# Lecture 9: A closer look at terms

- Theory
  - Introduce the == predicate
  - Take a closer look at term structure
  - Introduce strings in Prolog
  - Introduce operators
- Exercises
  - Exercises of LPN: 9.1, 9.2, 9.3, 9.4, 9.5
  - Practical session

# Comparing terms: ==/2

- Prolog contains an important predicate for comparing terms
- This is the identity predicate ==/2
- The identity predicate ==/2 does not instantiate variables, that is, it behaves differently from =/2

# Comparing terms: ==/2

- Prolog contains an important predicate for comparing terms
- This is the identity predicate ==/2
- The identity predicate ==/2 does not instantiate variables, that is, it behaves differently from =/2

```
?- a==a.
yes

?- a==b.
no

?- a=='a'.
yes

?- a==X.
X = _443
no
```

# Comparing variables

- Two different **uninstantiated** variables are not identical terms
- Variables **instantiated** with a term *T* are identical to *T*

# Comparing variables

- Two different **uninstantiated** variables are not identical terms
- Variables **instantiated** with a term *T* are identical to *T*

```
?- X==X.
X = _443
yes

?- Y==X.
Y = _442
X = _443
no

?- a=U, a==U.
U = _443
yes
```

# Comparing terms: \==/2

- The predicate \==/2 is defined so that it succeeds in precisely those cases where ==/2 fails
- In other words, it succeeds whenever two terms are **not identical**, and fails otherwise

# Comparing terms: \==/2

- The predicate \==/2 is defined so that it succeeds in precisely those cases where ==/2 fails
- In other words, it succeeds whenever two terms are **not identical**, and fails otherwise

```
?- a \== a.
no

?- a \== b.
yes

?- a \== 'a'.
no

?- a \== X.
X = _443
yes
```

# Terms with a special notation

- Sometimes terms look different, but Prolog regards them as identical
- For example: **a** and **'a‘**, but there are many other cases
- Why does Prolog do this?
  - Because it makes programming more pleasant
  - More natural way of coding Prolog programs

# Arithmetic terms

- Recall lecture 5 where we introduced arithmetic
- +, -, <, >, etc are functors and expressions such as 2+3 are actually ordinary complex terms
- The term 2+3 is identical to the term +(2,3)

# Arithmetic terms



- Recall lecture 5 where we introduced arithmetic
- +, -, <, >, etc are functors and expressions such as 2+3 are actually ordinary complex terms
- The term 2+3 is identical to the term +(2,3)

```
?- 2+3 == +(2,3).
yes

?-  -(2,3) == 2-3.
yes

?-  (4<2) == <(4,2).
yes
```

# Summary of comparison predicates

| | |
|---|---|
| = | Unification predicate |
| \= | Negation of unification predicate |
| == | Identity predicate |
| \== | Negation of identity predicate |
| =:= | Arithmetic equality predicate |
| =\= | Negation of arithmetic equality predicate |

# Lists as terms

- Another example of Prolog working with one internal representation, while showing another to the user
- Using the | constructor, there are many ways of writing the same list

```
?- [a,b,c,d] == [a|[b,c,d]].
yes
?- [a,b,c,d] == [a,b,c|[d]].
yes
?- [a,b,c,d] == [a,b,c,d|[]].
yes
?- [a,b,c,d] == [a,b|[c,d]].
yes
```

# Prolog lists internally

- Internally, lists are built out of two special terms:
  - [] (which represents the empty list)
  - ’.’ (a functor of arity 2 used to build non-empty lists)
- These two terms are also called *list constructors*
- A recursive definition shows how they construct lists

# Definition of prolog list

- The empty list is the term []. It has length 0.
- A non-empty list is any term of the form .(*term*,*list*), where *term* is any Prolog term, and *list* is any Prolog list. If *list* has length *n*, then .(*term*,*list*) has length *n*+1.

# A few examples…

```
?- .(a,[]) == [a].
yes

?- .(f(d,e),[]) == [f(d,e)].
yes

?- .(a,.(b,[])) == [a,b].
yes

?- .(a,.(b,.(f(d,e),[]))) == [a,b,f(d,e)].
yes
```

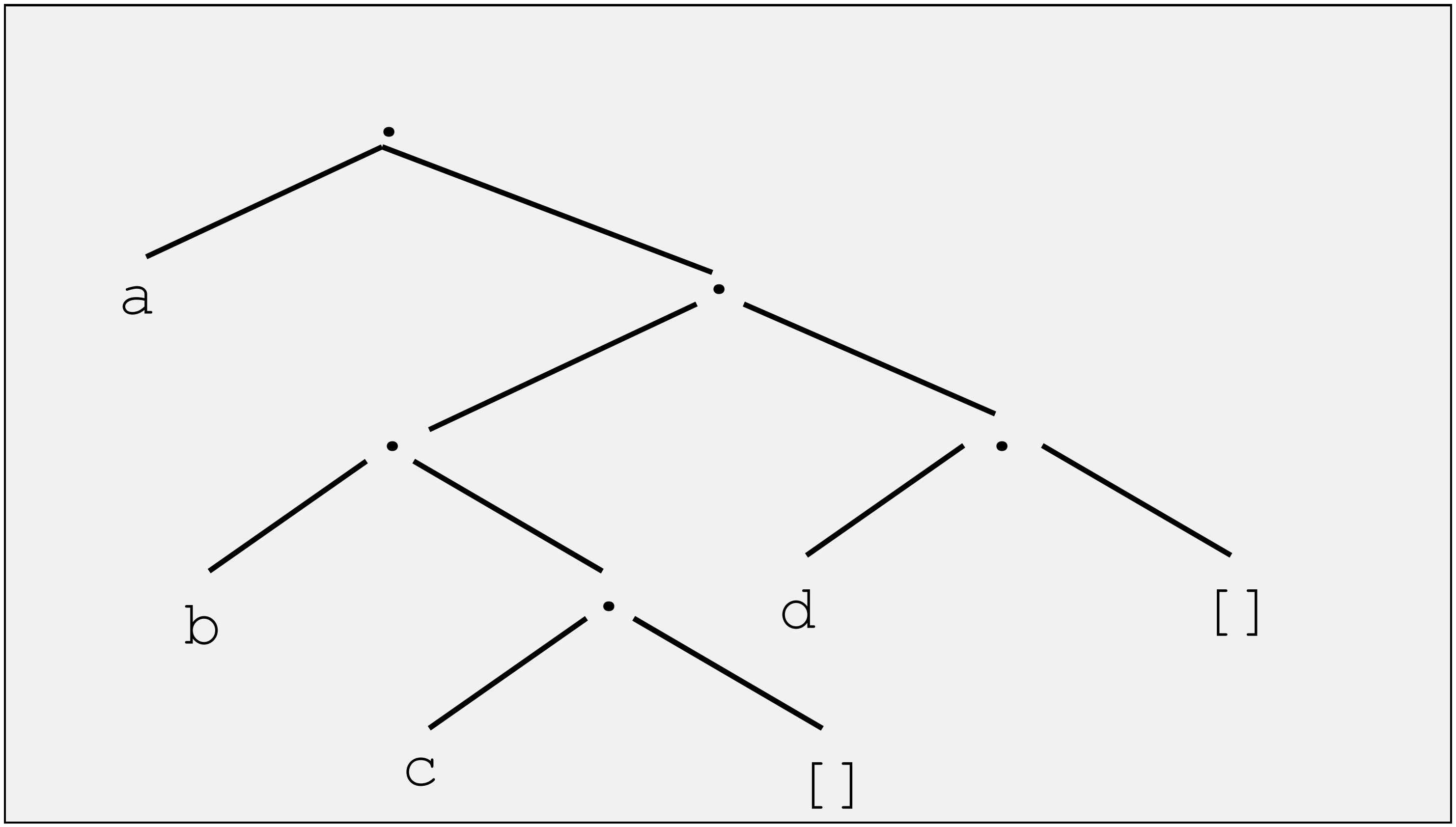
# Internal list representation

- Works similar to the | notation:
- It represents a list in two parts
  - Its first element, the *head*
  - the rest of the list, the *tail*
- The trick is to read these terms as trees
  - Internal nodes are labeled with **.**
  - All nodes have two daughter nodes
    - Subtree under left daughter is the head
    - Subtree under right daughter is the tail

# Example of a list as tree



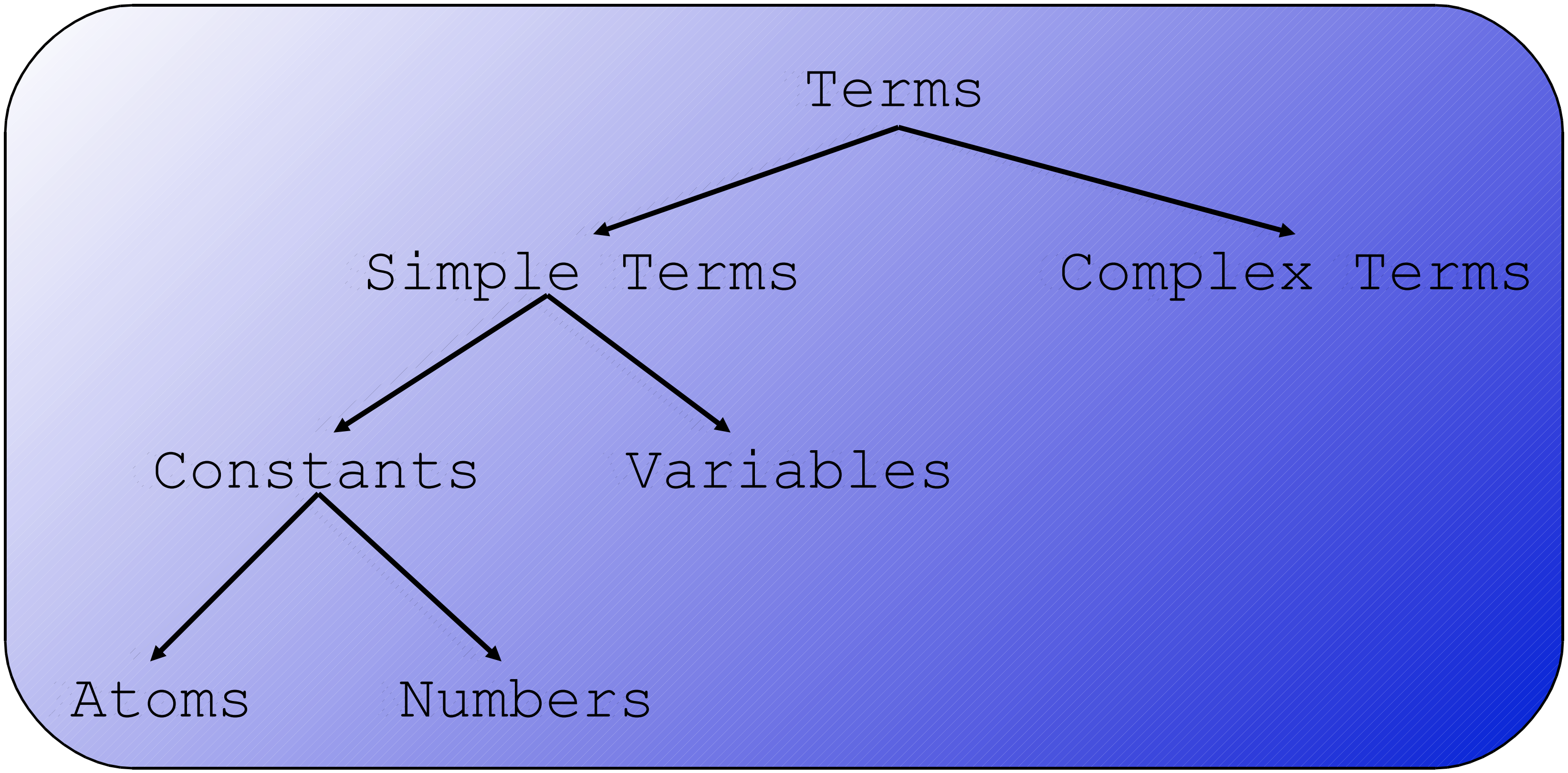
- Example: [a,[b,c],d]



# Examining terms

- We will now look at built-in predicates that let us examine Prolog terms more closely
  - Predicates that determine the type of terms
  - Predicates that tell us something about the internal structure of terms

# Type of terms



# Checking the type of a term

| | |
|---|---|
| atom/1 | *Is the argument an atom?* |
| integer/1 | *… an interger?* |
| float/1 | *… a floating point number?* |
| number/1 | *… an integer or float?* |
| atomic/1 | *… a constant?* |
| var/1 | *… an uninstantiated variable?* |
| nonvar/1 | *… an instantiated variable or another term that is not an uninstantiated variable* |

# Type checking: atom/1

```
?- atom(a).
yes

?- atom(7).
no

?- atom(X).
no
```

# Type checking: atom/1

```
?- X=a, atom(X).
X = a
yes

?- atom(X), X=a.
no
```

# Type checking: atomic/1

```
?- atomic(mia).
yes

?- atomic(5).
yes

?- atomic(loves(vincent,mia)).
no
```

# Type checking: var/1

```
?- var(mia).
no

?- var(X).
yes

?- X=5, var(X).
no
```

# Type checking: nonvar/1

```
?- nonvar(X).
no

?- nonvar(mia).
yes

?- nonvar(23).
yes
```

# The structure of terms

- Given a complex term of unknown structure, what kind of information might we want to extract from it?
- Obviously:
  - The functor
  - The arity
  - The argument
- Prolog provides built-in predicates to produce this information

# The functor/3 predicate

- The functor/3 predicate gives the functor and arity of a complex predicate

# The functor/3 predicate

- The functor/3 predicate gives the functor and arity of a complex predicate
  - ?- functor(friends(lou,andy),F,A).
    F = friends
    A = 2
    yes

# The functor/3 predicate

- The functor/3 predicate gives the functor and arity of a complex predicate
  - ?- functor(friends(lou,andy),F,A).
    F = friends
    A = 2
    yes
  - ?- functor([lou,andy,vicky],F,A).
    F = .
    A = 2
    yes

# functor/3 and constants

- What happens when we use functor/3 with constants?

# functor/3 and constants

- What happens when we use functor/3 with constants?
  - ```
    ?- functor(mia,F,A).
    F = mia
    A = 0
    yes
    ```
    ```

# functor/3 and constants

- What happens when we use functor/3 with constants?
  - ?- functor(mia,F,A).
    F = mia
    A = 0
    yes
  - ?- functor(14,F,A).
    F = 14
    A = 0
    yes

# functor/3 for constructing terms

- You can also use functor/3 to construct terms:
  - ?- functor(Term,friends,2).
    Term = friends(_,_)
    yes

# Checking for complex terms

```
complexTerm(X):-
     nonvar(X),
     functor(X,_,A),
     A > 0.
```

# Arguments: arg/3

- Prolog also provides us with the predicate arg/3
- This predicate tells us about the arguments of complex terms
- It takes three arguments:
  - A number *N*
  - A complex term *T*
  - The *N*th argument of *T*

# Arguments: arg/3

- Prolog also provides us with the predicate arg/3
- This predicate tells us about the arguments of complex terms
- It takes three arguments:
  - A number *N*
  - A complex term *T*
  - The *N*th argument of *T*

```
?- arg(2,likes(lou,andy),A).
A = andy
yes
```

# Strings

- Strings are represented in Prolog by a list of character codes
- Prolog offers double quotes for an easy notation for strings

```
?- S = “Vicky“.
S = [86,105,99,107,121]
yes
```

# Working with strings

- There are several standard predicates for working with strings
- A particular useful one is atom_codes/2

```
?- atom_codes(vicky,S).
S = [118,105,99,107,121]
yes
```

# Operators

- As we have seen, in certain cases, Prolog allows us to use operator notations that are more user friendly
- Recall, for instance, the arithmetic expressions such as 2+2 which internally means +(2,2)
- Prolog also has a mechanism to add your own operators

# Properties of operators

- Infix operators
  - Functors written <u>between</u> their arguments
  - Examples: + - = == , ; . -->
- Prefix operators
  - Functors written <u>before</u> their argument
  - Example: - (to represent negative numbers)
- Postfix operators
  - Functors written <u>after</u> their argument
  - Example: ++ in the C programming language

# Precedence

- Every operator has a certain precedence to work out ambiguous expressions
- For instance, does 2+3*3 mean 2+(3*3), or (2+3)*3?
- Because the precedence of + is greater than that of *, Prolog chooses + to be the main functor of 2+3*3

# Associativity

- Prolog uses associativity to disambiguate operators with the same precedence value
- Example: 2+3+4
  Does this mean (2+3)+4 or 2+(3+4)?
  - Left associative
  - Right associative
- Operators can also be defined as non-associative, in which case you are forced to use bracketing in ambiguous cases
  - Examples in Prolog: :- -->

# Defining operators

- Prolog lets you define your own operators
- Operator definitions look like this:

```
:- op(Precedence, Type, Name.
```

  - Precedence: number between 0 and 1200
  - Type: the type of operator

# Types of operators in Prolog

- yfx left-associative, infix
- xfy right-associative, infix
- xfx non-associative, infix
- fx non-associative, prefix
- fy right-associative, prefix
- xf non-associative, postfix
- yf left-associative, postfix

# Operators in SWI Prolog



| | | |
|---|---|---|
| 1200 | $xfx$ | `-->`, `:-` |
| 1200 | $fx$ | `:-`, `?-` |
| 1150 | $fx$ | `dynamic`, `discontiguous`, `initialization`, `module_transparent`, `multifile`, `thread_local`, `volatile` |
| 1100 | $xfy$ | `;`, `\|` |
| 1050 | $xfy$ | `->`, op`*->` |
| 1000 | $xfy$ | `,` |
| 954 | $xfy$ | `\` |
| 900 | $fy$ | `\+` |
| 900 | $fx$ | `~` |
| 700 | $xfx$ | `<`, `=`, `=..`, `=@=`, `=:=`, `=<`, `==`, `=\=`, `>`, `>=`, `@<`, `@=<`, `@>`, `@>=`, `\=`, `\==`, `is` |
| 600 | $xfy$ | `:` |
| 500 | $yfx$ | `+`, `-`, `/\`, `\/`, `xor` |
| 500 | $fx$ | `+`, `-`, `?`, `\` |
| 400 | $yfx$ | `*`, `/`, `//`, `rdiv`, `<<`, `>>`, `mod`, `rem` |
| 200 | $xfx$ | `**` |
| 200 | $xfy$ | `^` |

# Next lecture

- Cuts and negation
  - How to control Prolog`s backtracking behaviour with the help of the cut predicate
  - Explain how the cut can be packaged into a more structured form, namely negation as failure