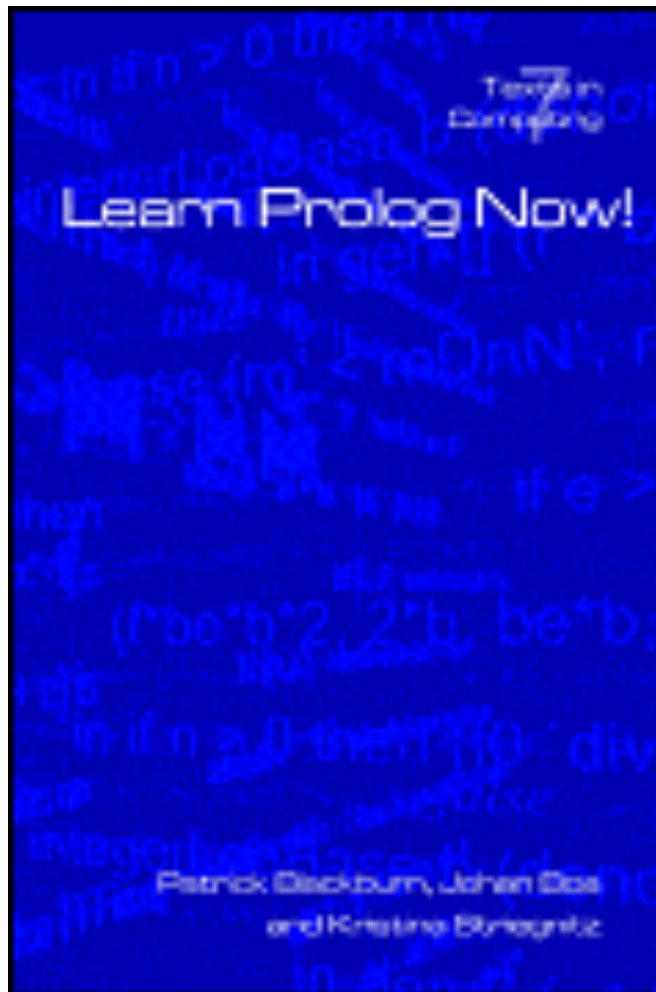


Logic Programming

- About the course
 - Taught in English
 - Tuesday: mostly theory
 - Thursday: practical work [lab]
- Teaching material
 - Learn Prolog Now!
 - SWI Prolog interpreter

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

Lecture 1

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

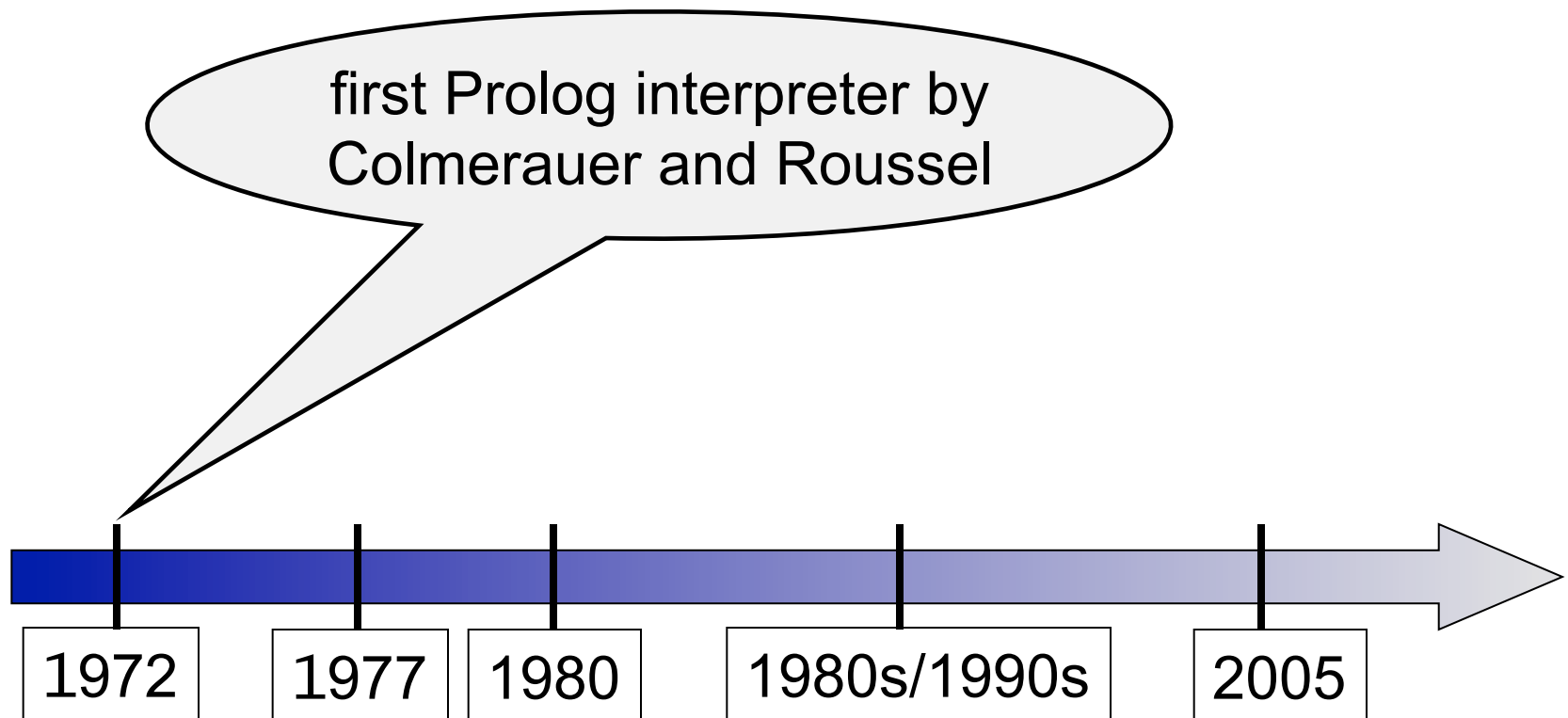
Aim of this lecture

- 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

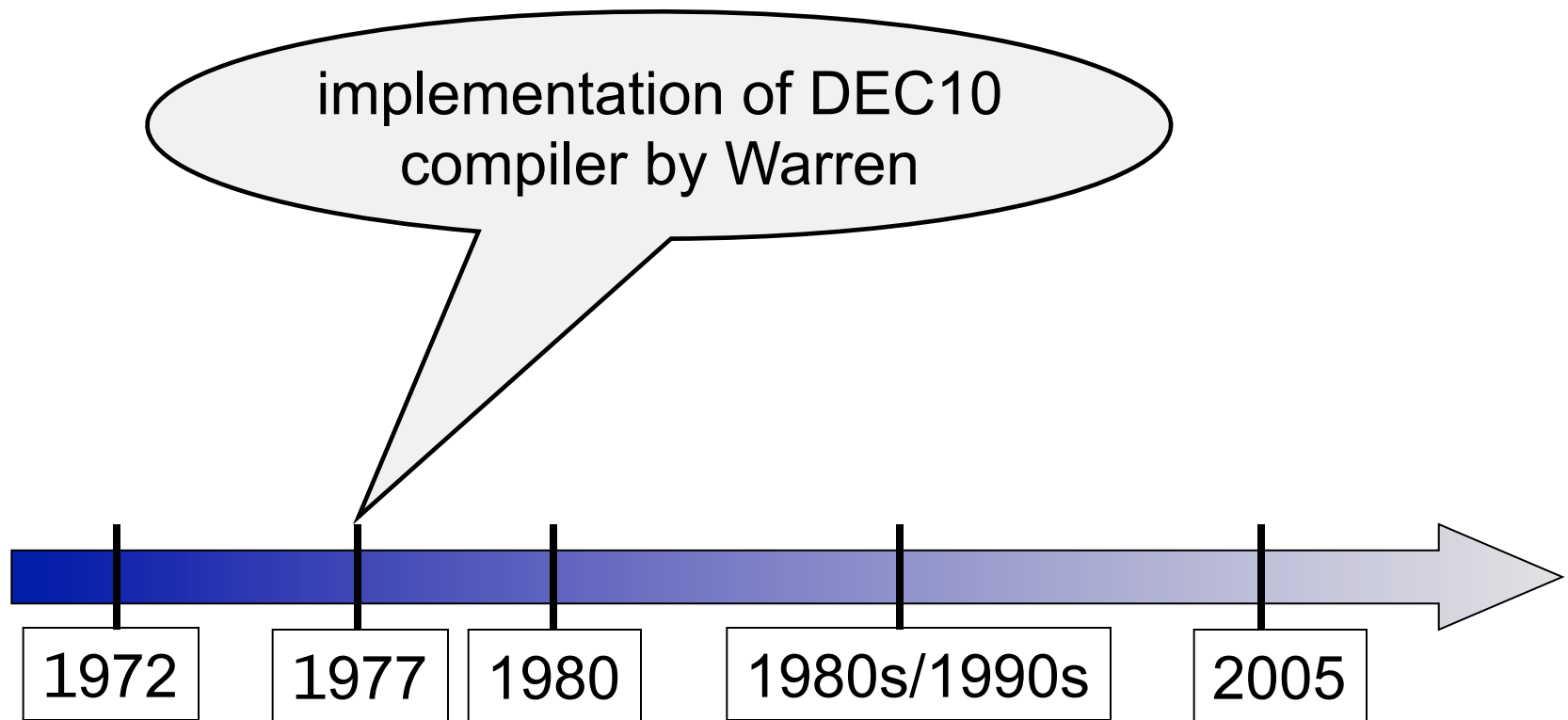
Prolog

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

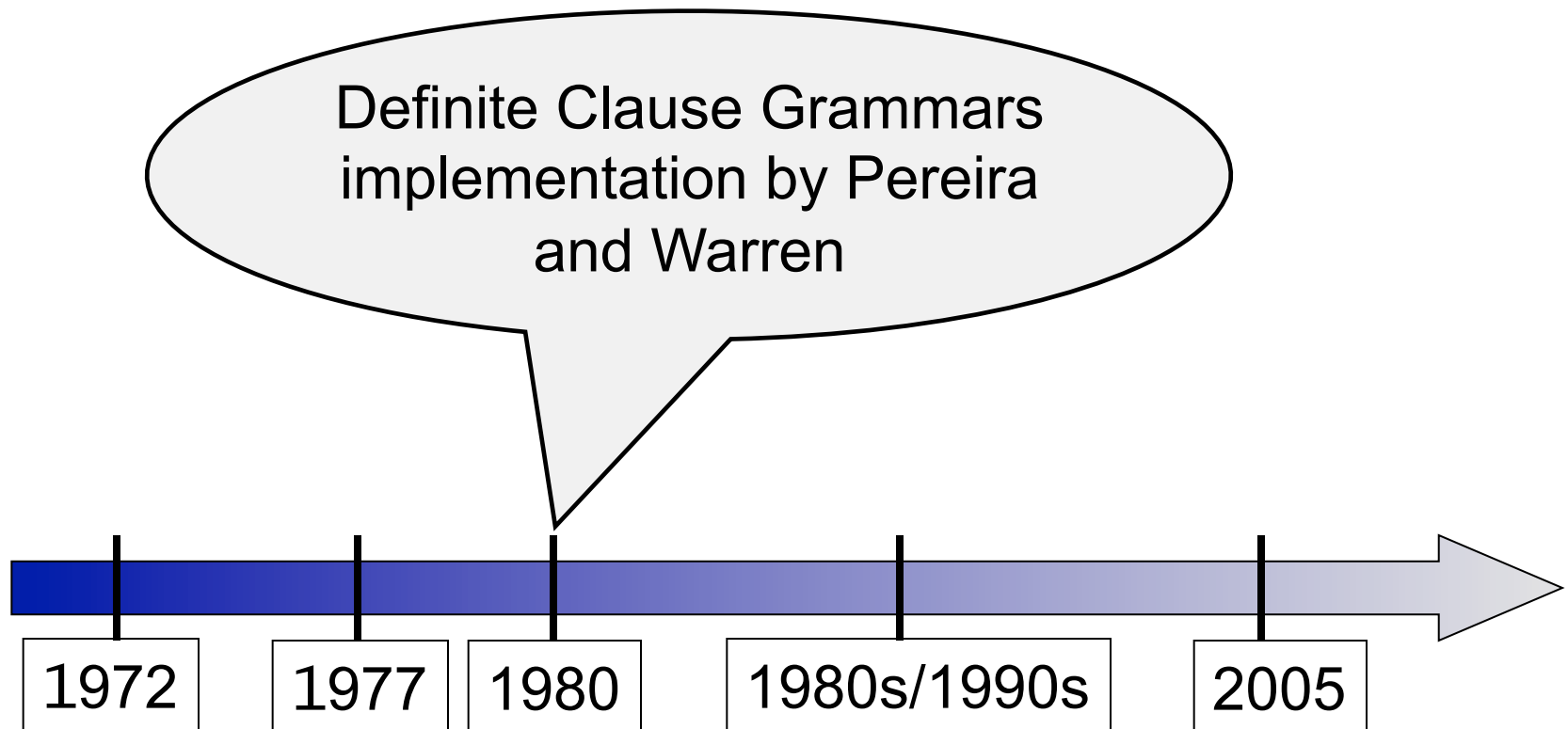
History of Prolog



History of Prolog

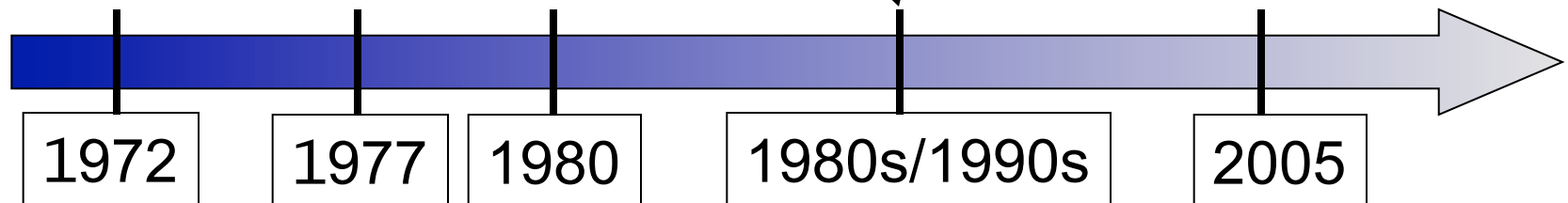


History of Prolog

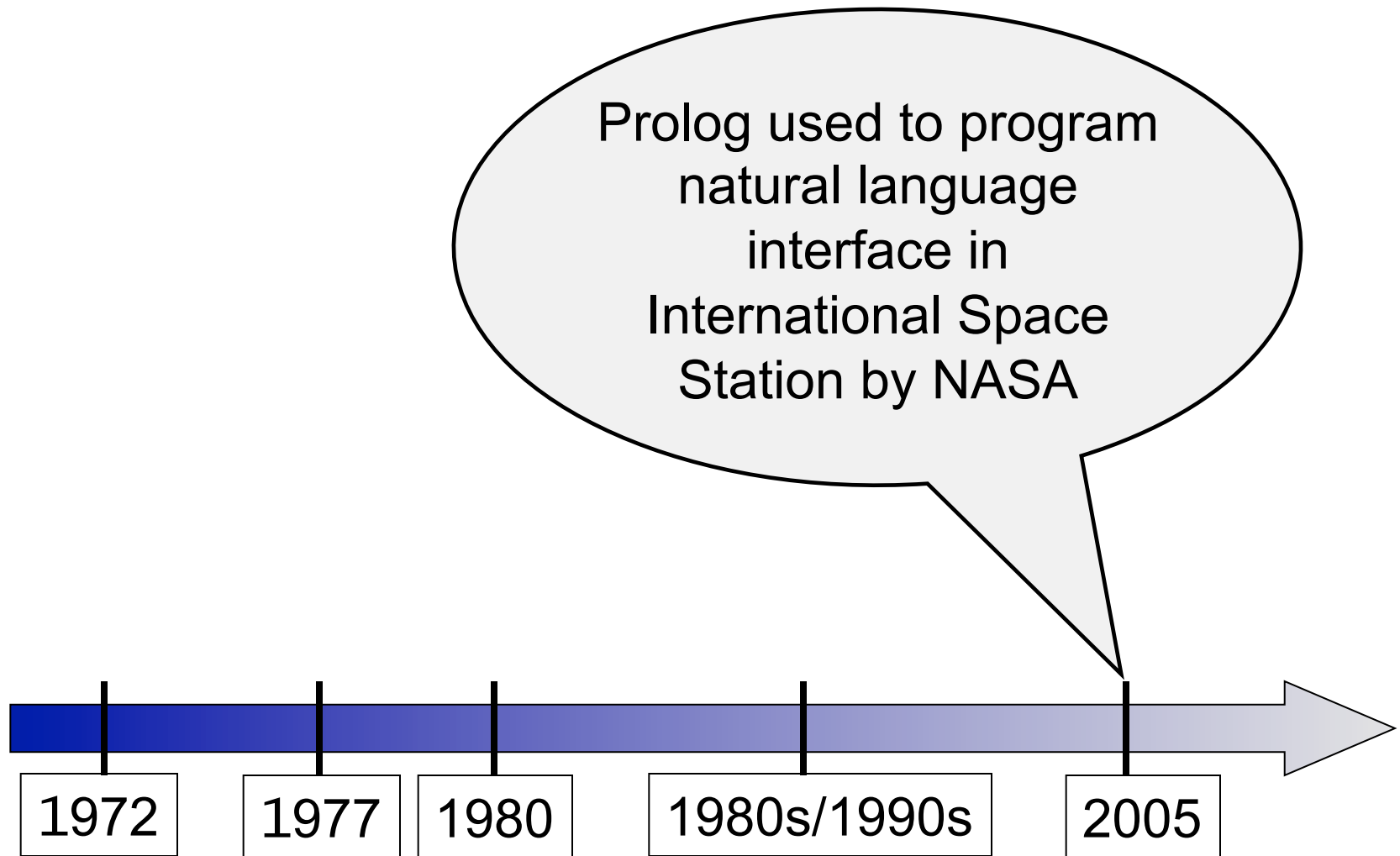


History of Prolog

Prolog grows in popularity especially in Europe and Japan



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.

?- tattooed(jody).

Knowledge Base 1

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

?- tattooed(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).

fact

listens2music(mia).

listens2music(yolanda):- happy(yolanda).

playsAirGuitar(mia):- listens2music(mia).

playsAirGuitar(yolanda):- listens2music(yolanda).

Knowledge Base 2

happy(yolanda).

fact

listens2music(mia).

fact

listens2music(yolanda):- happy(yolanda).

playsAirGuitar(mia):- listens2music(mia).

playsAirGuitar(yolanda):- listens2music(yolanda).

Knowledge Base 2

happy(yolanda).

fact

listens2music(mia).

fact

listens2music(yolanda):- happy(yolanda).

rule

playsAirGuitar(mia):- listens2music(mia).

playsAirGuitar(yolanda):- listens2music(yolanda).

Knowledge Base 2

happy(yolanda).

fact

listens2music(mia).

fact

listens2music(yolanda):- happy(yolanda).

rule

playsAirGuitar(mia):- listens2music(mia).

rule

playsAirGuitar(yolanda):- listens2music(yolanda).

Knowledge Base 2

happy(yolanda).

fact

listens2music(mia).

fact

listens2music(yolanda):- happy(yolanda).

rule

playsAirGuitar(mia):- listens2music(mia).

rule

playsAirGuitar(yolanda):- listens2music(yolanda).

rule

Knowledge Base 2

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



head

body

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).
```

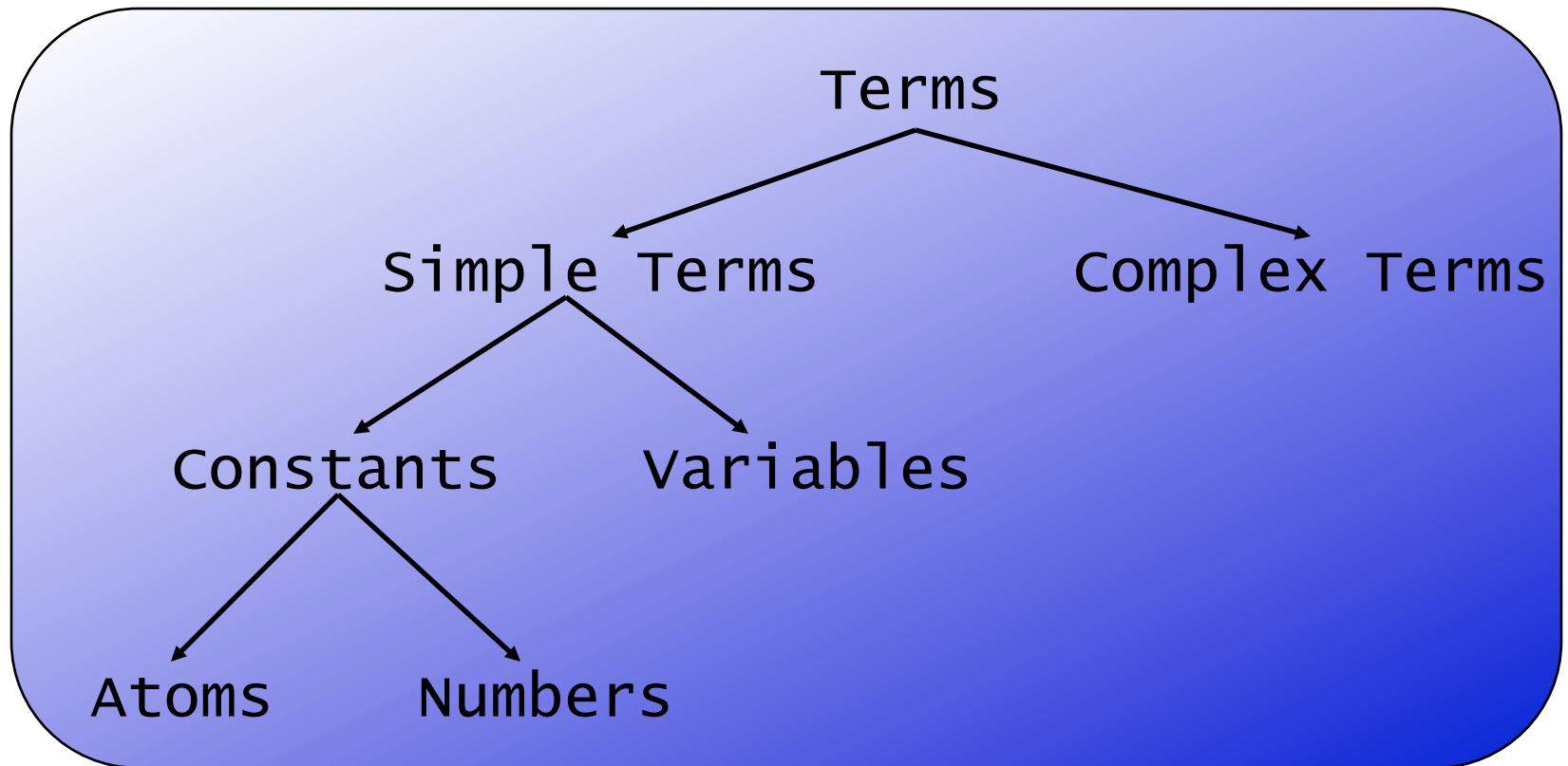
Knowledge Base 5

```
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

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