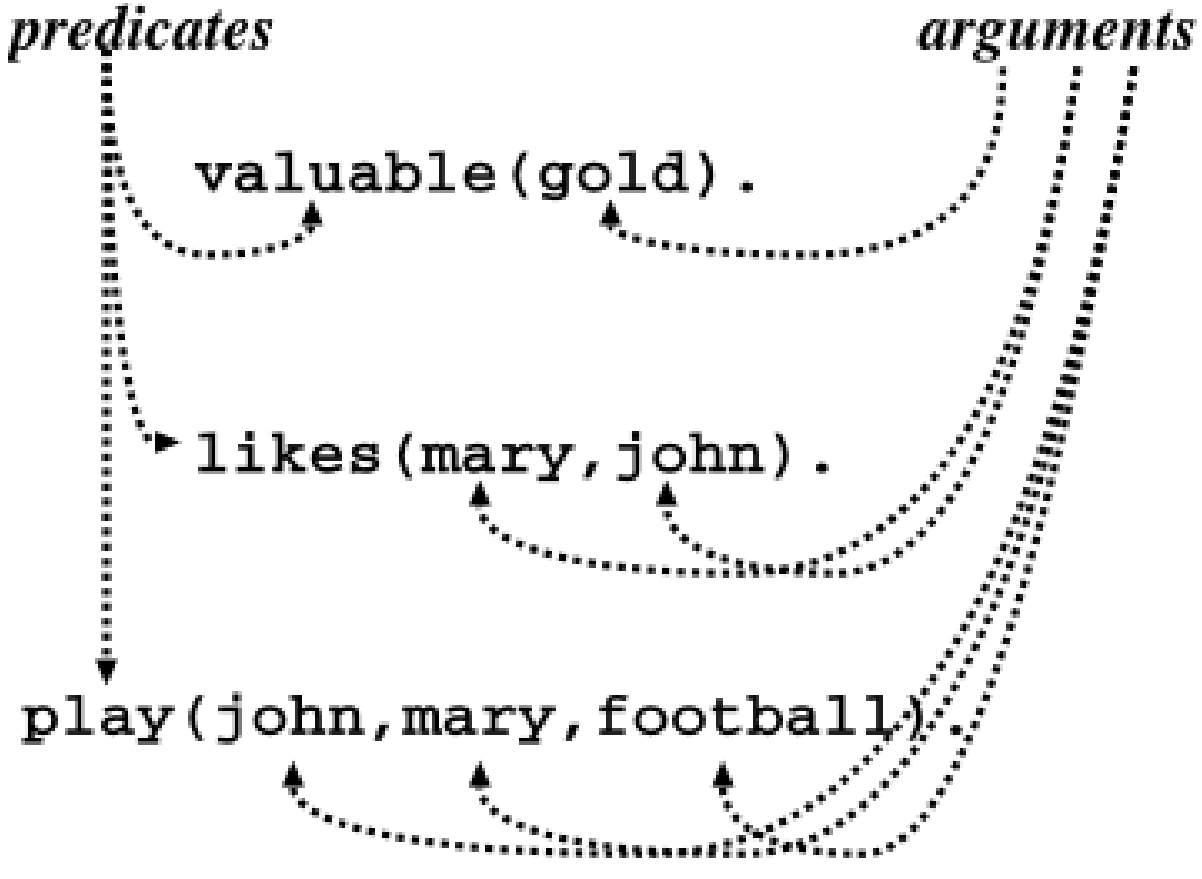
The name refers to an object.

- Semantic Meaning: Given by the programmer.
- Syntactic Meaning: a set of characters, as PROLOG sees it.

Interpretation of Names

- Name refers to an object.
- Name `gold` can refer to:
  - a particular lump of gold, or
  - the chemical element Gold having atomic number .79
- `valuable(gold)` can mean:
  - that particular lump of gold, named gold, is valuable, or
  - the chemical element Gold, named gold, is valuable.
- The programmer decides (in his/her usage) the meaning.

Fact Terminology



Database

Definition

In PROLOG, database is a collection of facts.

- PROLOG draws its knowledge from these facts.
- The programmer is responsible for their accuracy.

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Questions

- The database contains the facts from which the questions are answered.
- A Question can look exactly like a fact:
  - `owns(mary,book).`
- The difference is in which mode one is in

Questions

- In the interactive question mode (indicated by the question mark and dash): ?-

- Question: `?- owns(mary,book).`
  - Meaning: If mary is interpreted as a person called Mary, and book is interpreted as some particular book, then

- `?- owns(mary,book).`
  - means: Does Mary own the book?

Database Search

Example

Facts in the database:

```
likes(joe,fish).
likes(joe,mary).
likes(mary,book).
likes(john,book).
```

Questions:

```
?- likes(joe,money). no
?- likes(joe,mary). yes
?- king(john,france).no
```

Knowledge

The questions are always answered with respect to the database.

Example

Facts in the database:

```
human(socrates).
human(aristotle).
athenian(socrates).
```

Question:
Is Socrates Greek؟

```
?- greek(socrates)
```

The answer with respect to this database is **No**.

Questions

Up until now questions just reflect exactly the database.

Does Mary like the book?

```
?- likes(mary,book).
```

More Interesting Question: What objects does Mary like؟

Variables.

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Question With Variables

What does John like?

```
?- likes(john,X).
```

or

```
?- likes(john,SomethingThatJohnLikes).
```

X and SomethingThatJohnLikes are variables.

Variable begins with a capital letter.

PROLOG Answer

Database:

```
likes(john,flowers).
```

Question:

```
?- likes(john,X).
```

PROLOG answers:

```
X=flowers
```

Many Answers

Database:

```
likes(john,flowers).
likes(john,mary).
likes(paul,mary).
```

Question:

```
?-likes(john,X).
```

PROLOG answers:

X=flowers
and the user acknowledges
X=mary
and the user acknowledges
no

Placemarker

- The first match is found: `X=flowers`.
- The user acknowledges.
  - From that place on the next match is found (the search continues).
  - From the place of the last instantiation no more match was found.
  - Thus answer: no.

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Conjunctions

More Complicated Relationships:

Does Mary like John and does John like Mary?

Both Conditions must be fulfilled.

Conjunctions

Database:

```
likes(mary,food).
likes(mary,cola).
likes(john,cola).
likes(john,mary).
```

Comma means Conjunction:

```
?- likes(john,mary), likes(mary,john).
```

Answer: no
A match for `likes(john,mary)`
but none for `likes(mary,john)`

Conjunctions with Variables

Is there anything that both mary and john like?

Find out what Mary likes and then see if John likes it.

```
?- likes(mary,X), likes(john,X).
```

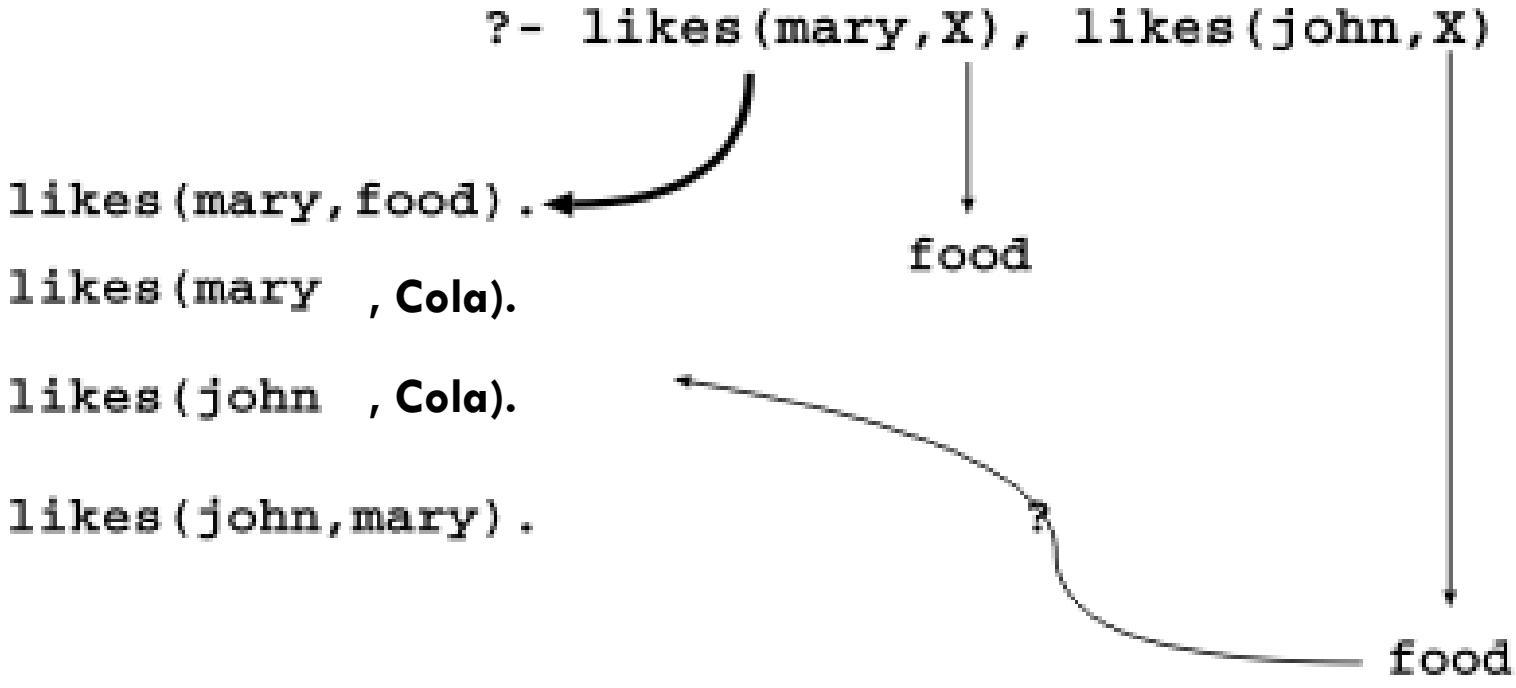
PROLOG answers:

```
X=cola
```

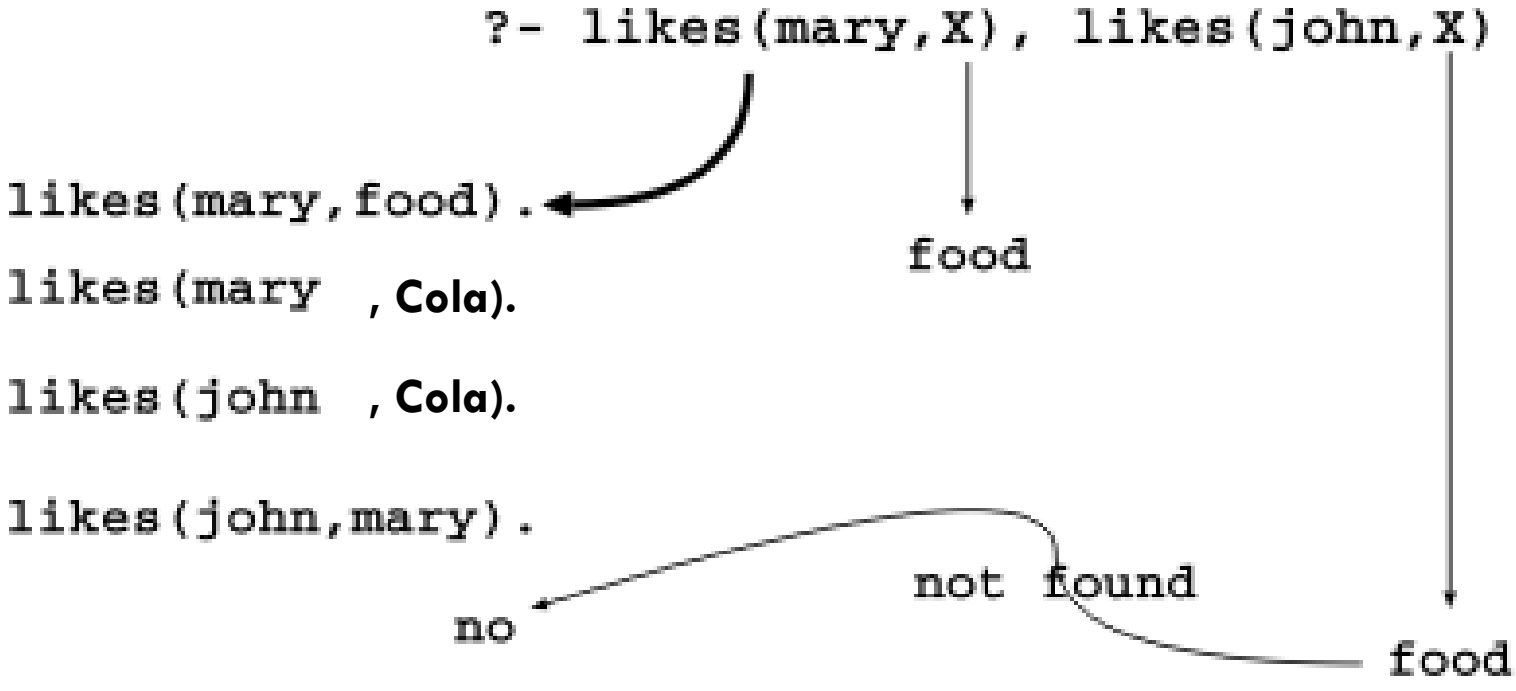
Backtracking

- Find match for the first goal.
- Then see if matches the second.
- If not, find another match for the first.
- See if this matches the second.
- …etc.

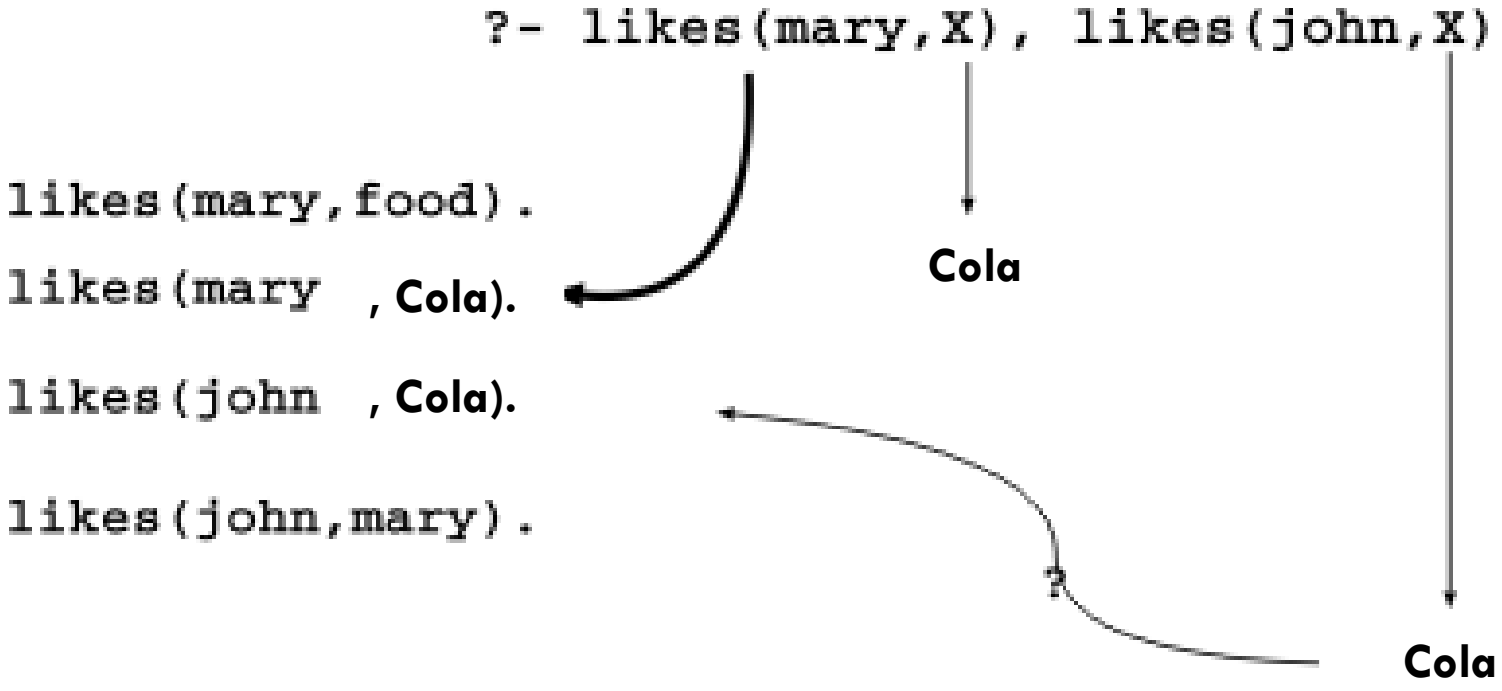
Match First


?- likes(mary,X), likes(john,X)
likes(mary,food).
likes(mary , Cola).
likes(john , Cola).
likes(john,mary).
food
?
food

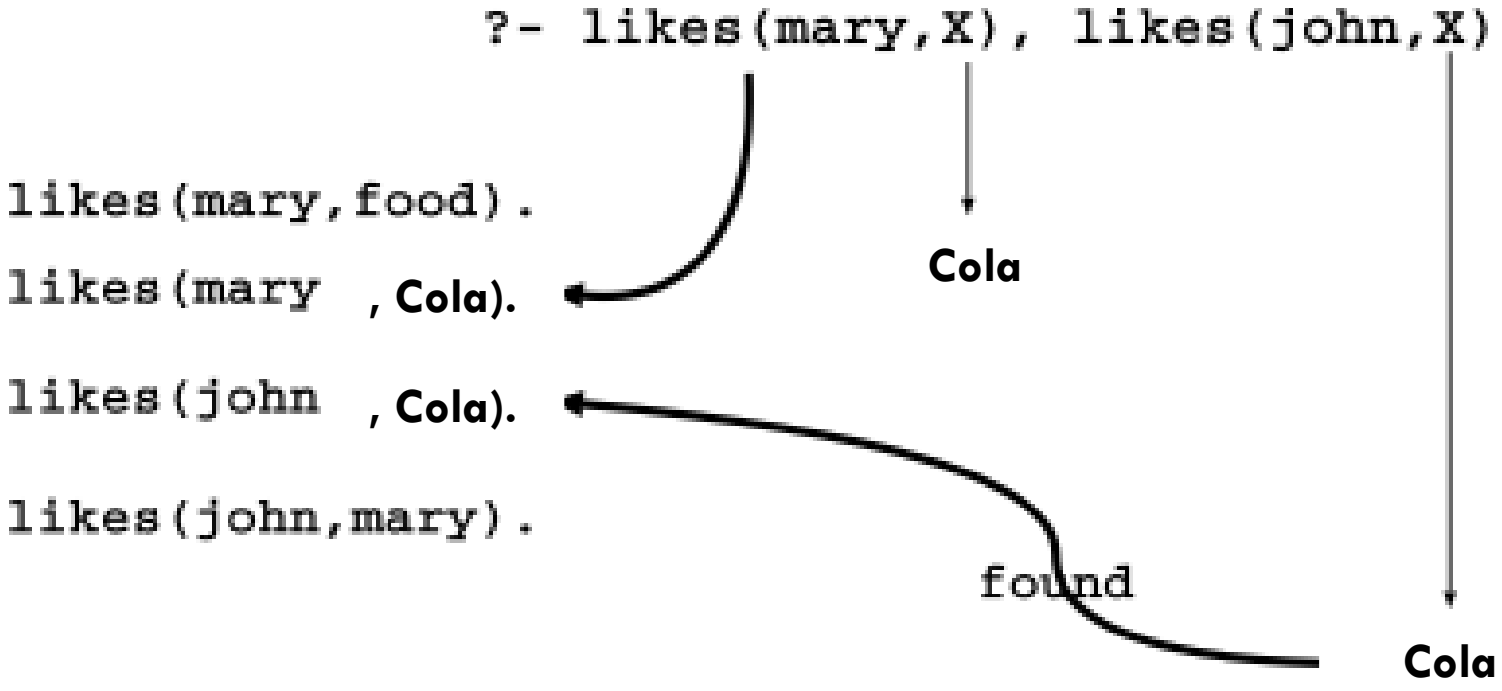
Match Second



Backtrack


?- likes(mary,X), likes(john,X)
likes(mary,food).
likes(mary , Cola).
likes(john , Cola).
likes(john,mary).
Cola
Cola

Success


?- likes(mary,X), likes(john,X)
likes(mary,food).
likes(mary , Cola).
likes(john , Cola).
likes(john,mary).
Cola
found
Cola

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Rules

- How to express that John likes all people؟
- Listing all people؟
  - likes(john، alfred).
  - likes(john، bertrand).
  - likes(john، charles).
  - likes(john، david).
  - etc.
- Not feasible. More compact way: Using rules.
  John likes any object provided(if) it is a person.

Rule Examples

- Rules state Dependence:

I use an umbrella **if** there is rain.

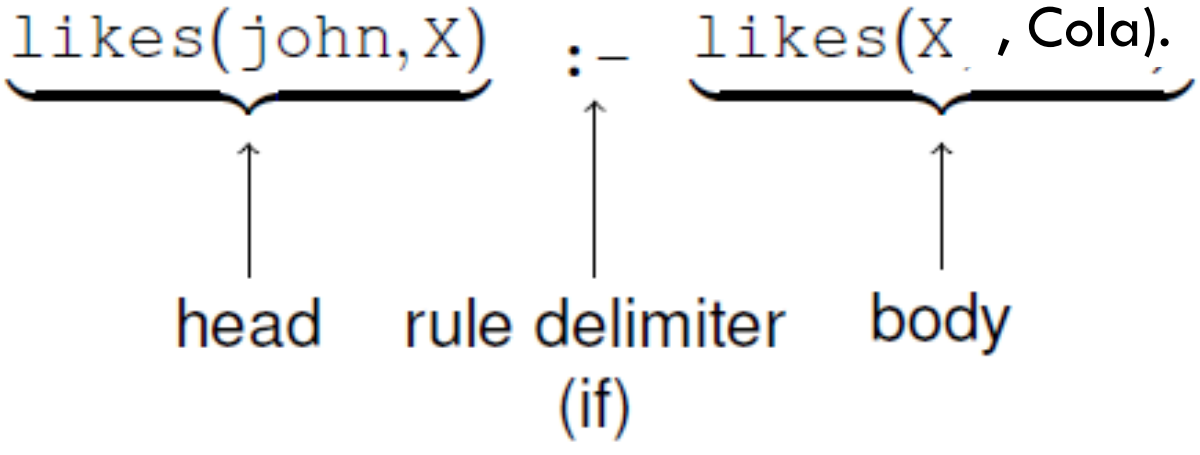
- Rules Define:

X is a bird **if** X is an animal and X has feathers.

Formulating Rules

- John likes anyone who likes cola.
- John likes any Something if it likes cola
- John likes X if X likes cola

Rule Syntax



Variable Scope

The occurrences of X within a rule refer to the same object:

```
likes(john,X):- likes(X ،cola),likes(X,food).
```

```
likes(john,mary):-
likes(mary،cola),likes(mary,food).
likes(john,adam):-likes(adam، cola),likes(adam,
food).
```

Royal Parents

Example

The parents of X are Y and Z.

Y is the mother.

Z is the father.

Database:

```
male(albert).
male(edward).
female(alice).
female(victoria).
parents(edward,victoria,albert).
parents(alice,victoria,albert).
```

Sisters

Example

X is a sister of Y if:

- X is female.
- X has parents M and F.
- Y has parents M and F.

Rule:

```
sister(X,Y):-female(X),
             parents(X,M,F),
             parents(Y,M,F).
```

Sisters Question


```
sister(X,Y):-female(X),
             parents(X,M,F),
             parents(Y,M,F)
```

Question:

```
?- sister(alice,edward).
```

The question (goal) matches the head of the rule, if one replaces X with `alice` and Y with edward.

The instance of the body becomes new goal:

```
female(alice), parents(alice,M,F),
parents(edward,M,F).
```

Is Alice Edward's Sister?

(1) male(albert).

(2) male(edward).

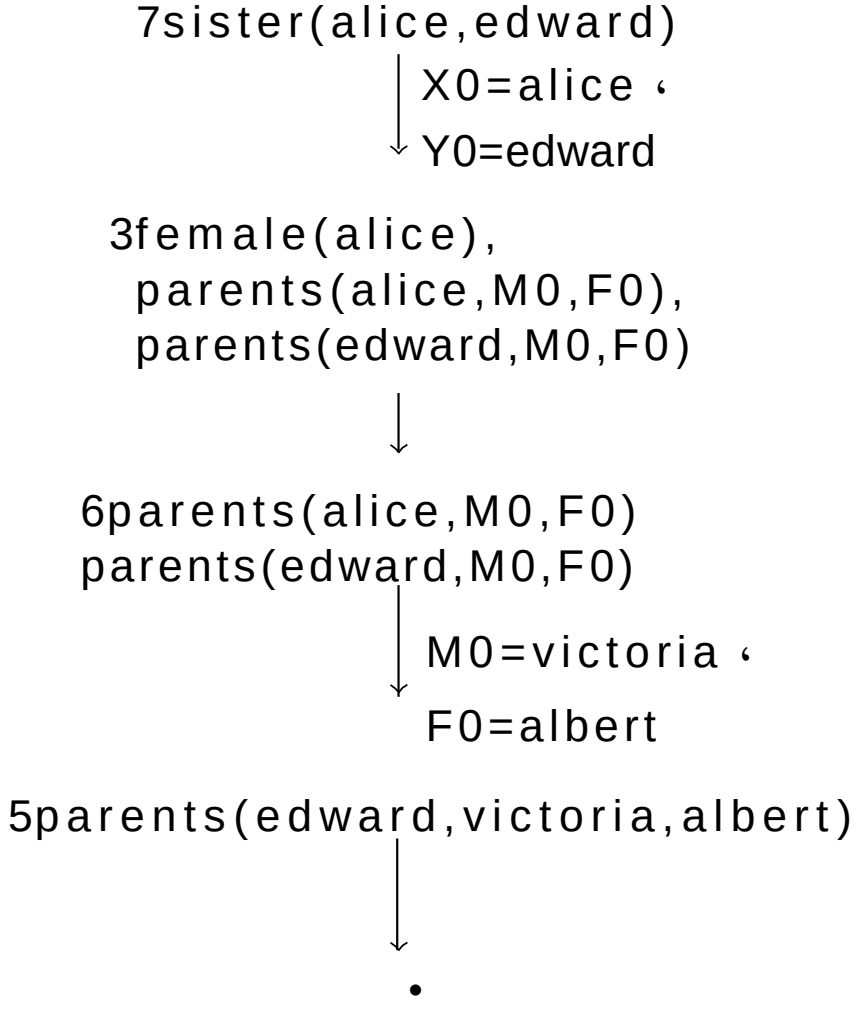
(3) female(alice).

(4) female(victoria).

(5) parents(edward, victoria, albert).

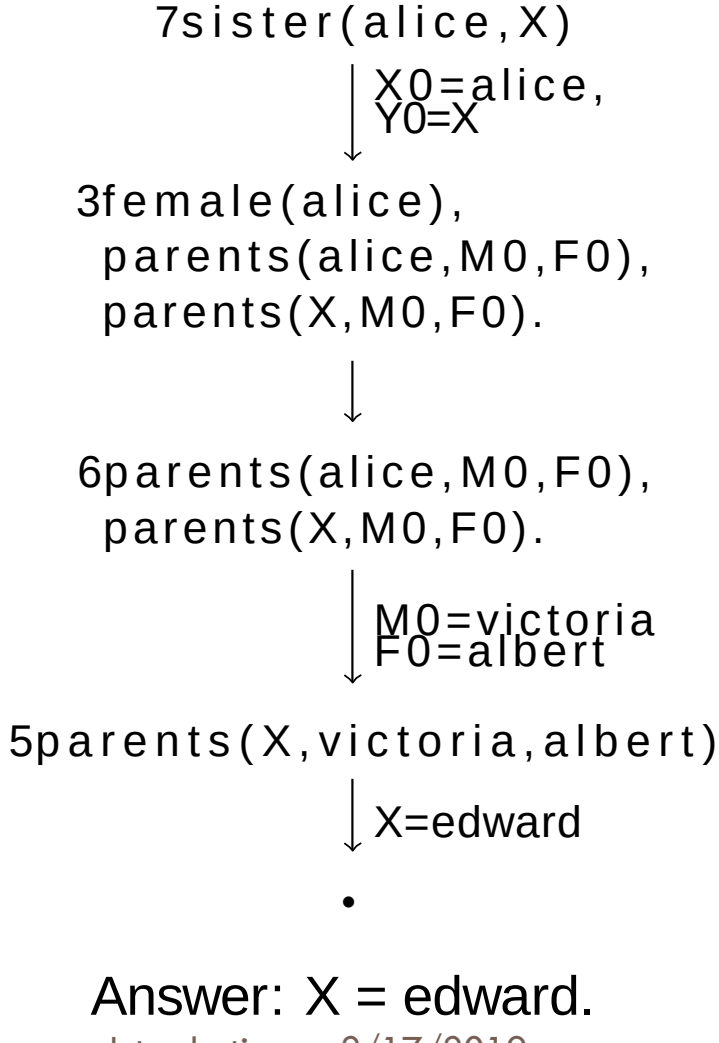
(6) parents(alice, victoria, albert).

(7) sister(X,Y):-
female(X),
parents(X,M,F),
parents(Y,M,F).



Who's Sister Is Alice?


```
(1) male(albert).
(2) male(edward).
(3) female(alice).
(4) female(victoria).
(5) parents(edward,
        victoria, albert).
(6) parents(alice,
        victoria,albert).
(7) sister(X,Y):-
        female(X),
        parents(X,M,F),
        parents(Y,M,F).
```



Answer: X = edward.