Artificial Intelligence

- Course and exercises web site
  http://www2.kbs.uni-hannover.de/ki.html
- About the AI exercises (Prolog)
  - Taught in English
  - Thursdays morning 11:00-11:45

Artificial Intelligence Introduction to Prolog

- Exercises Teaching Material
  - Learn Prolog Now!
    http://www.learnprolognow.org
  - SWI Prolog interpreter
    http://www.swi-prolog.org/

Learn Prolog Now!

- Each chapter is composed of
  - Prolog theory (presented in KI Übungen)
  - Prolog exercises (corrected in class)
    - Assigned exercises are corrected in class after the presentation of Prolog's theory
    - Corrections available on the course web site
  - Practical session (not covered)
    - Not covered in the lecture, but it is strongly encouraged to do them!
    - Knowledge bases code available at http://l3s.de/~gaugaz/ki/prolog/

SWI Prolog

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

Lecture 1

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

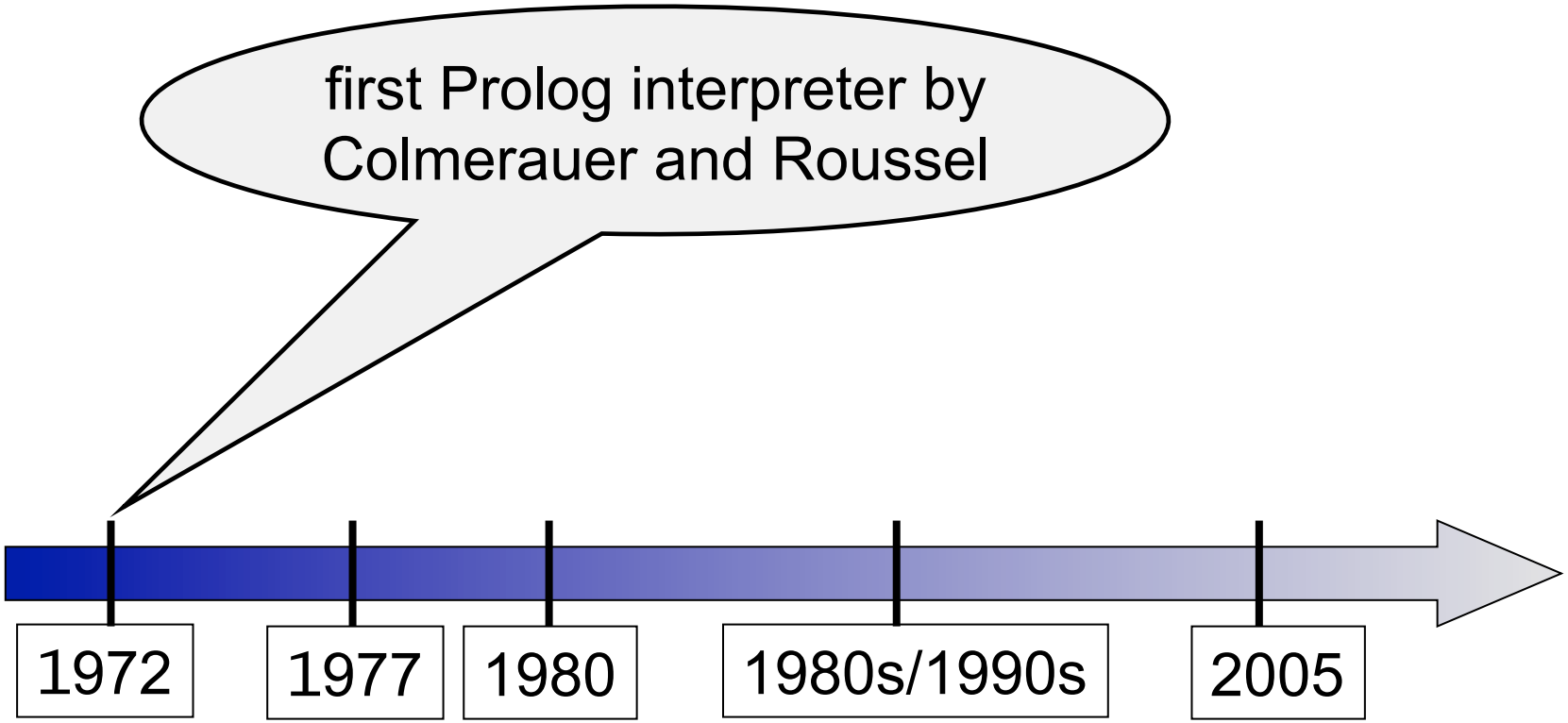
Aim of this lecture

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

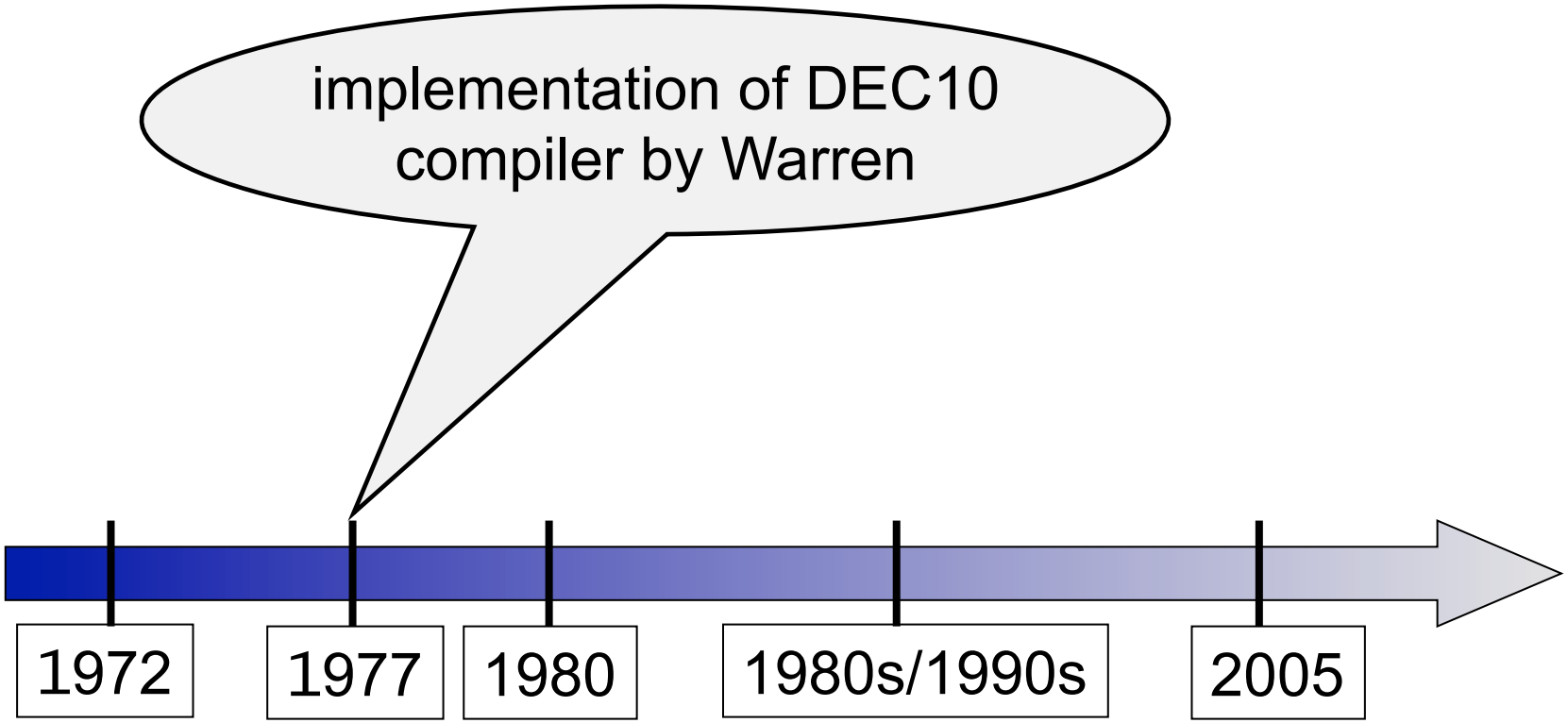
Prolog

- "Programming with Logic"
- Declarative
- Very different from other (procedural) programming languages
- Good for knowledge-rich tasks

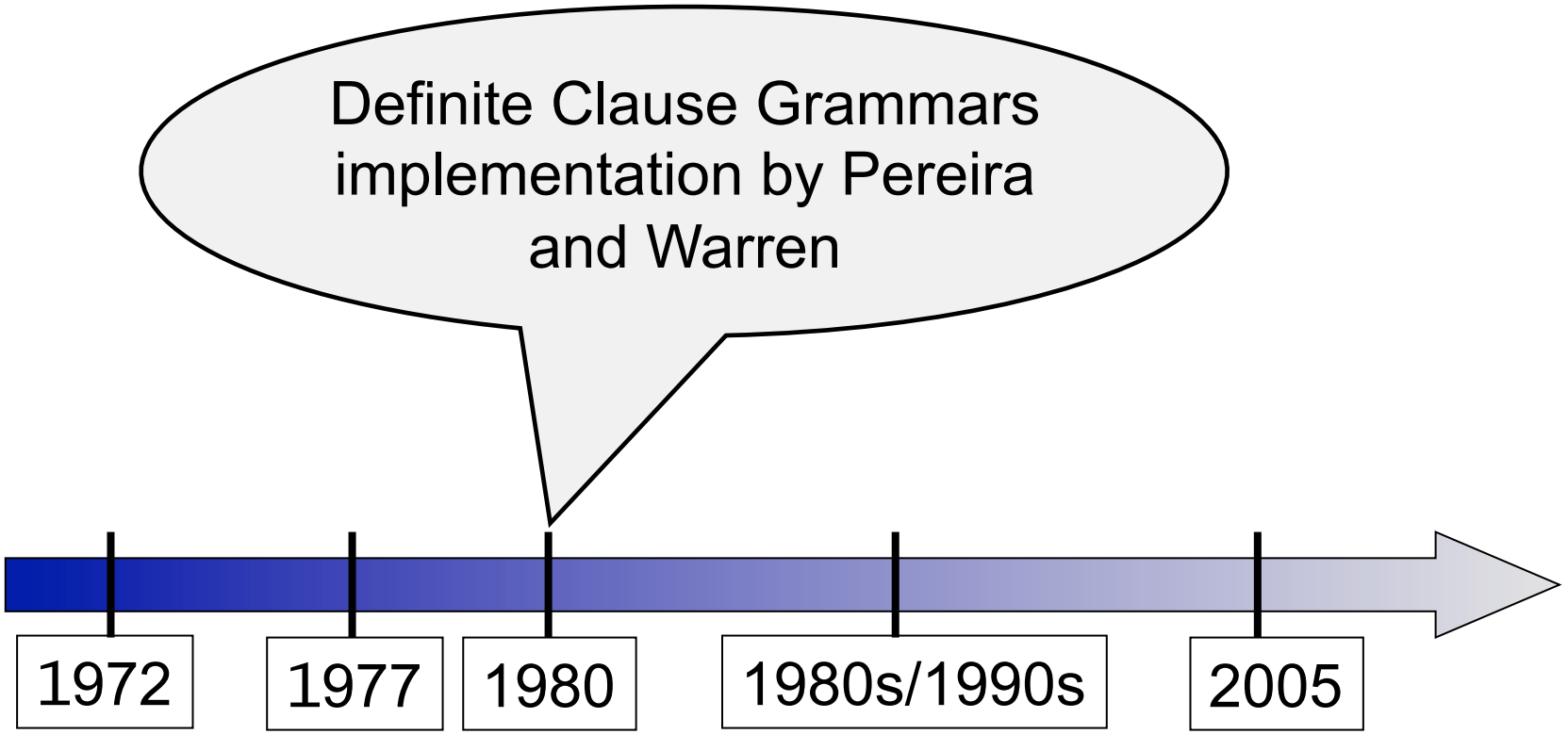
History of Prolog



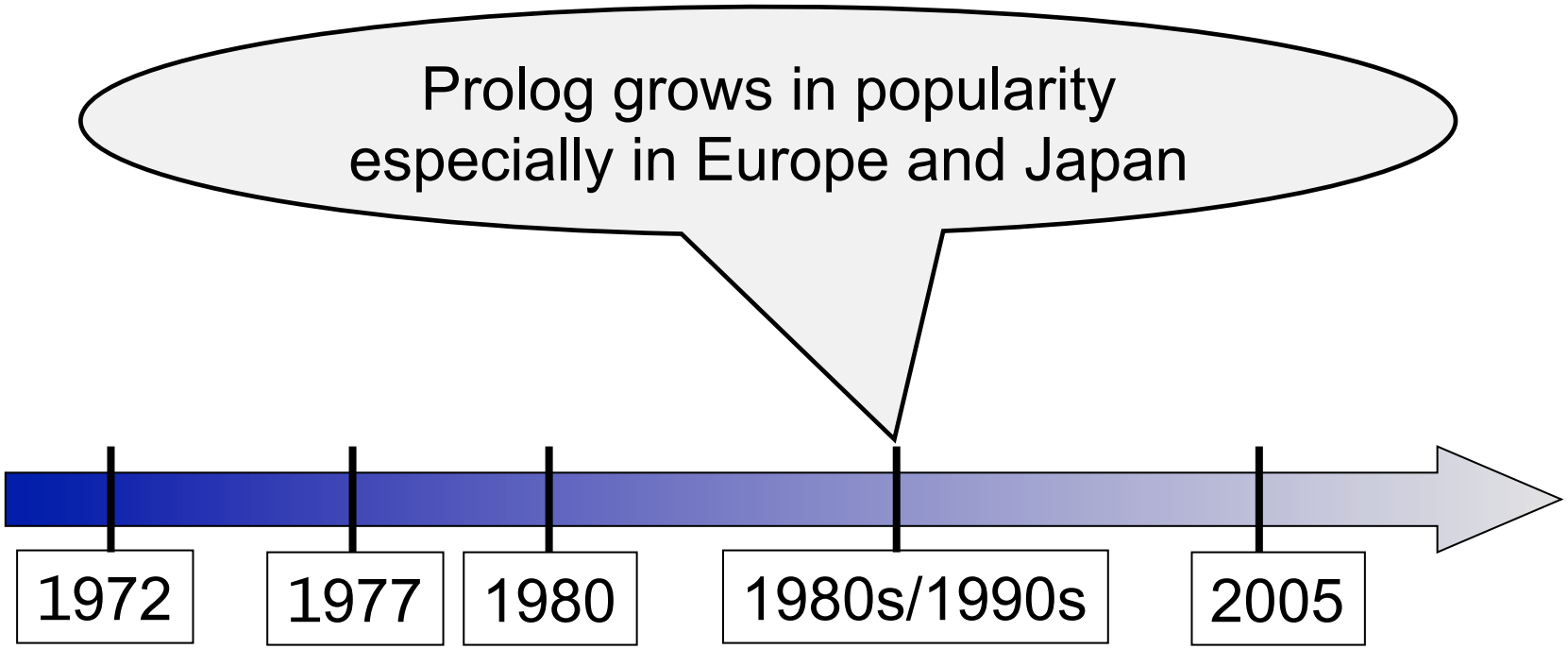
History of Prolog



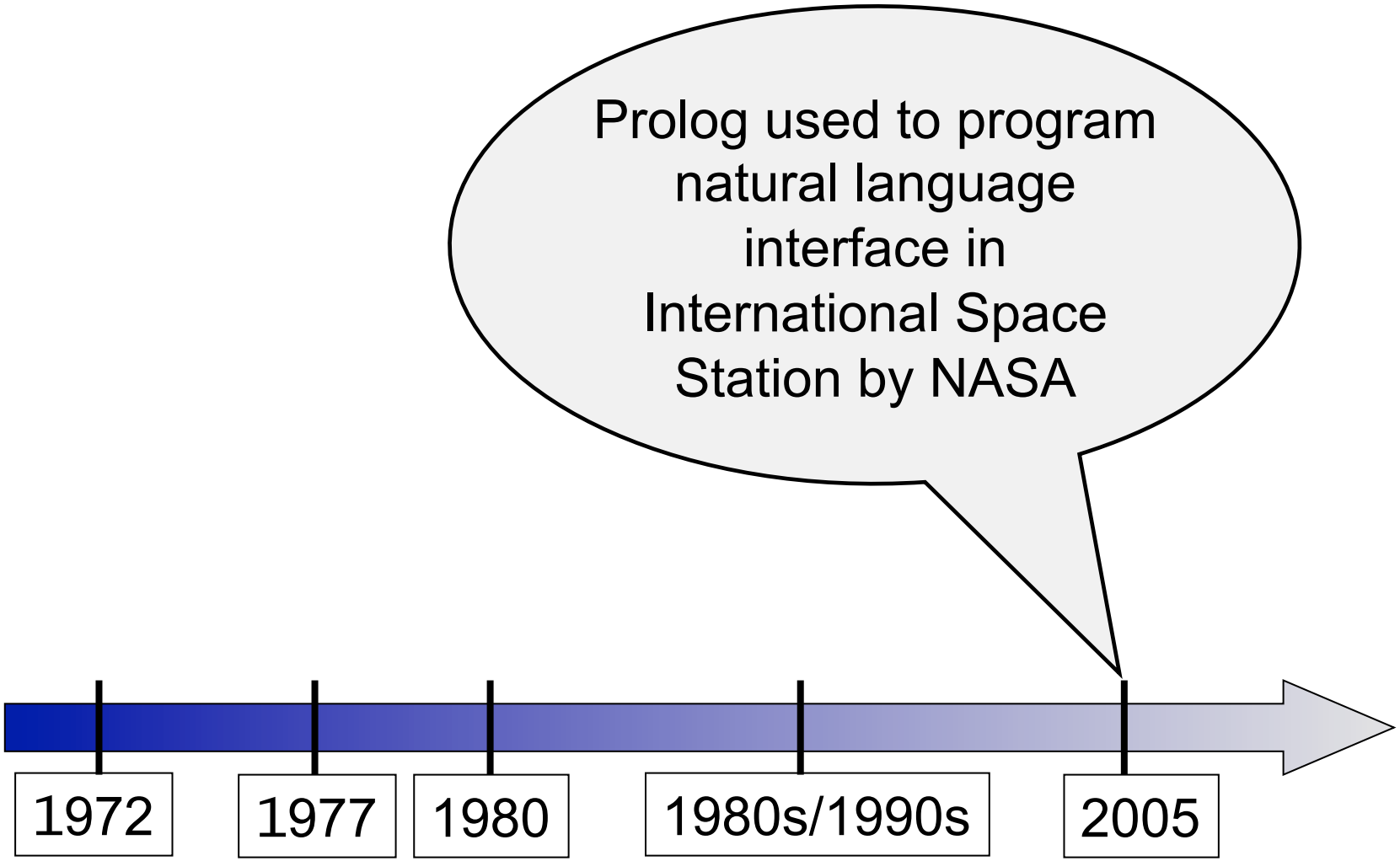
History of Prolog



History of Prolog



History of Prolog



Basic idea of Prolog

- Describe the situation of interest
- Ask a question
- Prolog logically deduces new facts about the situation we described
- Prolog 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 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

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

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

Knowledge Base 1

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

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

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

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

fact

fact

Knowledge Base 2

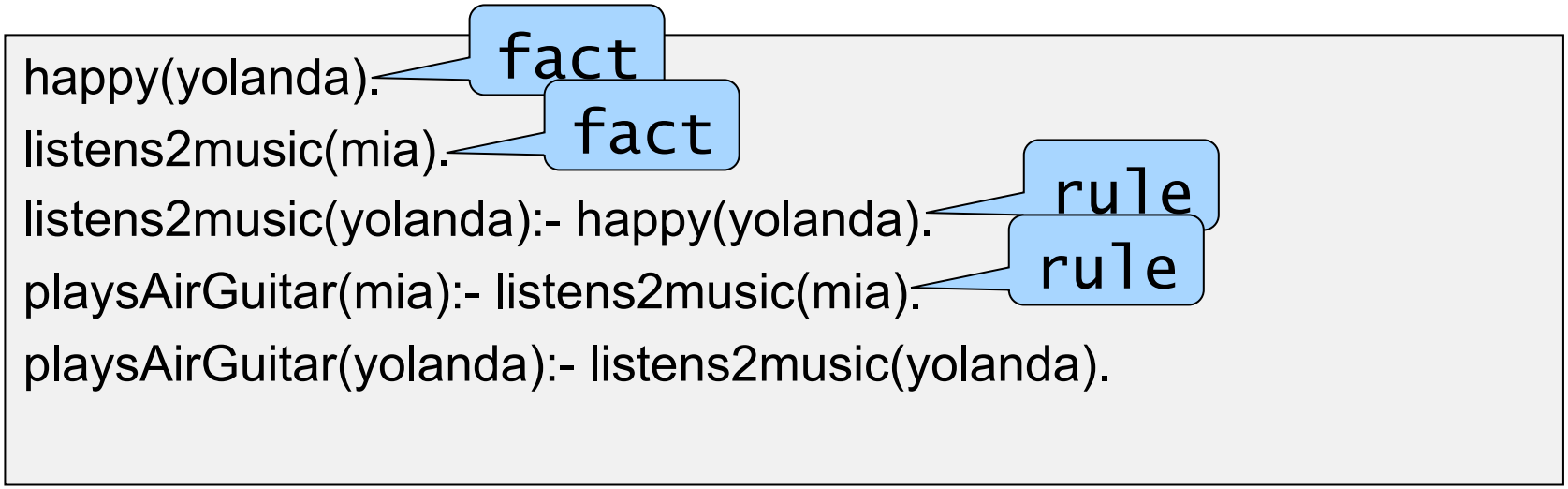
```
happy(yolanda).
listens2music(mia).
listens2music(yolanda):- happy(yolanda).
playsAirGuitar(mia):- listens2music(mia).
playsAirGuitar(yolanda):- listens2music(yolanda).
```

fact

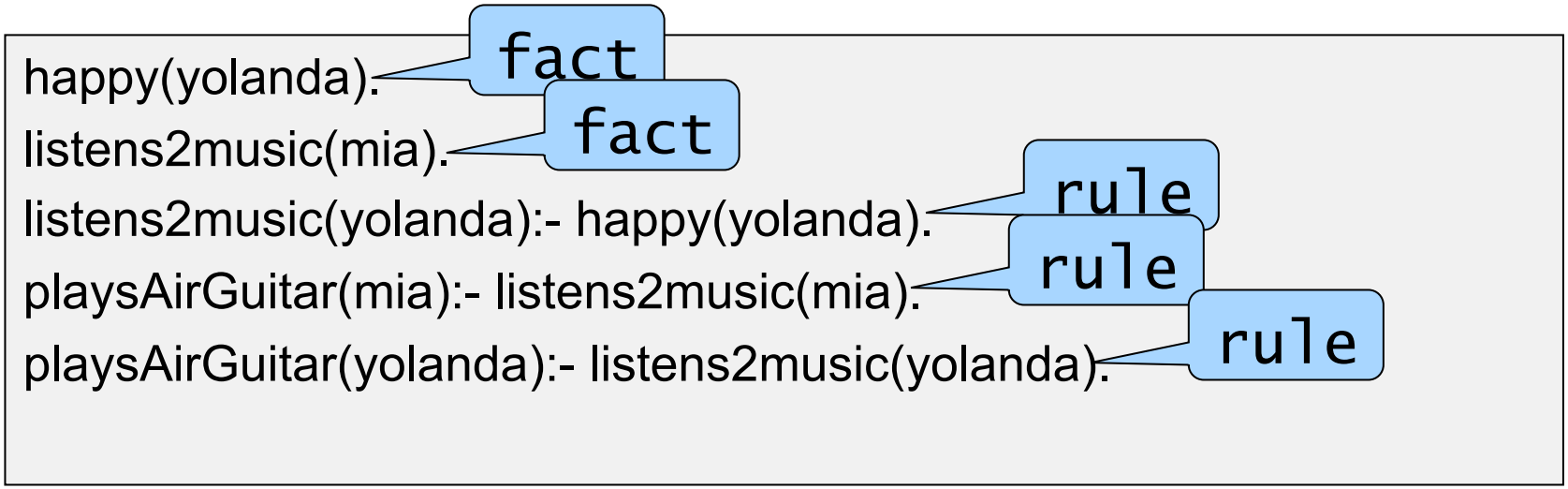
fact

rule

Knowledge Base 2

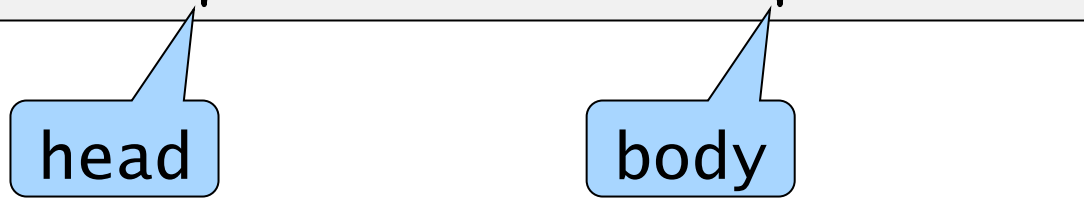


Knowledge Base 2



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).
no
?-
```

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
- Operators
  - Implication :-
  - Conjunction ,
  - Disjunction ;
- Use of 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

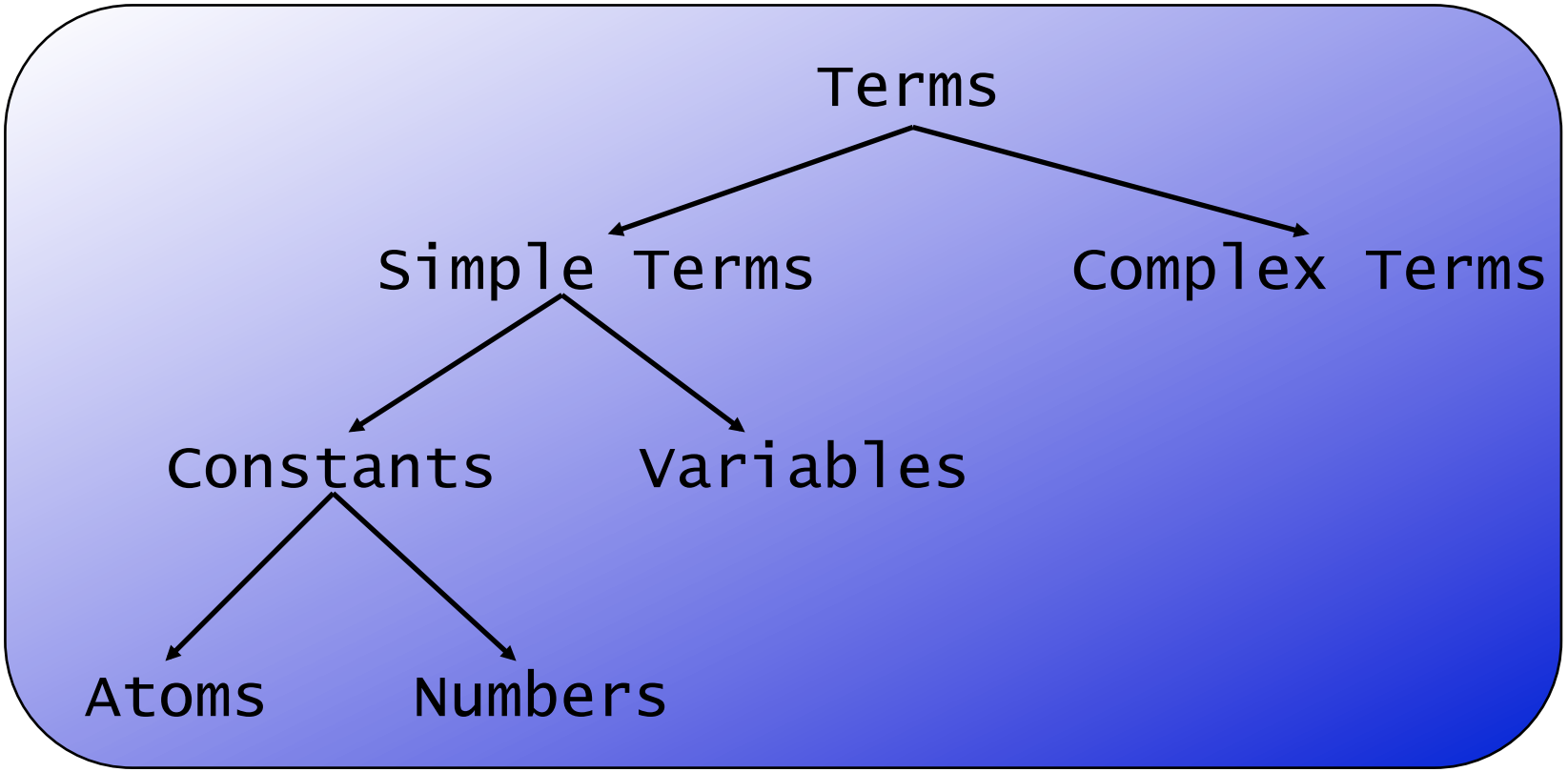
```
loves(vincent,mia).
loves(marsellus,mia).
loves(pumpkin, honey_bunny).
loves(honey_bunny, pumpkin).

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

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

Prolog Syntax

- What exactly are facts, rules and queries built out of?



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

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

- In Prolog 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

Exercises

- In next lecture we will correct the following exercises
  - 1.1, 1.2, 1.3

Summary of this lecture

- Simple examples of Prolog programs
- Introduced three basic constructs in Prolog:
  - Facts
  - Rules
  - Queries
- Discussed other concepts, such as
  - the role of logic
  - unification with the help of variables
- Definition of Prolog constructs:
  terms, atoms, and variables

Next lecture

- Discuss **unification** in Prolog
- Prolog's search strategy