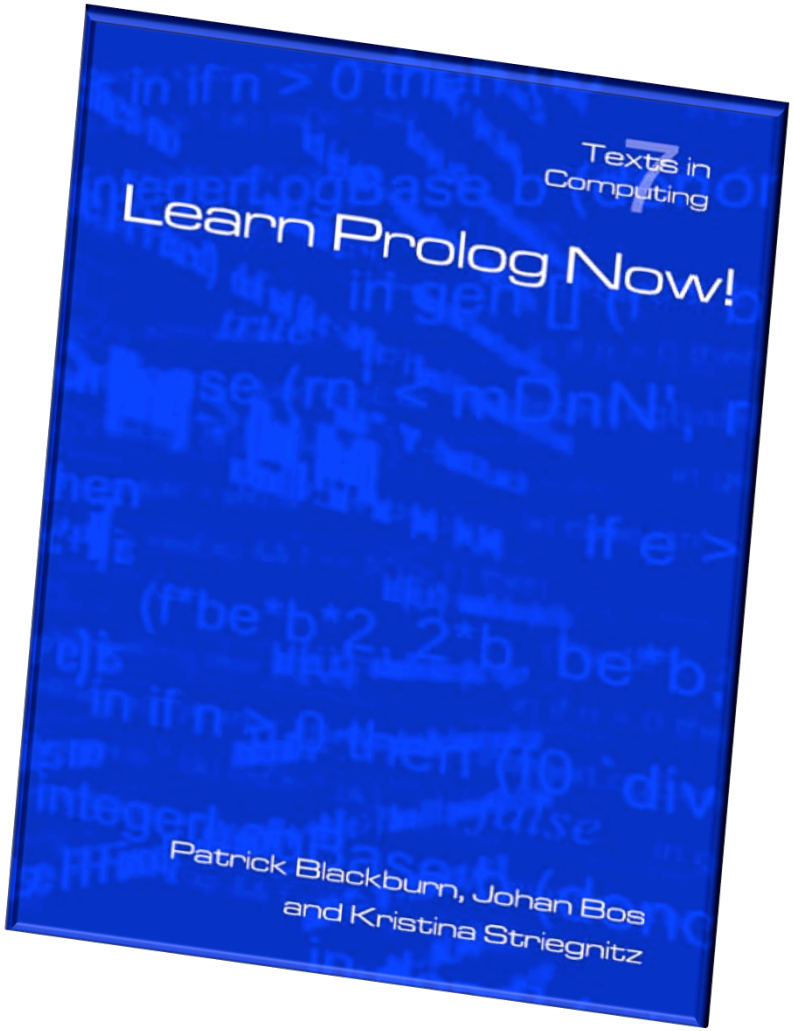
Learn Prolog Now!

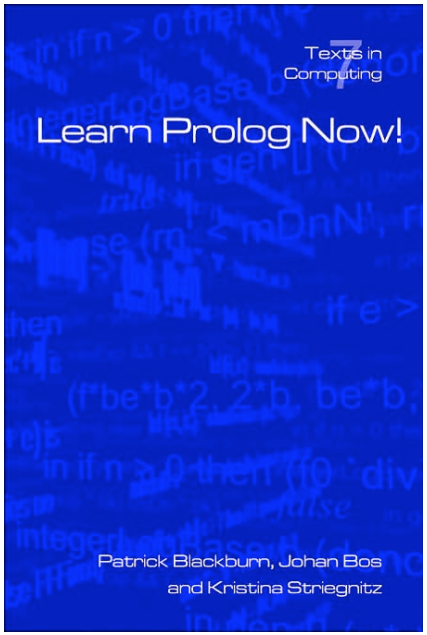


SWI Prolog

- Freely available Prolog interpreter
- Works with
  - Linux,
  - Windows, or
  - Mac OS
- There are many more Prolog interpreters
- Not all are ISO compliant/free

Lecture 1

- Theory
  - Introduction to Prolog
  - Facts, Rules and Queries
  - Prolog Syntax
- Exercises
  - Exercises of LPN chapter 1
  - Practical work



Aim of this lecture (1/2)

- Give some simple examples of Prolog programs
- Discuss the three basic constructs in Prolog:
  - Facts
  - Rules
  - Queries

Aim of this lecture (2/2)

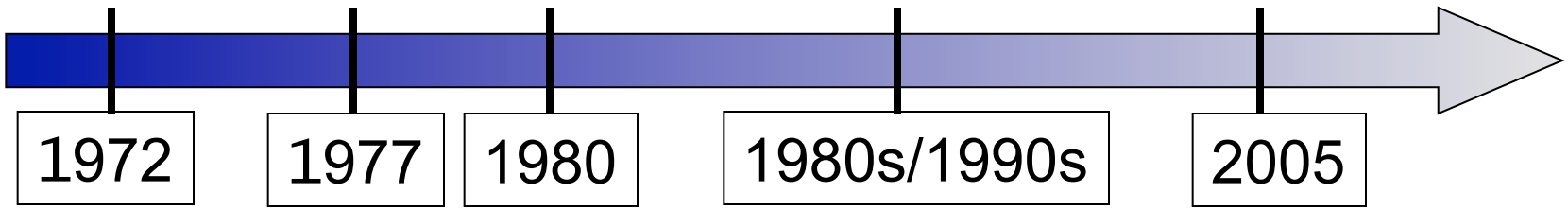
- Introduce other concepts, such as
  - the role of logic
  - unification with the help of variables
- Begin the systematic study of Prolog by defining
  - terms
  - atoms, and
  - variables

Prolog

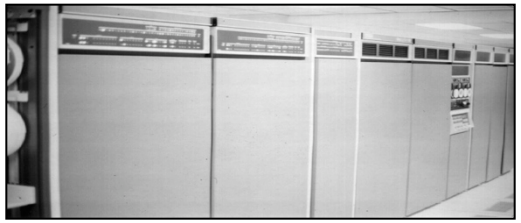
- "Programming with Logic"
- Very different from other programming languages
  - Declarative (not procedural)
  - Recursion (no “for” or “while” loops)
  - Relations (no functions)
  - Unification

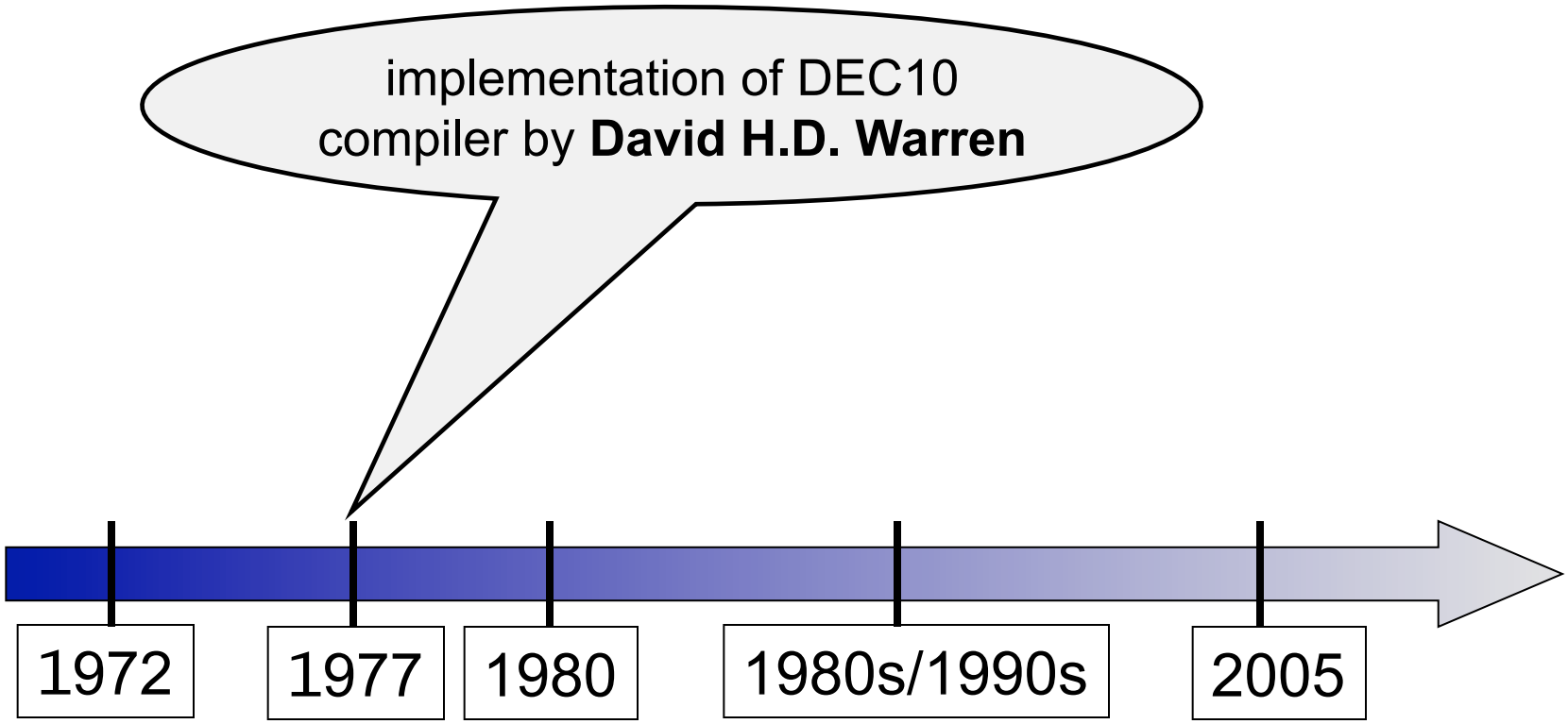
History of Prolog

first Prolog interpreter by
Alain Colmerauer and
Philippe Roussel

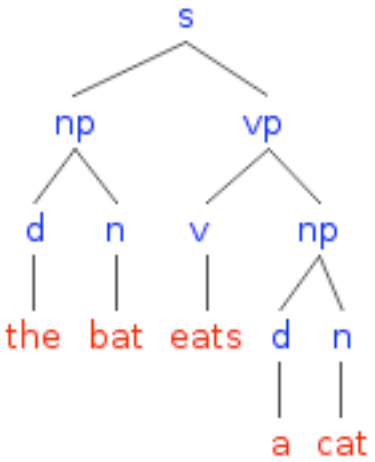


History of Prolog

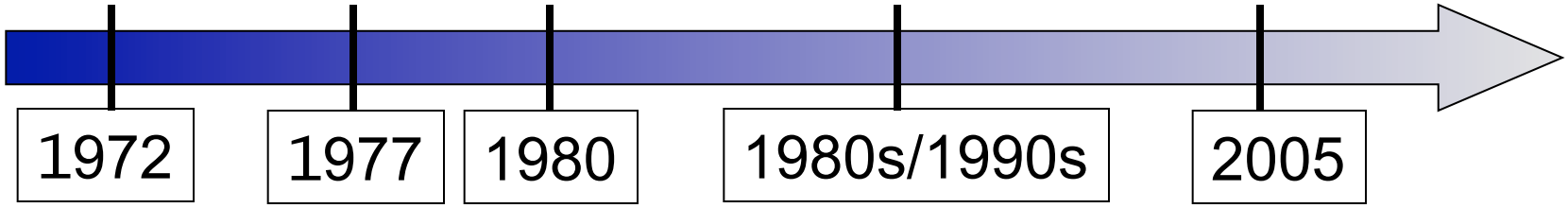




History of Prolog

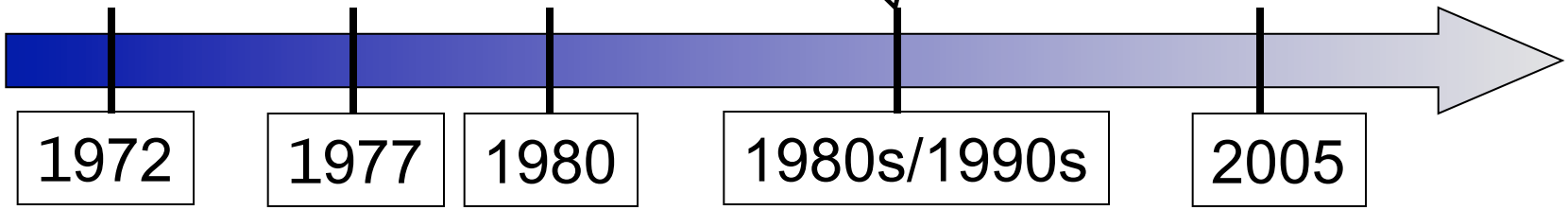


Definite Clause Grammars implementation by **Pereira** and **Warren**

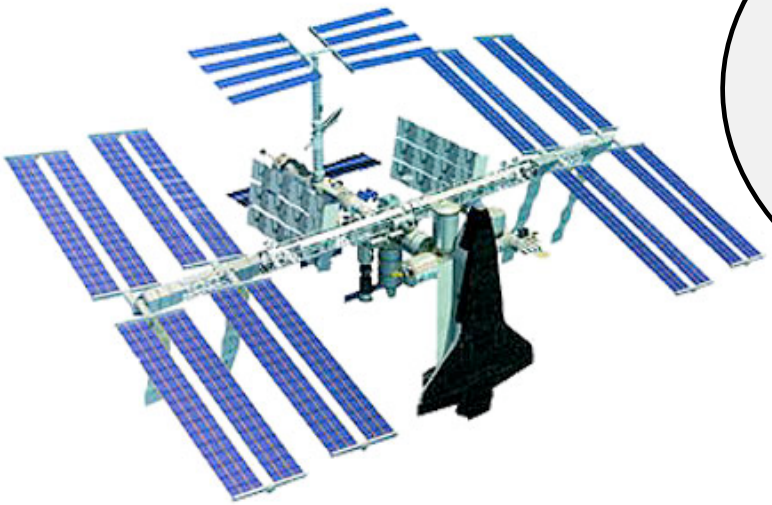


History of Prolog

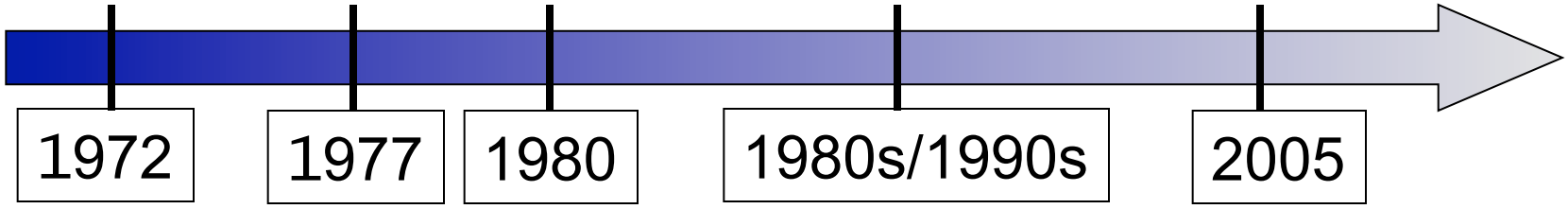
Prolog grows in popularity
especially in Japan and Europe



History of Prolog

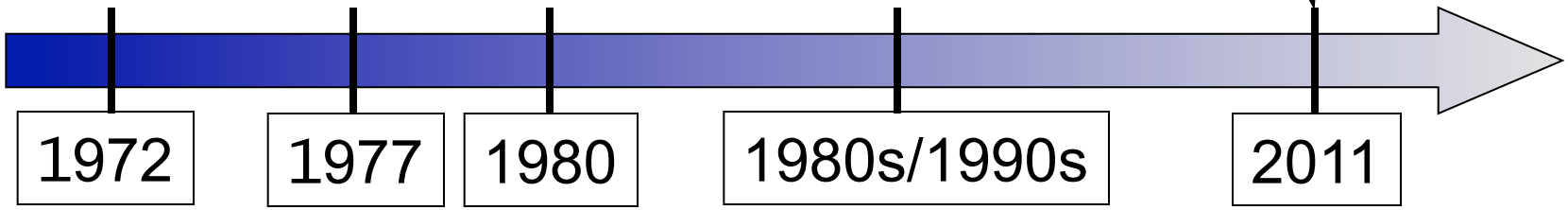


Prolog used to program natural language interface in International Space Station by NASA



History of Prolog

Parts of IBM's Watson QA supercomputer were coded in Prolog



Prolog and Web Applications

- prolog programs are often smaller
- smallness encourages well written code
- hence, easier to maintain

Source:

http://www.pathwayslms.com/swipltuts/

Basic idea of Prolog

- Describe the situation of interest
- Ask a question
- Prolog:
  - logically deduces new facts about the situation we described
  - gives us its deductions back as answers

Consequences

- Think declaratively, not procedurally
  - Challenging
  - Requires a different mindset
- High-level language
  - Not as efficient as, say, C
  - Good for rapid prototyping
  - Useful in many AI applications (knowledge representation, inference)

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?-
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- woman(mia).
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- woman(mia).
yes
?-
```

Knowledge Base 1

```
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woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- woman(mia).
yes
?- playsAirGuitar(jody).
```

Knowledge Base 1

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party.
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yes
?- playsAirGuitar(jody).
yes
?-
```

Knowledge Base 1

```
woman(mia).
woman(jody).
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playsAirGuitar(jody).
party.
```

```
?- woman(mia).
yes
?- playsAirGuitar(jody).
yes
?- playsAirGuitar(mia).
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- woman(mia).
yes
?- playsAirGuitar(jody).
yes
?- playsAirGuitar(mia).
no
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- tattoed(jody).
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- tattoed(jody).
no
?-
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- tattoed(jody).
ERROR: predicate tattoed/1 not defined.
?-
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- party.
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- party.
yes
?-
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- rockConcert.
```

Knowledge Base 1

```
woman(mia).
woman(jody).
woman(yolanda).
playsAirGuitar(jody).
party.
```

```
?- rockConcert.
no
?-
```

Knowledge Base 2

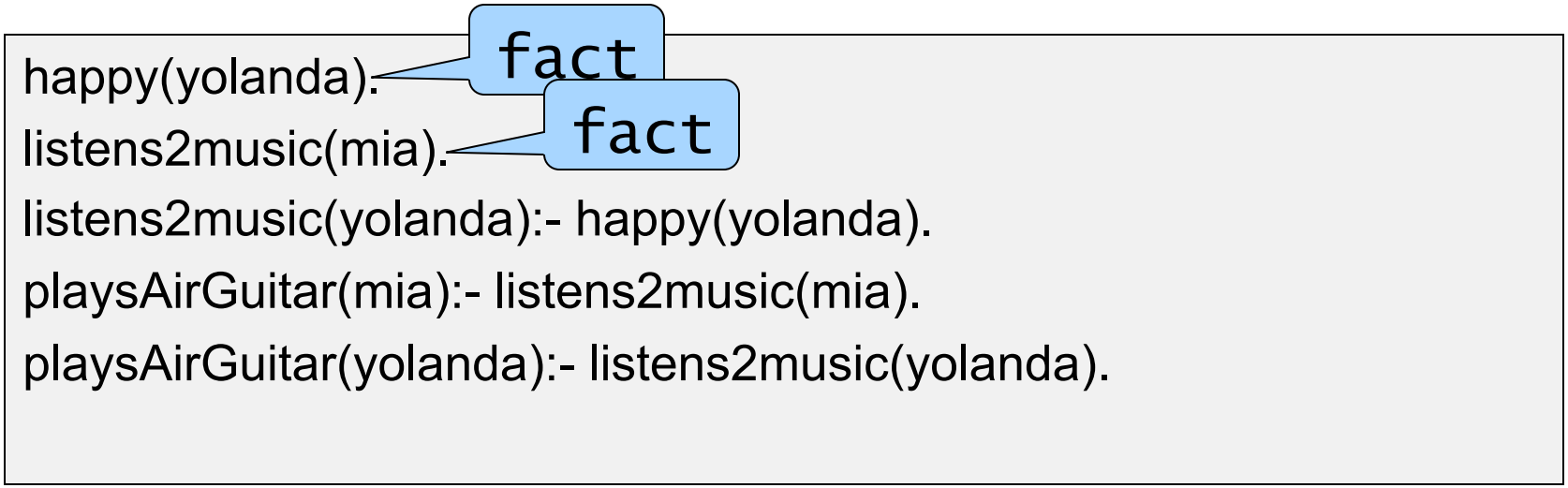
```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

Knowledge Base 2

```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

fact

Knowledge Base 2



Knowledge Base 2

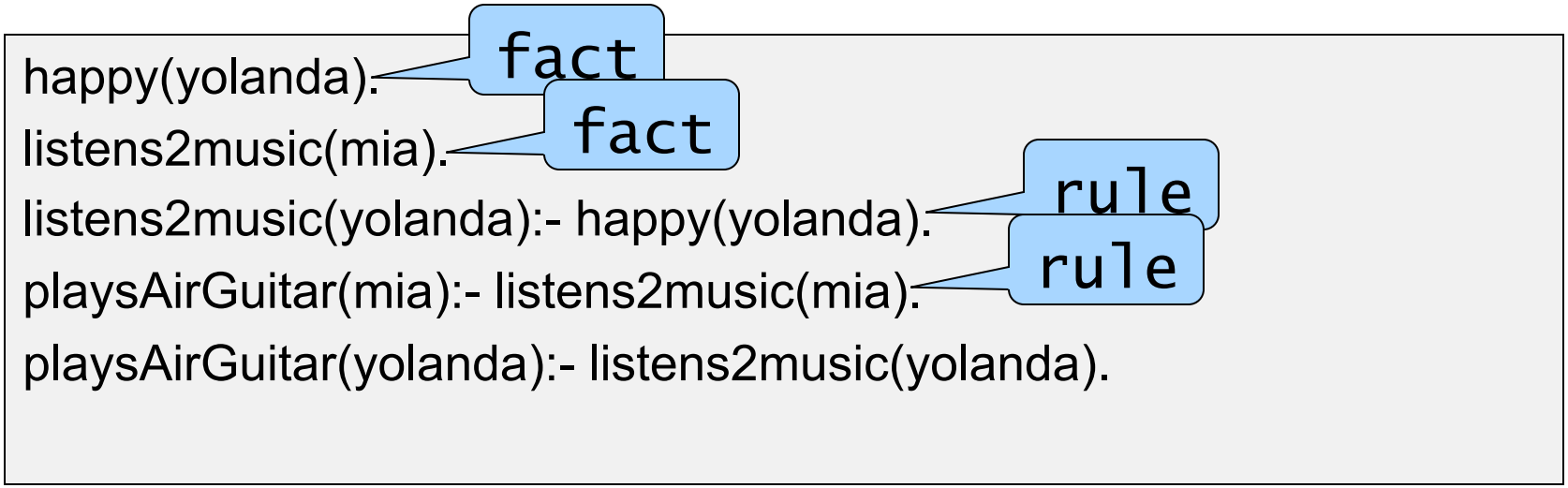
```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

fact

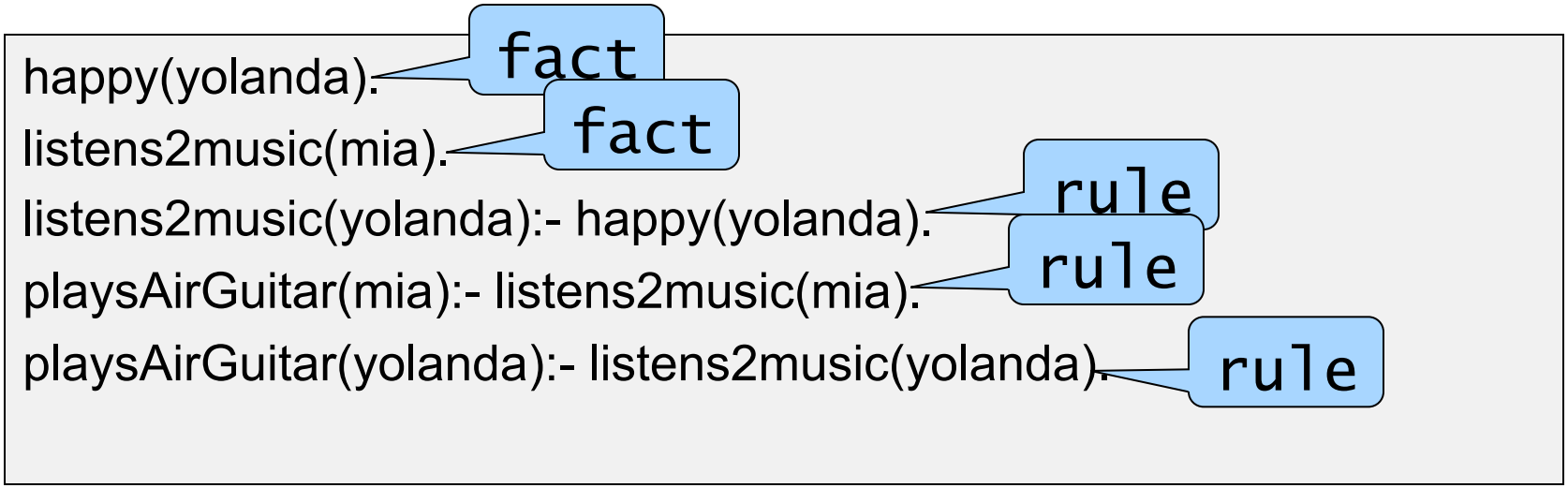
fact

rule

Knowledge Base 2

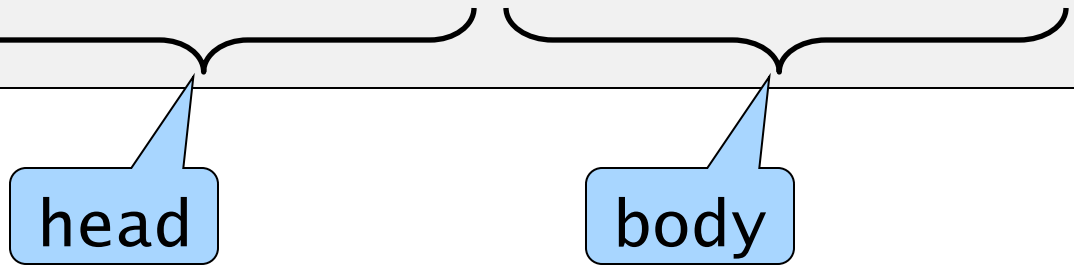


Knowledge Base 2



Knowledge Base 2

```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```



Knowledge Base 2

```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

```
?-
```

Knowledge Base 2

```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

```
?- playsAirGuitar(mia).
yes
?-
```

Knowledge Base 2

```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

```
?- playsAirGuitar(mia).
yes
?- playsAirGuitar(yolanda).
yes
```

Clauses

```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

There are five clauses in this knowledge base: two facts, and three rules.

The end of a clause is marked with a full stop.

Predicates

```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

*There are three **predicates** in this knowledge base:*

happy, listens2music, and playsAirGuitar

Knowledge Base 3

```
happy(vincent).
listens2music(butch).
playsAirGuitar(vincent):- listens2music(vincent), happy(vincent).
playsAirGuitar(butch):- happy(butch).
playsAirGuitar(butch):- listens2music(butch).
```

Expressing Conjunction

```
happy(vincent).
listens2music(butch).
playsAirGuitar(vincent):- listens2music(vincent), happy(vincent).
playsAirGuitar(butch):- happy(butch).
playsAirGuitar(butch):- listens2music(butch).
```

The comma "," expresses conjunction in Prolog

Knowledge Base 3

```
happy(vincent).
listens2music(butch).
playsAirGuitar(vincent):- listens2music(vincent), happy(vincent).
playsAirGuitar(butch):- happy(butch).
playsAirGuitar(butch):- listens2music(butch).
```

```
?- playsAirGuitar(vincent).
```

Knowledge Base 3

```
happy(vincent).
listens2music(butch).
playsAirGuitar(vincent):- listens2music(vincent), happy(vincent).
playsAirGuitar(butch):- happy(butch).
playsAirGuitar(butch):- listens2music(butch).
```

```
?- playsAirGuitar(vincent).
no
?-
```

Knowledge Base 3

```
happy(vincent).
listens2music(butch).
playsAirGuitar(vincent):- listens2music(vincent), happy(vincent).
playsAirGuitar(butch):- happy(butch).
playsAirGuitar(butch):- listens2music(butch).
```

```
?- playsAirGuitar(butch).
```

Knowledge Base 3

```
happy(vincent).
listens2music(butch).
playsAirGuitar(vincent):- listens2music(vincent), happy(vincent).
playsAirGuitar(butch):- happy(butch).
playsAirGuitar(butch):- listens2music(butch).
```

```
?- playsAirGuitar(butch).
yes
?-
```

Expressing Disjunction

```
happy(vincent).
listens2music(butch).
playsAirGuitar(vincent):- listens2music(vincent), happy(vincent).
playsAirGuitar(butch):- happy(butch).
playsAirGuitar(butch):- listens2music(butch).
```

```
happy(vincent).
listens2music(butch).
playsAirGuitar(vincent):- listens2music(vincent), happy(vincent).
playsAirGuitar(butch):- happy(butch); listens2music(butch).
```

Prolog and Logic

- Clearly, Prolog has something to do with logic...

	Prolog	Logic
Implication	A :- B	$B \rightarrow A$
Conjunction	A,B	$A \wedge B$
Disjunction	A;B	$A \vee B$

- Use of inference (modus ponens)
- Negation (?)

Knowledge Base 4

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

Prolog Variables

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- woman(X).
```

Variable Instantiation

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- woman(X).
X=mia
```

Asking Alternatives

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- woman(X).
X=mia;
```

Asking Alternatives

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- woman(X).
X=mia;
X=jody
```

Asking Alternatives

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- woman(X).
X=mia;
X=jody;
X=yolanda
```

Asking Alternatives

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- woman(X).
X=mia;
X=jody;
X=yolanda;
no
```

Knowledge Base 4

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- loves(marsellus,X), woman(X).
```

Knowledge Base 4

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- loves(marsellus,X), woman(X).
X=mia
yes
?-
```

Knowledge Base 4

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- loves(pumpkin,X), woman(X).
```

Knowledge Base 4

```
woman(mia).
woman(jody).
woman(yolanda).

loves(vincent, mia).
loves(marsellus, mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).
```

```
?- loves(pumpkin,X), woman(X).
no
?-
```

Knowledge Base 5

```
loves(vincent,mia).
loves(marsellus,mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).

jealous(X,Y):- loves(X,Z), loves(Y,Z).
```

Knowledge Base 5

```
loves(vincent,mia).
loves(marsellus,mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).

jealous(X,Y):- loves(X,Z), loves(Y,Z).
```

```
?- jealous(marsellus,W).
```

Knowledge Base 5

```
loves(vincent,mia).
loves(marsellus,mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).

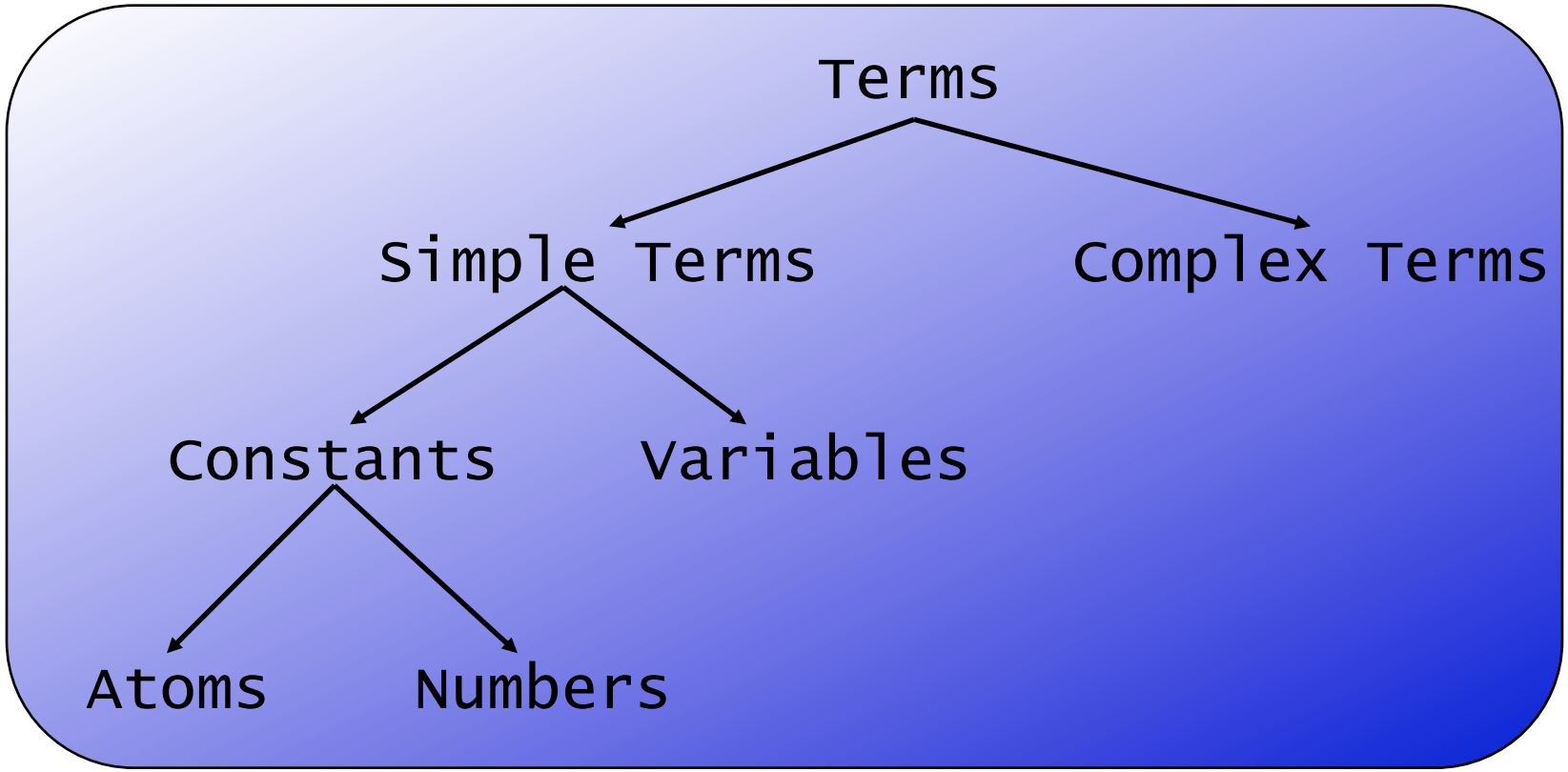
jealous(X,Y):- loves(X,Z), loves(Y,Z).
```

```
?- jealous(marsellus,W).
W=vincent
?-
```

Syntax of Prolog

- Q: What exactly are facts, rules and queries built out of?
- A: Prolog terms

Prolog terms



Atoms

- A sequence of characters of upper-case letters, lower-case letters, digits, or underscore, starting with a lowercase letter
  - *Examples*: **butch**, **big_kahuna_burger**, **playGuitar**

Atoms

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  - *Examples*: **butch**, **big_kahuna_burger**, **playGuitar**

- An arbitrary sequence of characters enclosed in single quotes
  - *Examples*: **'Vincent'**, **'Five dollar shake'**, **'@$%'**

Atoms

- A sequence of characters of upper-case letters, lower-case letters, digits, or underscore, starting with a lowercase letter
  - *Examples*: **butch**, **big_kahuna_burger**, **playGuitar**
- An arbitrary sequence of characters enclosed in single quotes
  - *Examples*: **'Vincent'**, **'Five dollar shake'**, **'@$%'**
- A sequence of special characters
  - *Examples*: **: , ; . :-**

Numbers

- Integers:

  12, -34, 22342

- Floats:

  34573.3234, 0.3435

Variables

- A sequence of characters of upper-case letters, lower-case letters, digits, or underscore, starting with either an uppercase letter or an underscore

- Examples:

  X, Y, Variable, Vincent, _tag

Complex Terms

- Atoms, numbers and variables are building blocks for **complex terms**
- Complex terms are built out of a **functor** directly followed by a sequence of **arguments**
  - Arguments are put in round brackets, separated by commas
  - The functor must be an atom

Examples of complex terms

- Examples we have seen before:
  - playsAirGuitar(jody)
  - loves(vincent, mia)
  - jealous(marsellus, W)
- Complex terms inside complex terms:
  - hide(X,father(father(father(butch))))

Arity

- The number of arguments a complex term has is called its arity

- Examples:

woman(mia) is a term with arity 1
loves(vincent,mia) has arity 2
father(father(butch)) arity 1

Arity is important

- You can define two predicates with the same functor but with different arity
- Prolog would treat this as two different predicates!
- In Prolog documentation, arity of a predicate is usually indicated with the suffix "/" followed by a number to indicate the arity

Example of Arity

```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

- This knowledge base defines
  - happy/1
  - listens2music/1
  - playsAirGuitar/1