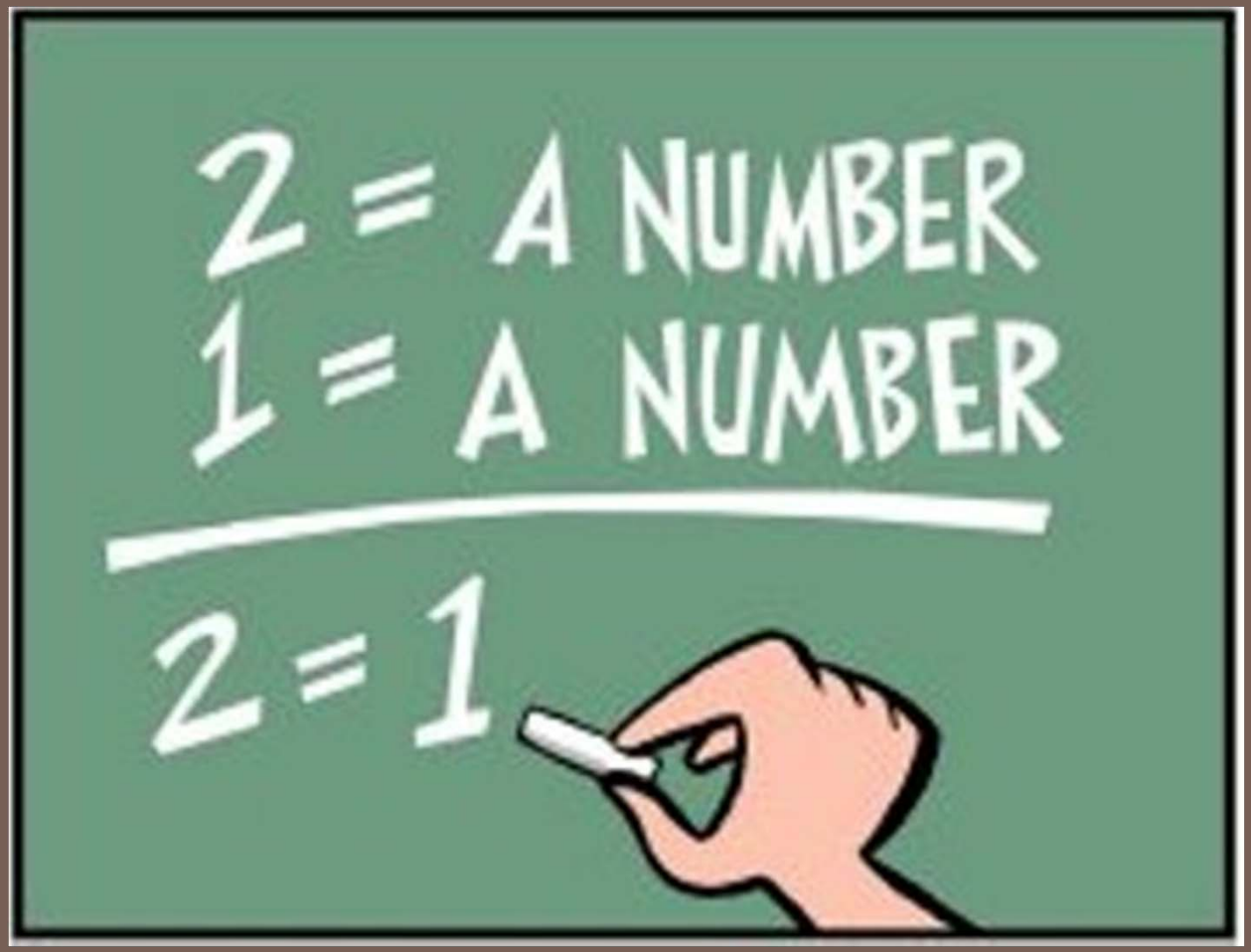
LOGIC PROGRAMMING




# Chapter 1: Introduction

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Slides based on original lecture slides Dr. Temur Kutsia

# "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.

# 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).
```

# Logic Programming



- A declarative style programming paradigm.
- Computation through logical deduction.
- Uses the language of logic to express data and programs.
- Most of current logic programming languages use first order logic (FOL).
- Prolog – the most popular logic programming language.

# Historical Facts



1970-ies:

- Bob Kowalski.
  "Predicate Logic as a Programming Language".
  IFIP Congress, Stockholm
- Alain Colmerauer and his group.
  Interpreter of the first logic programming language Prolog.
  Marseille

# Prolog



- Prolog is the main subject of this course
- Used in Artificial Intelligence, Natural Language Processing, Automated Reasoning, XML Querying...
- Exists in many dialects (Sicstus Prolog, SWI Prolog, Prolog IV, BinProlog, Ciao Prolog, Prolog LPA, Visual Prolog, YAP Prolog, Strawberry Prolog(...
- (Almost) all the dialects agree on the “core" part (ISO Standard for Prolog)

# Prolog in Industrial Applications



Clarissa:

- A fully voice-operated procedure browser.
- Developed at NASA.
- Used on the International Space Station.
- Enables astronauts to give full attention to the task while they navigate through complex procedures using spoken commands.
- Implemented in SICStus Prolog.

# Prolog in Industrial Applications



## Some other solutions:

- **FleetWatch –** fully integrated operations control and schedules planning solution. Used by 21 international airlines, among them Comair (USA), Italian branch of Lauda Air, Malev (Hungary), DHL Europe, Asiana (South Korea), Hainan (China), Royal Jordanian, Kuwait Airways, Cimber Air (Denmark), etc.

- **SCORE –** a long term airport capacity management system for coordinated airports. Successfully Used at IATA Scheduling Conferences. Users in more than 20 countries.

- **ARGOS –** a Decision Support System (DSS) for enhancing Crisis Management for incidents with Chemical, Biological, Radiological, and Nuclear (CBRN) releases.

# Contents



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

# PROLOG



Used to solve problems involving

- objects, and
- relationships between objects.

# Relationships



## Example

John owns the book

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

Directional:

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

# PROLOG



- 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.

# 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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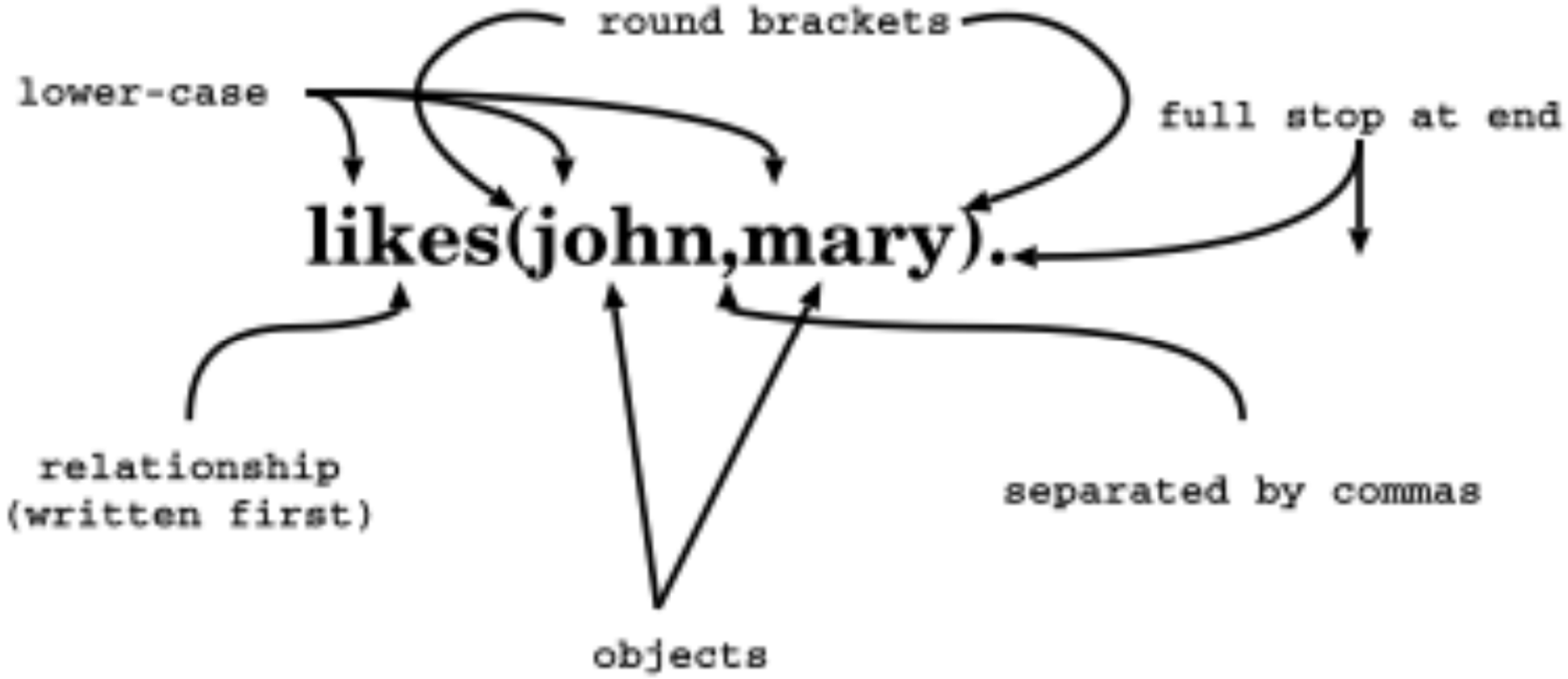
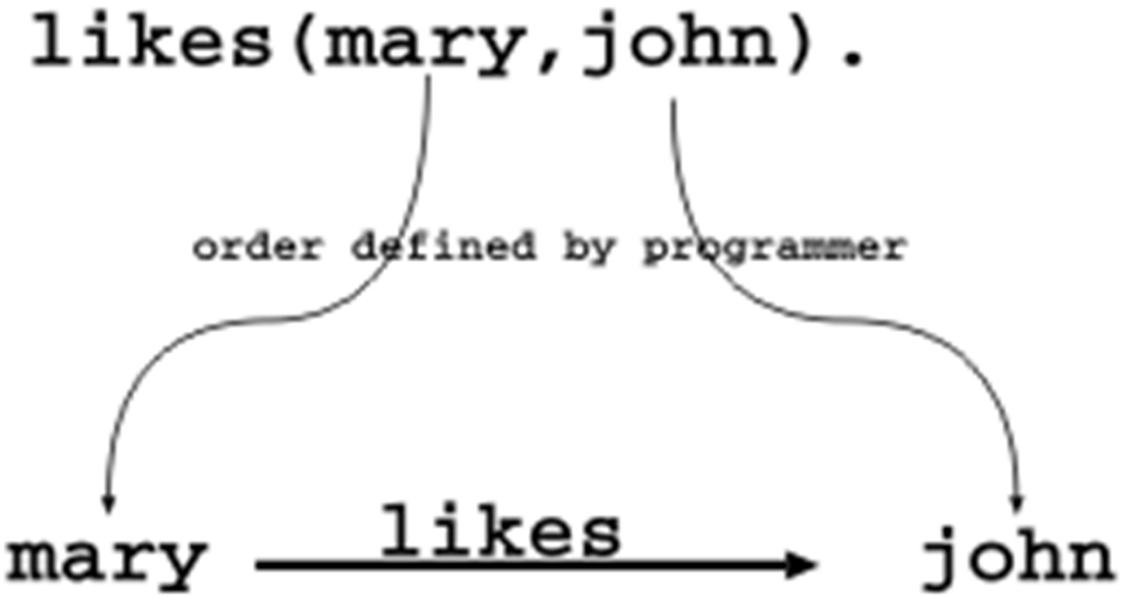
# Parts of Fact



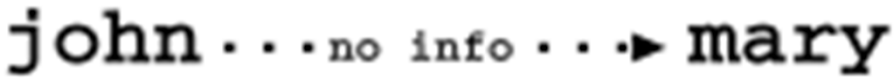


# Order of Objects






The fact says nothing
about how john likes mary



# 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.

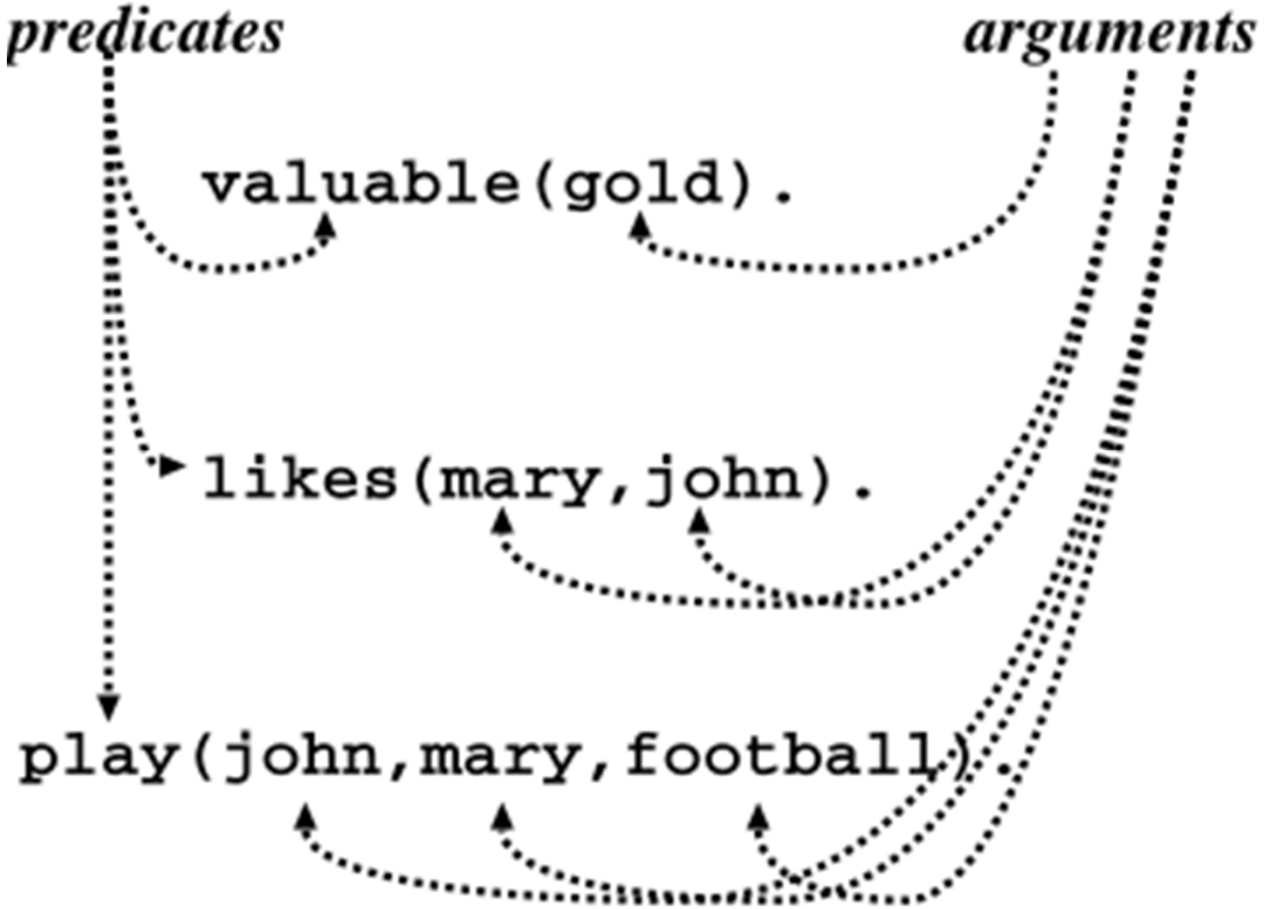
# Interpretation of Names



- 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 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.

# Contents



- Basics of PROLOG
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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).
  - Meanins: 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.

# Contents



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# Variables



Tiresome to ask about every object:

```
likes(john,this).
likes(john,that).
```

Better to ask:

What does John like?

or

Does John like X?

(i.e. use variables)

# Question With Variables



Does John like X?

```
?- 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).
```

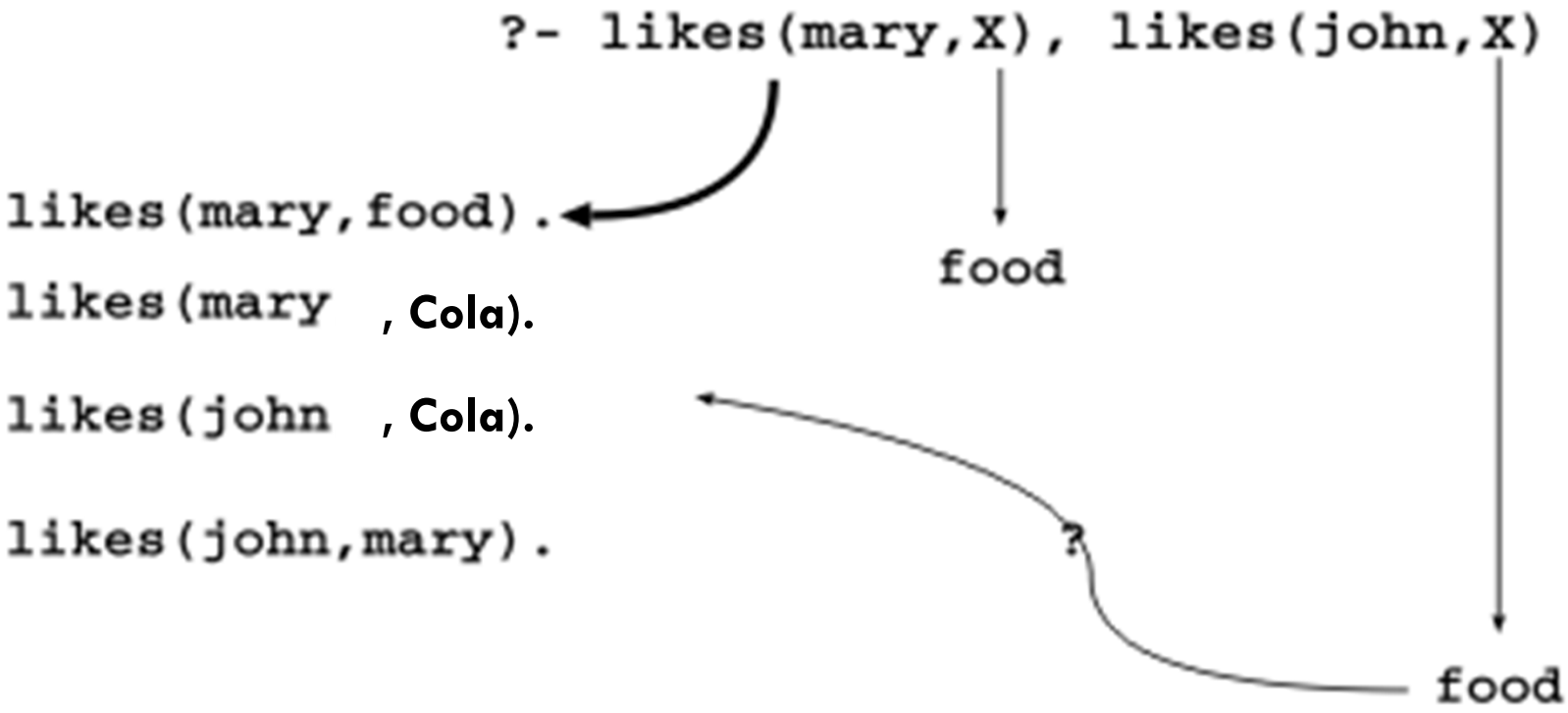
# Backtracking



- 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.

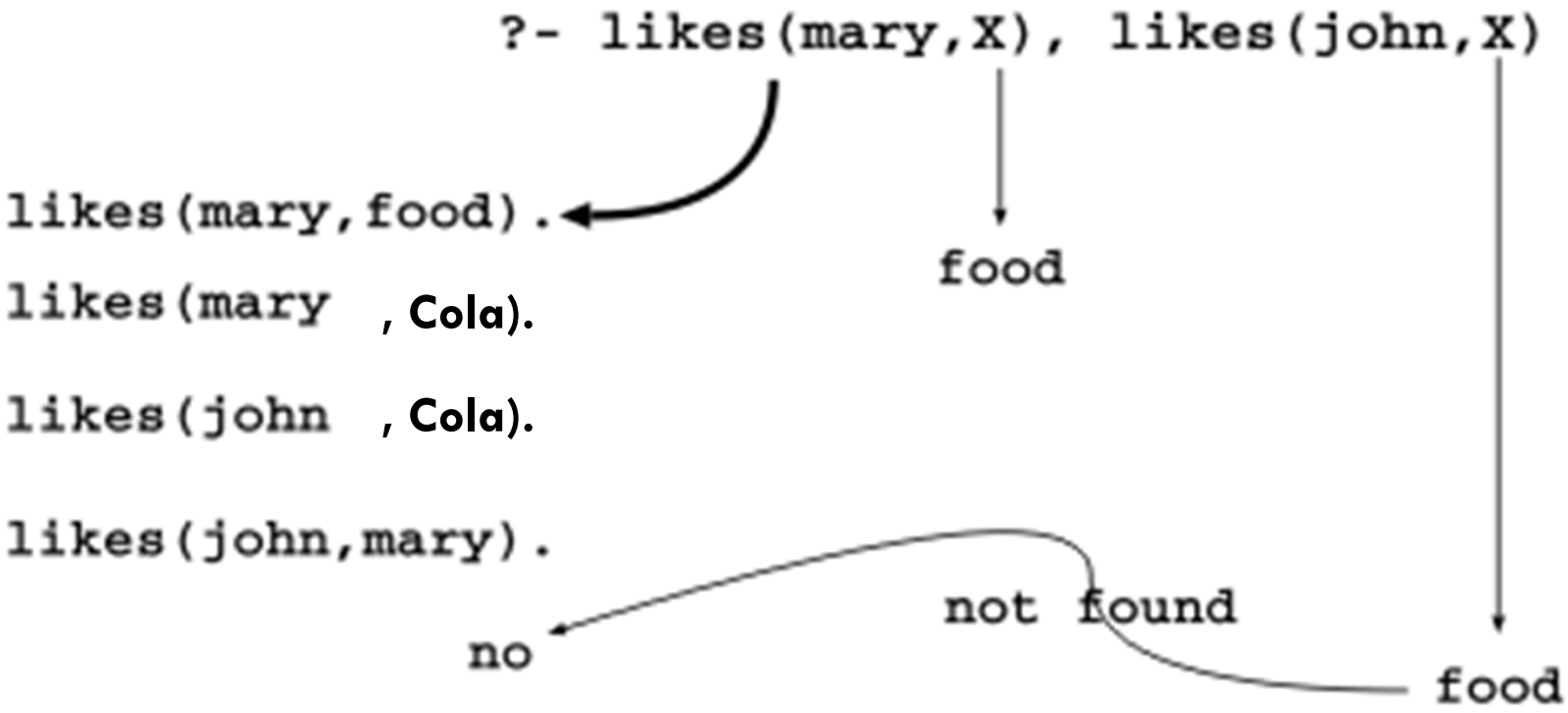
# Match First




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

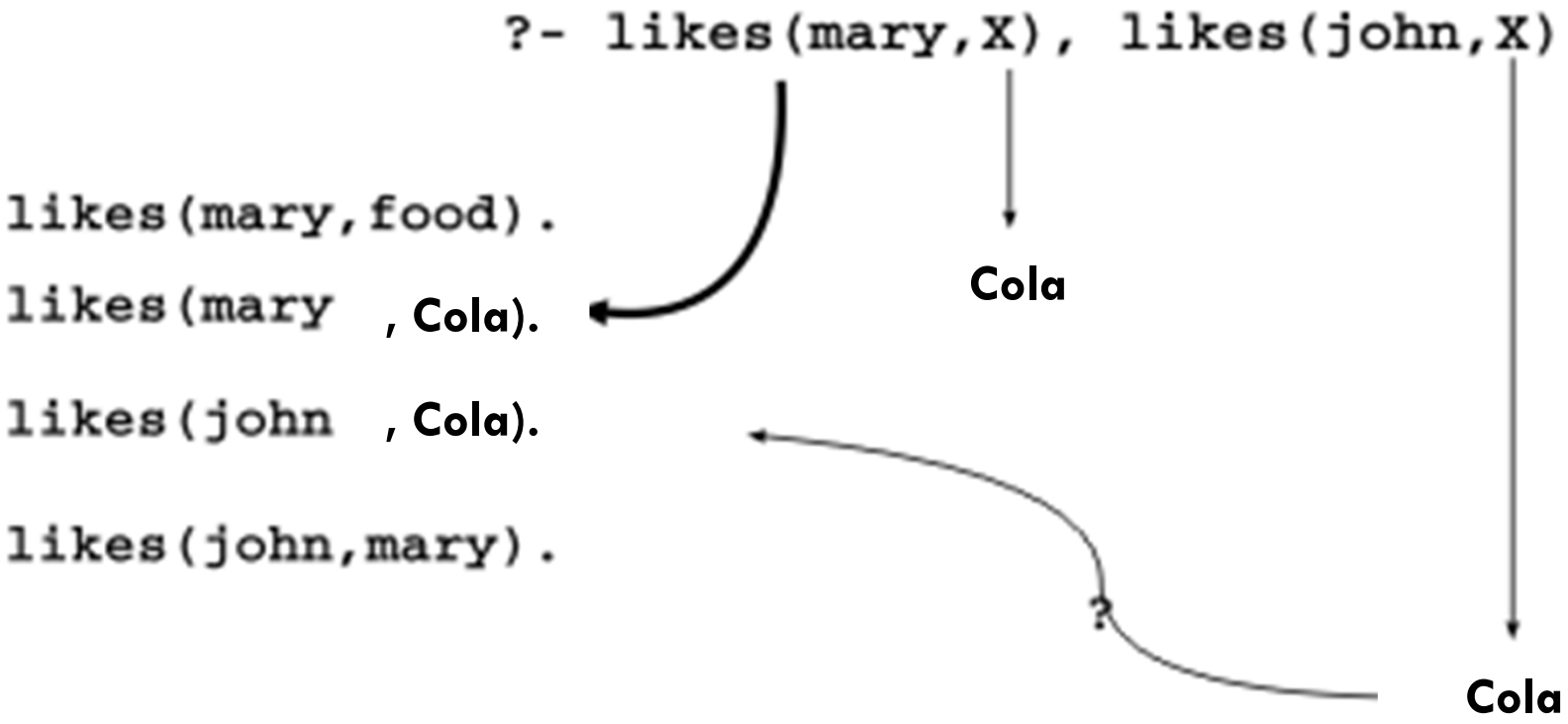
# Match Second





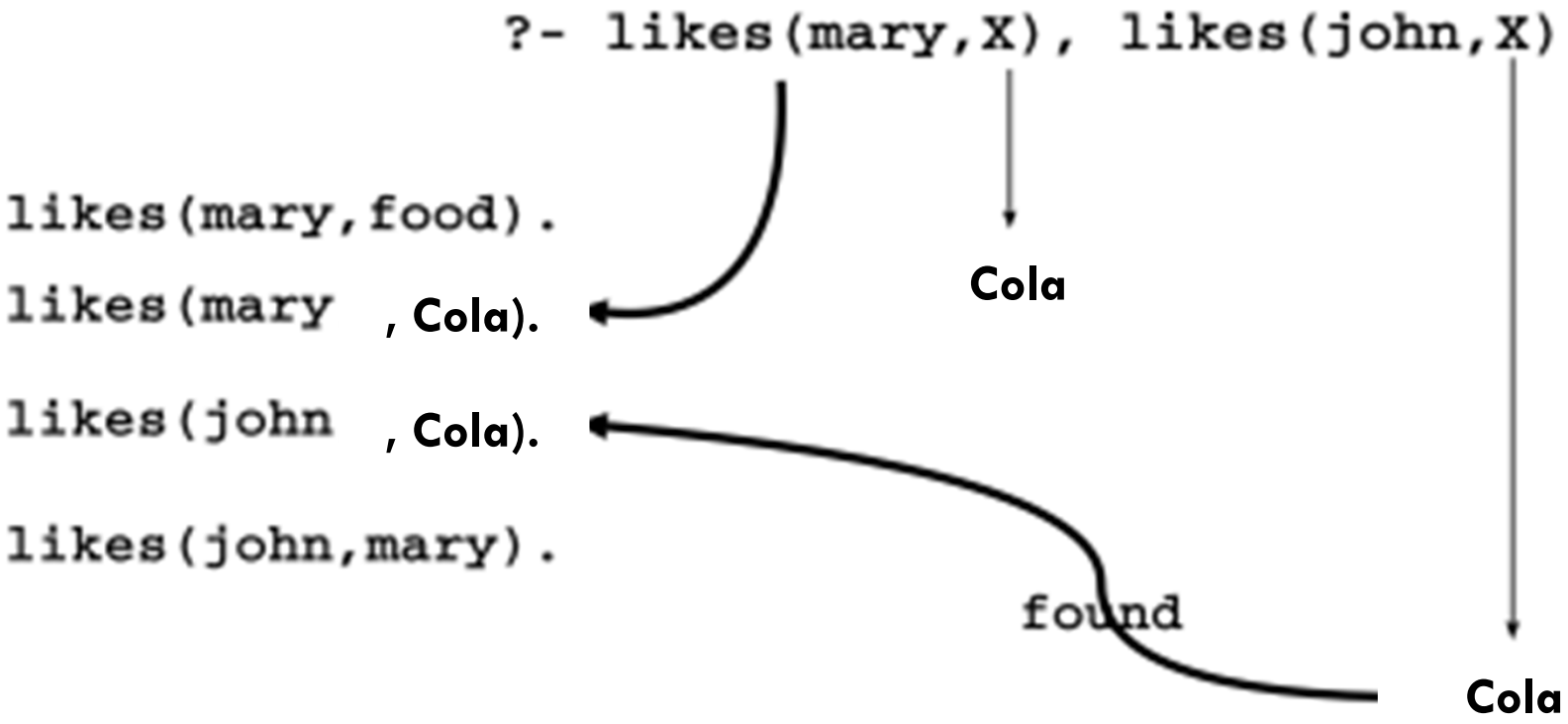
# Backtrack




?- 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 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.

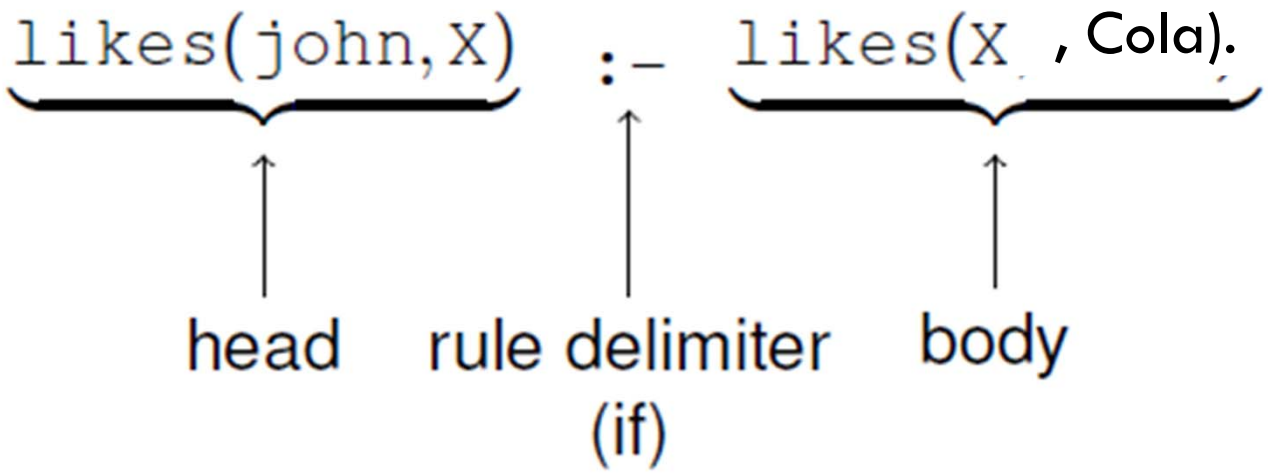
# Formulating Rules



- 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



Question:

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

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

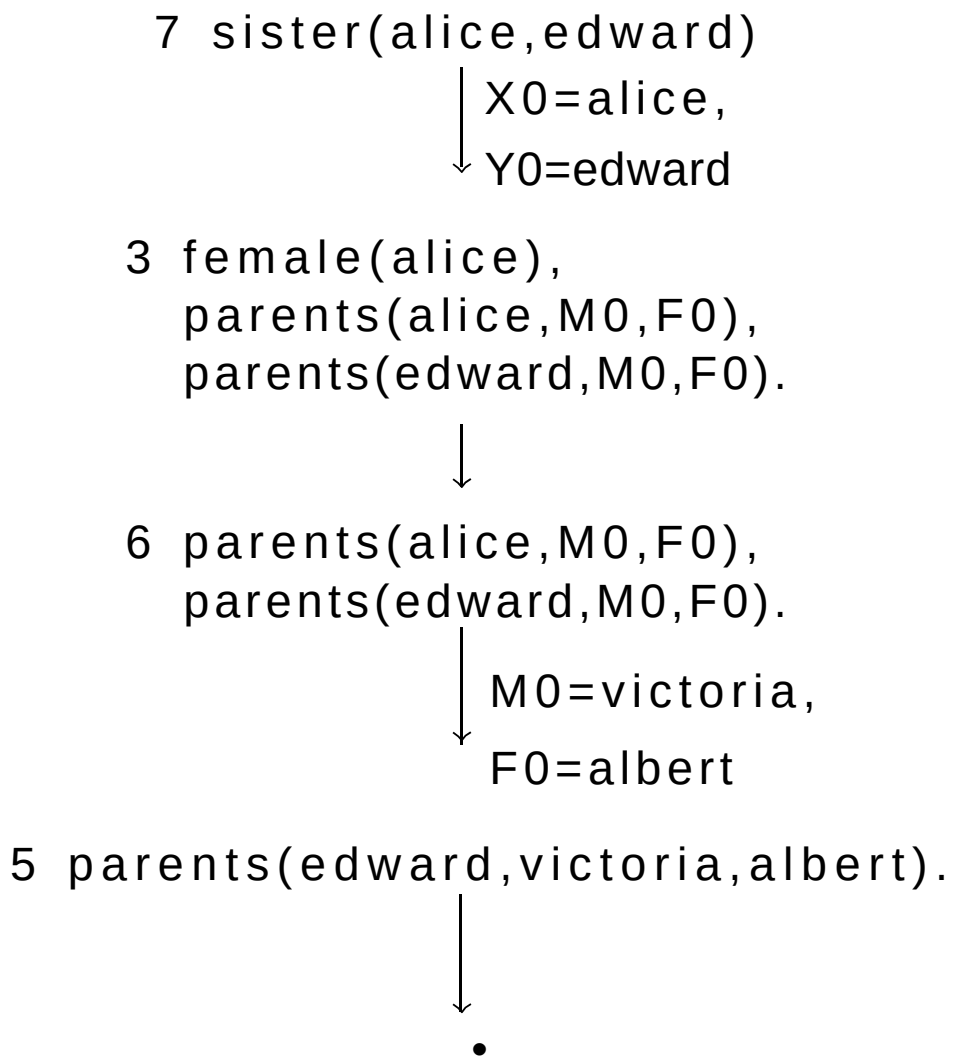
The instance of the body becomes new goal:

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

# Is Alice Edward's Sister?



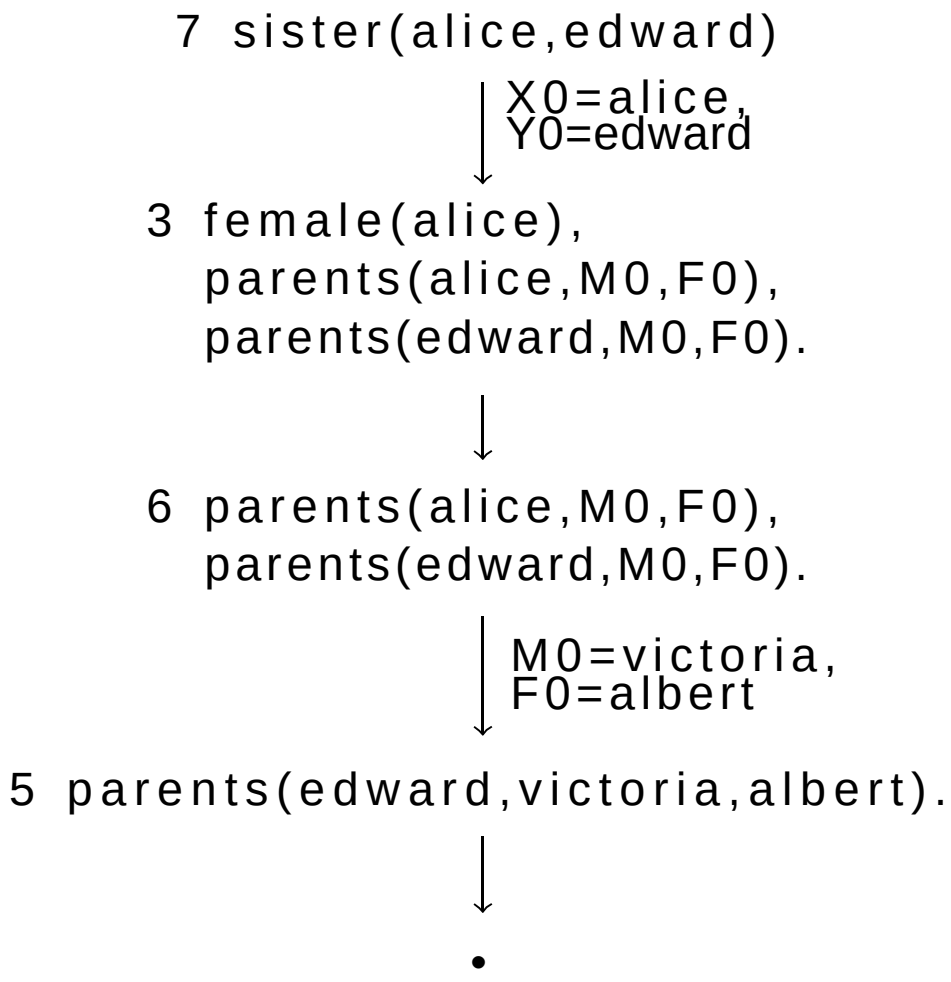
```
(1) male(albert).
(2) male(edward).
(3) female(alice).
(4) female(victoria).
(5) parents(edward,
        victoria, albert).
(6) parents(alice,
        victoria,albert).
(7) sister(X,Y):-
        female(X),
        parents(X,M,F),
        parents(Y,M,F).
```



# Is Alice Edward's Sister?



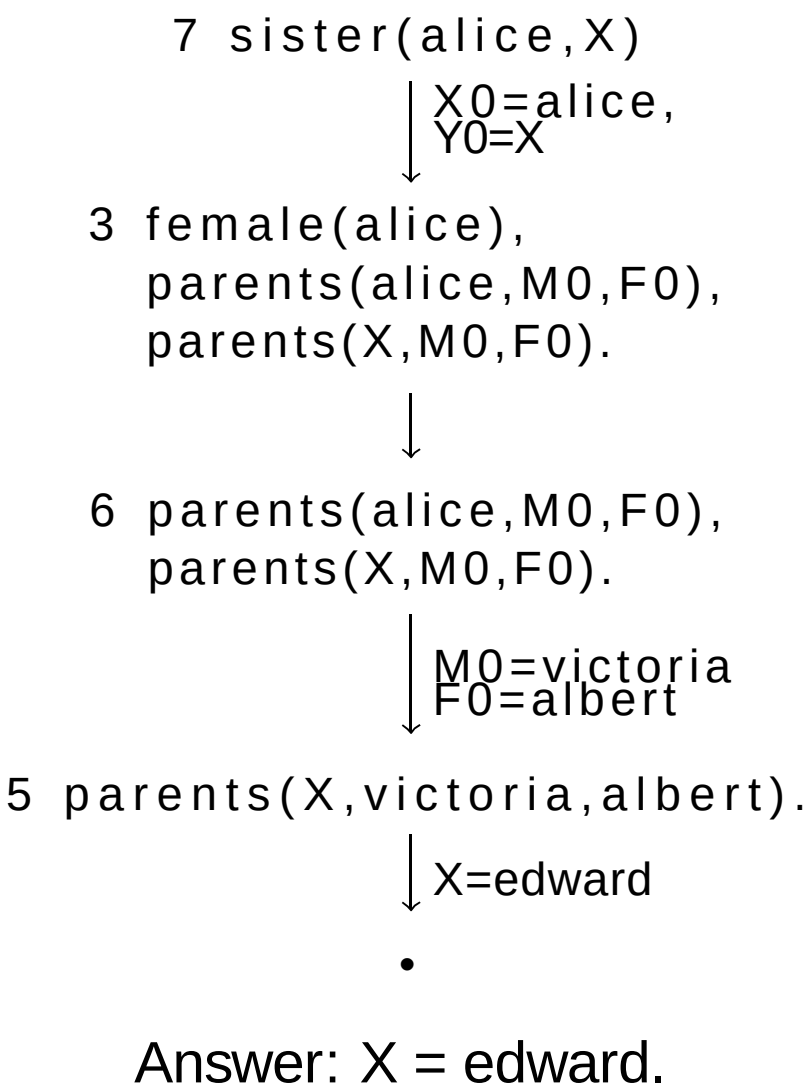
```
(1) male(albert).
(2) male(edward).
(3) female(alice).
(4) female(victoria).
(5) parents(edward,
        victoria, albert).
(6) parents(alice,
        victoria,albert).
(7) sister(X,Y):-
        female(X),
        parents(X,M,F),
        parents(Y,M,F).
```



# 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.

# Useful Links



- SWI-Prolog:
- http://www.swi-prolog.org/
- SWI-Prolog Editor (Windows, SWI-x86 only) http://lakk.bildung.hessen.de/netzwerk/faecher/informatik/swiprolog/index.html
- Prolog mode for (X)Emacs: http://turing.ubishops.ca/home/bruda/emacs-prolog/
- Prolog newsgroup: http://groups.google.com/groups?group=comp.lang.prolog
- Links from SWI-Prolog Web page: http://www.swi-prolog.org/Links.html