Common Lisp S-Expressions: Atoms and Lists

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  If a function you write for this course returns a dotted list, then either your code has a bug or an inappropriate argument value was passed to the function.

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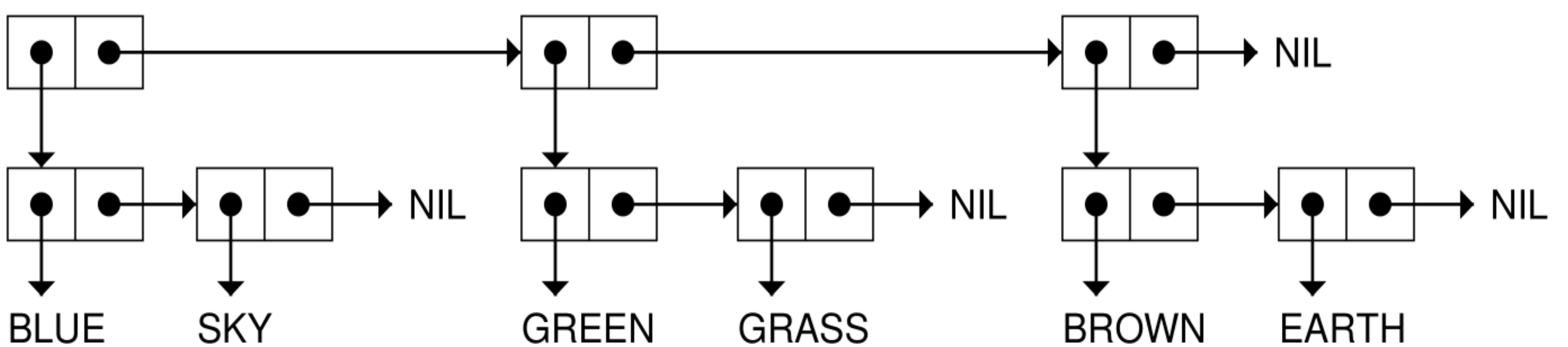

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   - More generally, if a Lisp expression can be evaluated, then its value (i.e., the result of its evaluation) will usually be an S-expression.

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- Lisp *macros*, which are used to extend the syntax of Lisp (i.e., "define new keywords"), depend on this property.
  - Ch. 14 of Touretzky explains how to write macros, but you will ***not*** be expected to do that: All the macros you need to use will be predefined (i.e., built-in) macros.

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From the Common Lisp Hyperspec (http://www.lispworks.com/documentation/common-lisp.html):

The set of *special operator names* is fixed in Common Lisp; no way is provided for the user to define a *special operator*. The next figure lists all of the Common Lisp *symbols* that have definitions as *special operators*.

block	let*	return-from
catch	load-time-value	setq
eval-when	locally	symbol-macrolet
flet	macrolet	tagbody
function	multiple-value-call	the
go	multiple-value-prog1	throw
if	progn	unwind-protect
labels	progv	
let	quote	

Figure 3-2. Common Lisp Special Operators

Just a few of these 25 special operators (probably just QUOTE, IF, LET, LET*, and LABELS) will be covered later. You will ***not*** be expected to know the rest!

More on Numbers, Symbols, and Lists in Common Lisp

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- Numbers are one of the two kinds of Common Lisp atom that will be used extensively in this course.

  Symbols, which we consider next, are the other kind of atom we will use extensively.

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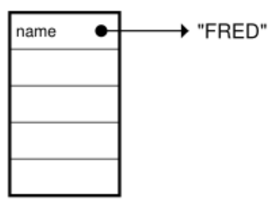
Symbols as defined here are also called ***symbol names***.

- The data object represented by a symbol name (see pp. 105-6) is called a symbol too, so use of the term *symbol name* may avoid confusion of the two concepts.

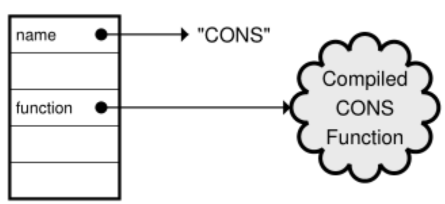
3.18 INTERNAL STRUCTURE OF SYMBOLS

So far in this book we have been drawing symbols by writing their names. But symbols in Common Lisp are actually composite objects, meaning they have several parts to them. Conceptually, a symbol is a block of five pointers, one of which points to the representation of the symbol's name. The others will be defined later. The internal structure of the symbol FRED looks like this:

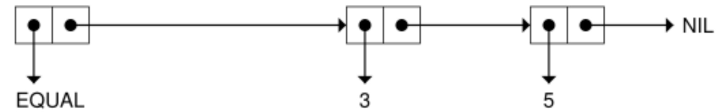


The ''FRED'' appearing above in quotation marks is called a **string**. Strings are sequences of characters; they will be covered more fully in Chapter 9. For now it suffices to note that strings are used to store the names of symbols; a symbol and its name are actually two different things.

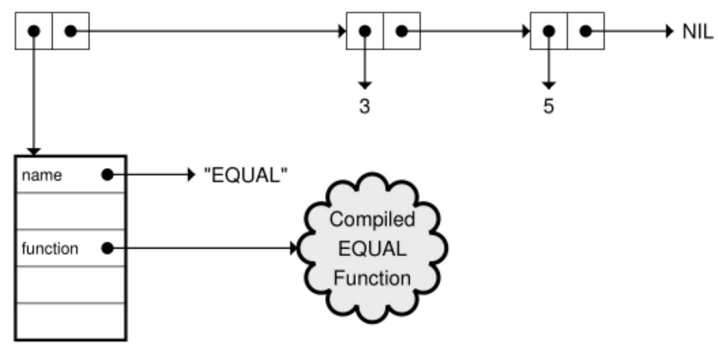
Some symbols, like CONS or +, are used to name built-in Lisp functions. The symbol CONS has a pointer in its **function cell** to a ''compiled code object'' that represents the machine language instructions for creating new cons cells.



When we draw Lisp expressions such as (EQUAL 3 5) as cons cell chains, we usually write just the name of the symbol instead of showing its internal structure:



But if we choose we can show more detail, in which case the expression (EQUAL 3 5) looks like this:



We can extract the various components of a symbol using built-in Common Lisp functions like SYMBOL-NAME and SYMBOL-FUNCTION. The following dialog illustrates this; you'll see something slightly different if you try it on your computer, but the basic idea is the same.

```
> (symbol-name 'equal)
"EQUAL"

> (symbol-function 'equal)
#<Compiled EQUAL function {60463B0}>
```

Note: Symbols are memory unique; see sec. 6.13.

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- Symbol names are very often used like Java/C++ **enum** constants, but they don't need to be declared.
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  Comment: Escape characters can also be used to create symbols with names that would otherwise not be allowed. But we will not use such symbols in this course.

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- **T** is a constant that is the *usual* way to represent **true**, though any S-expression other than NIL can also be used to represent **true**.
- T and NIL evaluate to themselves:
  The value of T is always T itself;
  the value of NIL is always NIL itself.

  The values of T and NIL can't be changed, and you ***can't*** use T or NIL as a variable / formal parameter!

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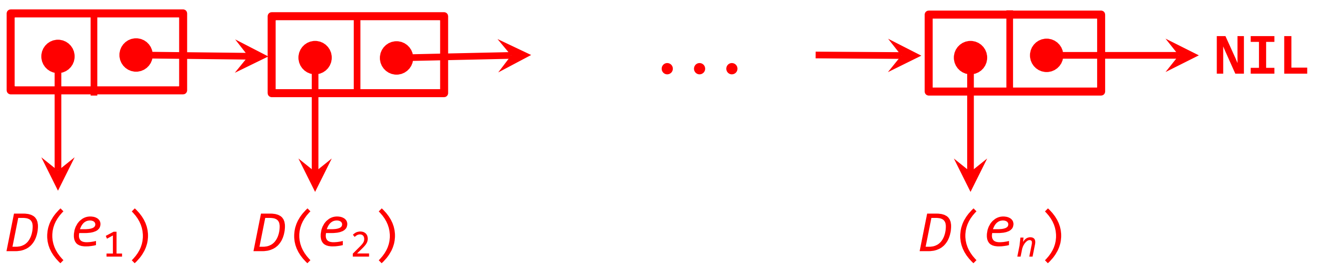

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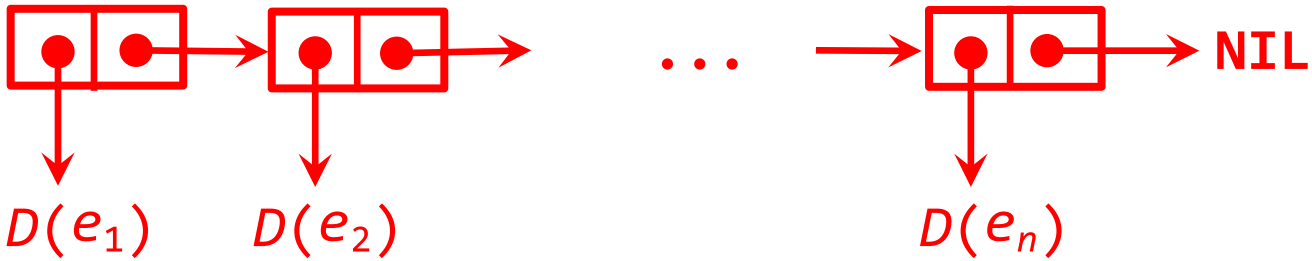

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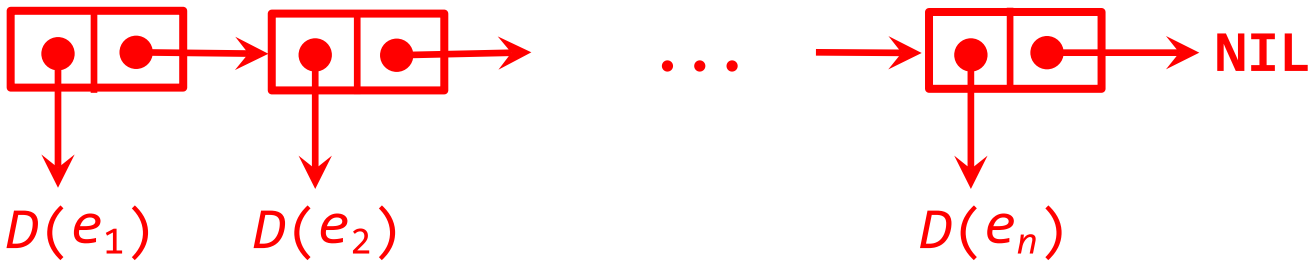

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Example from p. 34 of Touretzky.

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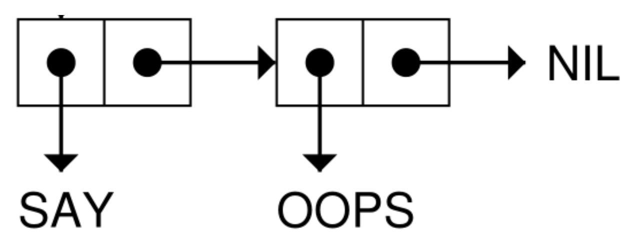

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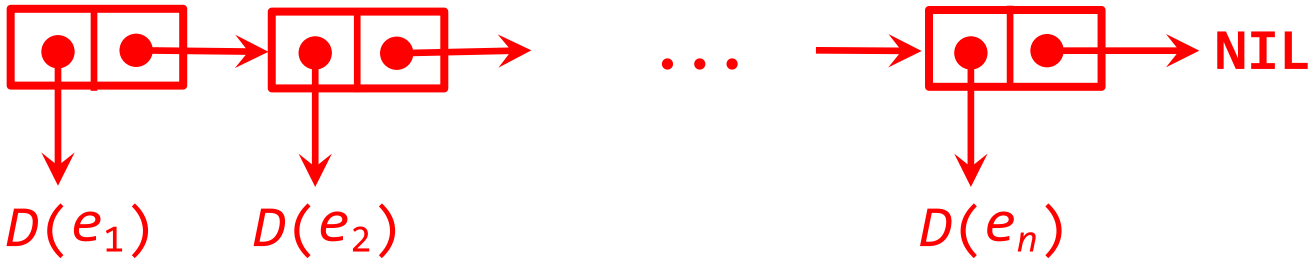

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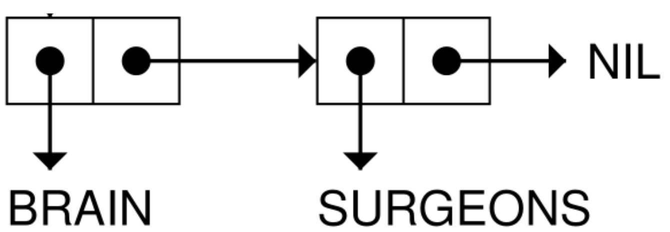

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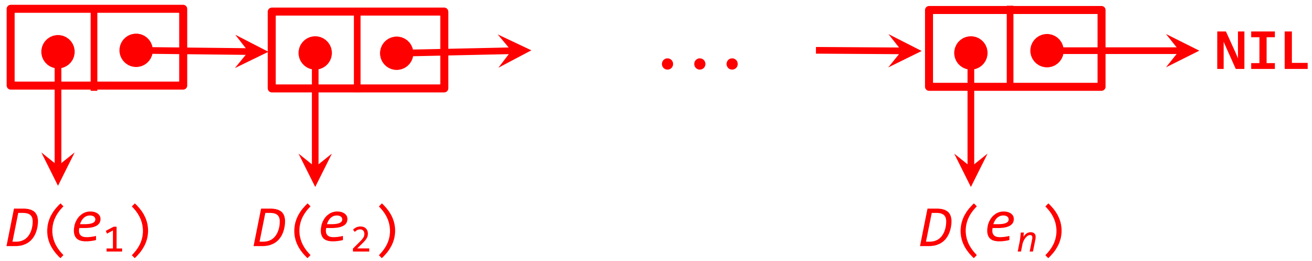

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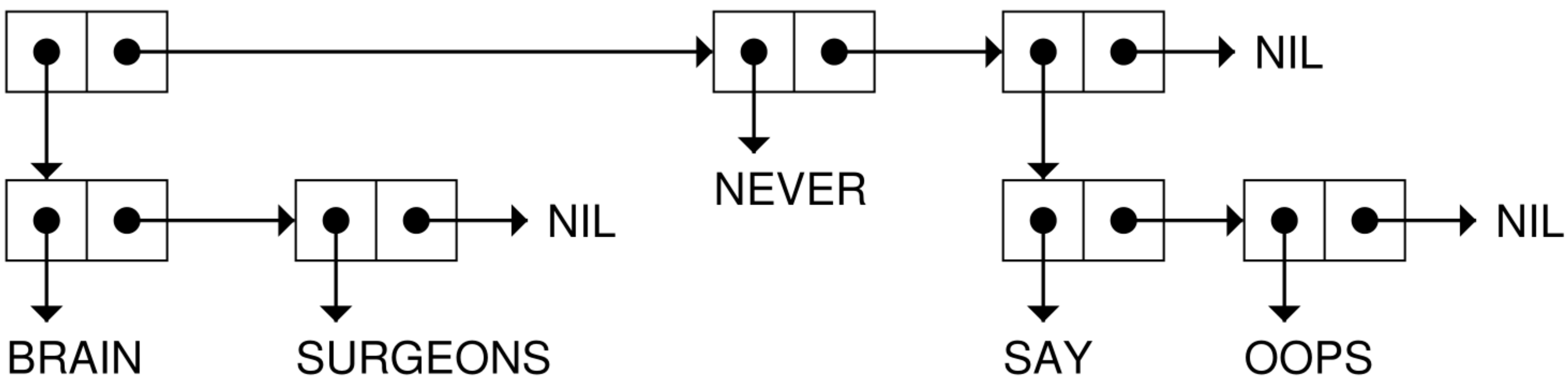

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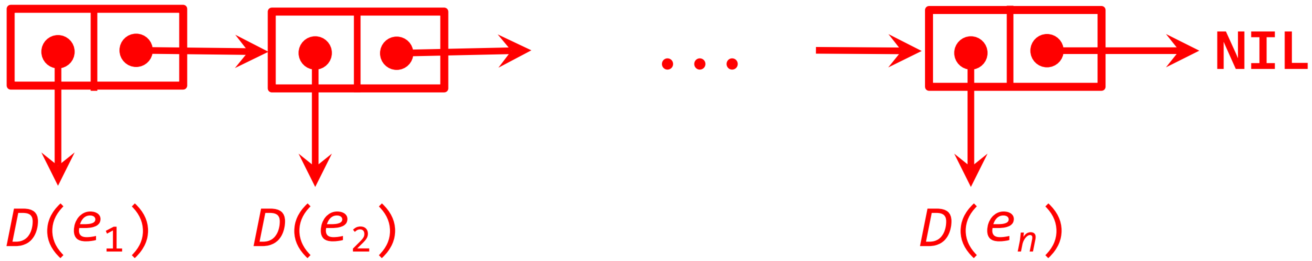

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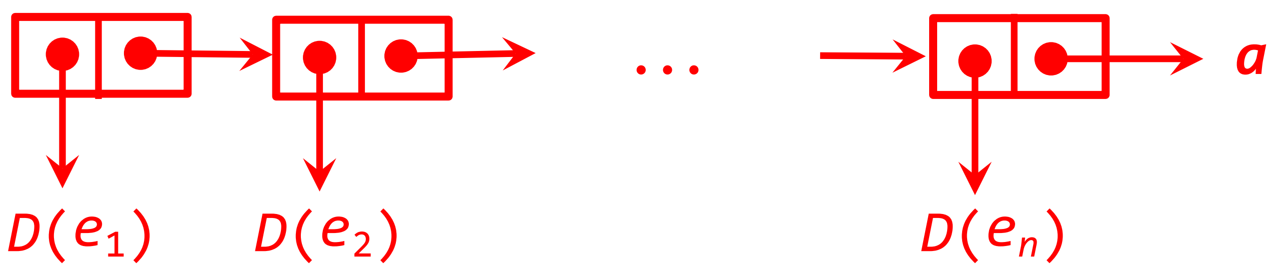

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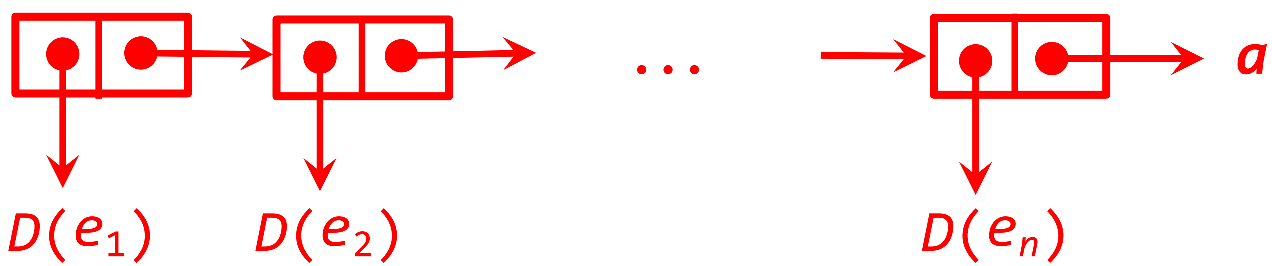

Examples from pp. 72-3 of Touretzky

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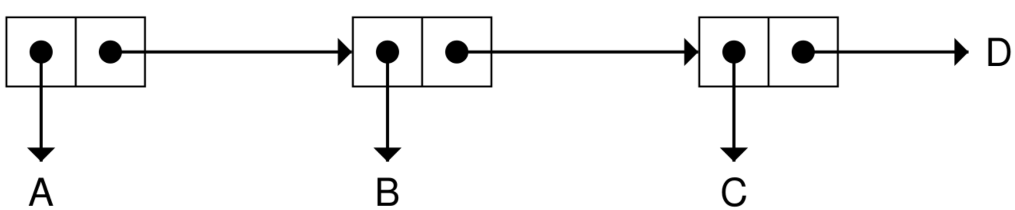

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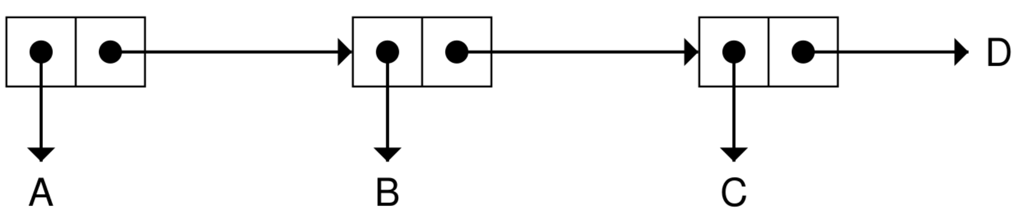

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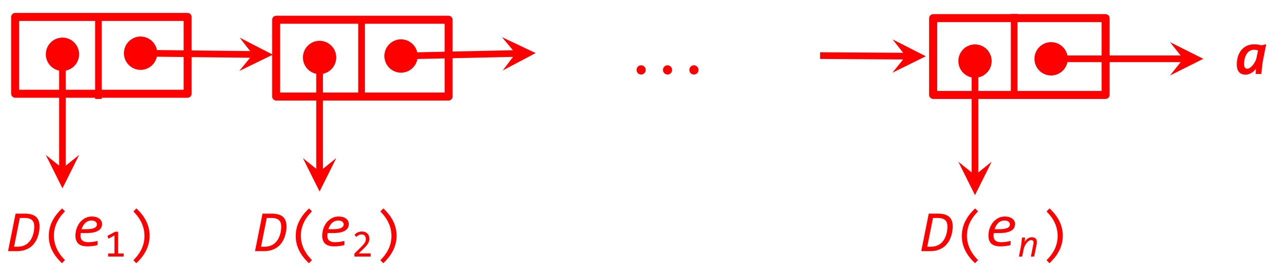
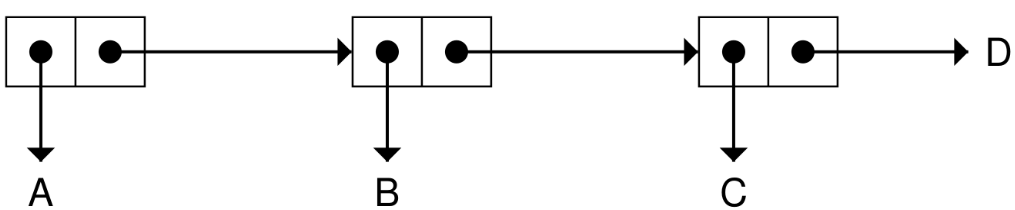
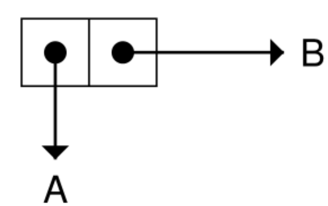


Examples from pp. 72-3 of Touretzky

The dotted list (A B C . D) represents:



The dotted pair (A . B) represents:



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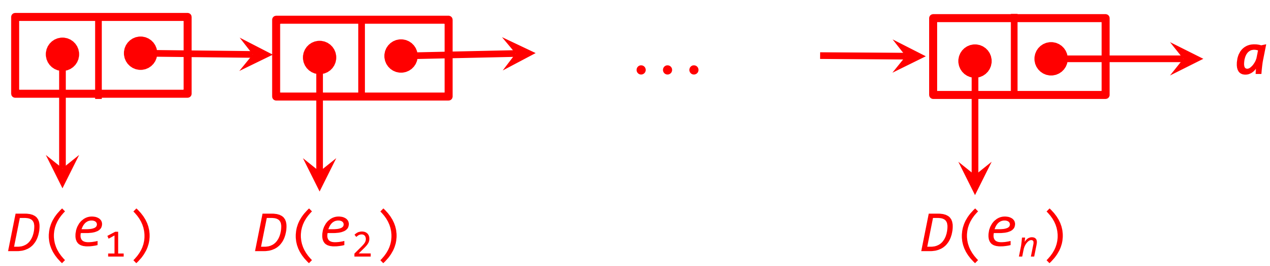

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$$(e_1 \;\ldots\; e_n \;.\; \text{NIL}) =$$
$$(e_1 \;\ldots\; e_n \;.\; (e_{n+1})) =$$
$$(e_1 \;\ldots\; e_n \;.\; (e_{n+1} \;\ldots\; e_{n+k})) =$$
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- So we'll write (e_1 … e_n . a) ***only when a is an atom other than* NIL**.

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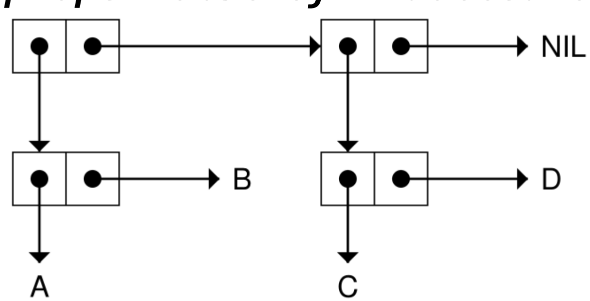

This example is from p. 73 and p. C-18 of Touretzky.

Further Comments on Dotted Lists

- If a is an atom, then (e_1 … e_n . a) represents a singly-linked list data structure that may be drawn as follows:

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- Dotted lists are used much less than proper lists.
- The term ***list*** is often used to mean ***proper list***!
- If a function you write for this course returns a dotted list, then either your code has a bug or an inappropriate argument value was passed to the function!

Tree Representation of S-Expressions

These "box and arrow" drawings are quite often simplified to ***binary trees*** in which the two children of any internal node v are ***either*** south and east of v ***or*** southwest and southeast of v:

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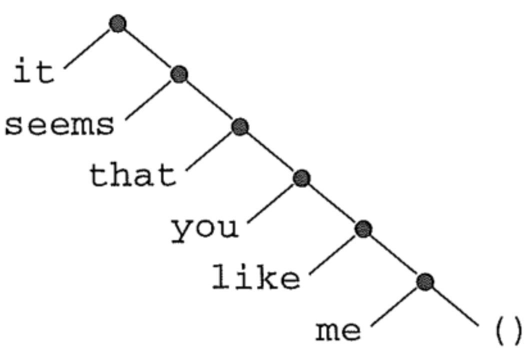
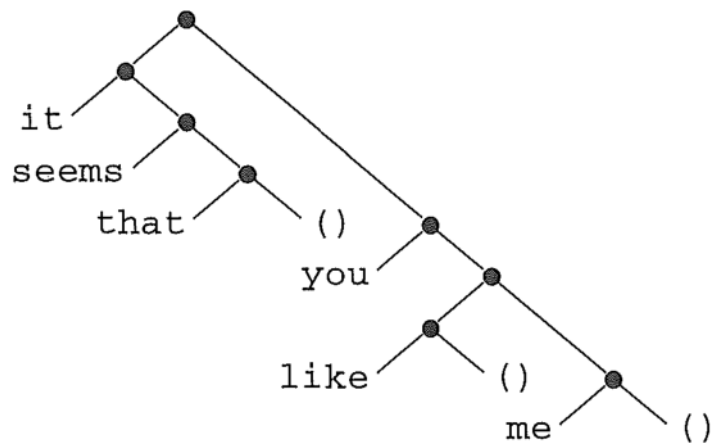


(it seems that you like me)



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These two examples are from p. 393 of Sethi's book.

Memory Uniqueness of Symbols

(TIME AFTER TIME) represents:

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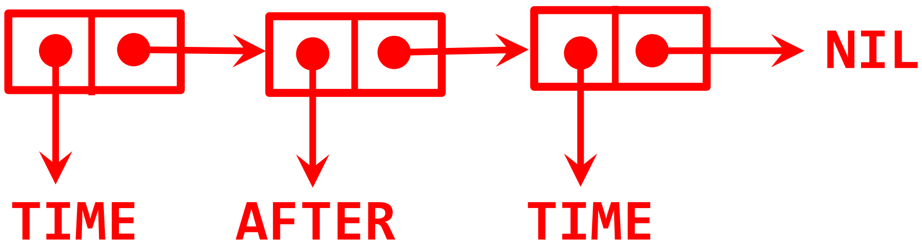

But this drawing needs careful interpretation because the two occurrences of TIME represent ***the same identical*** ***symbol object***.

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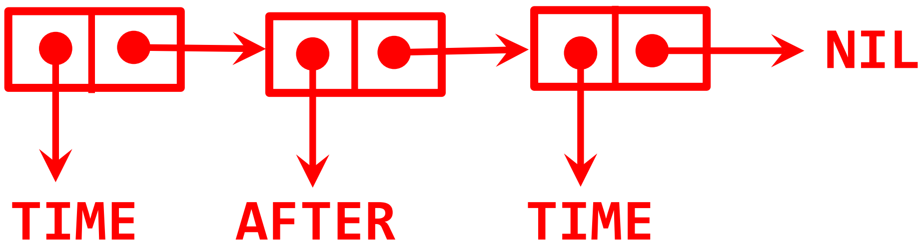

But this drawing needs careful interpretation because the two occurrences of TIME represent ***the same identical*** ***symbol object***.

Touretzky explains this as follows on p. 195:

In Lisp, symbols are unique, meaning there can be only one symbol in the computer's memory with a given name.** Every object in the memory has a numbered location, called its **address**. Since a symbol exists in only one place in memory, symbols have unique addresses. So in the list (TIME AFTER TIME), the two occurrences of the symbol TIME must refer to the same address. There cannot be two separate symbols named TIME.

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The following more detailed depiction of the data structure represented by **(TIME AFTER TIME)** is given on p. 196 of Touretzky:

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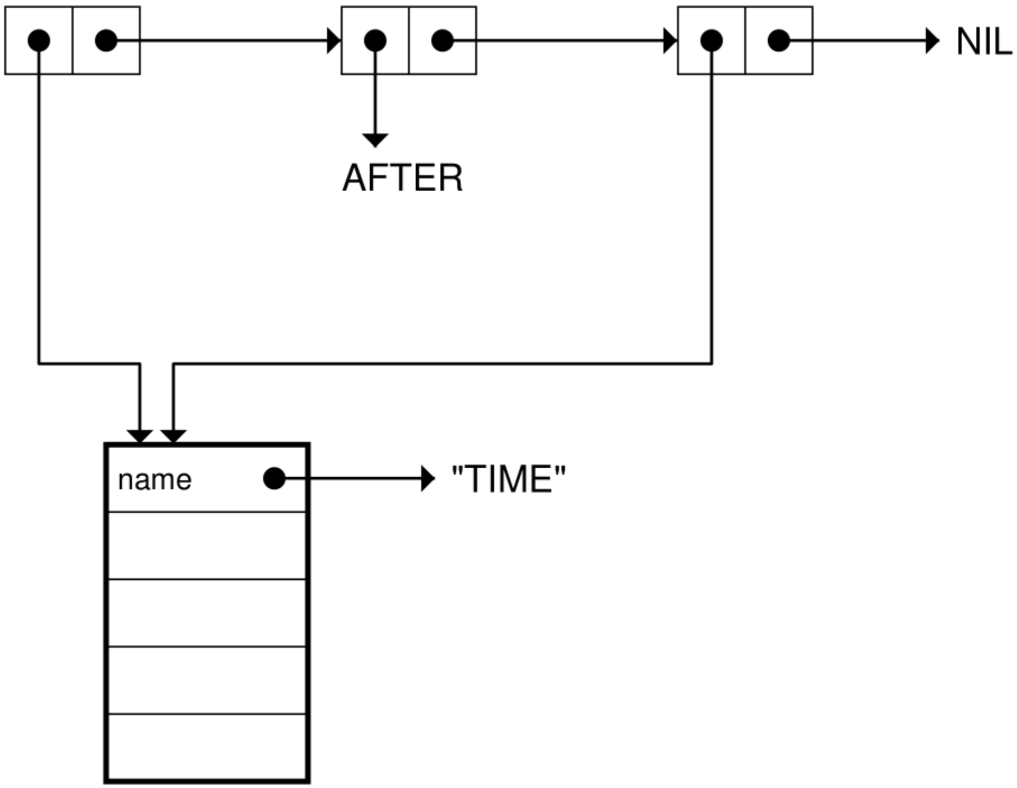

There is ***just one*** TIME ***symbol object***!

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Similarly, all occurrences of the symbol NIL that are shown below represent ***the same identical symbol object***:

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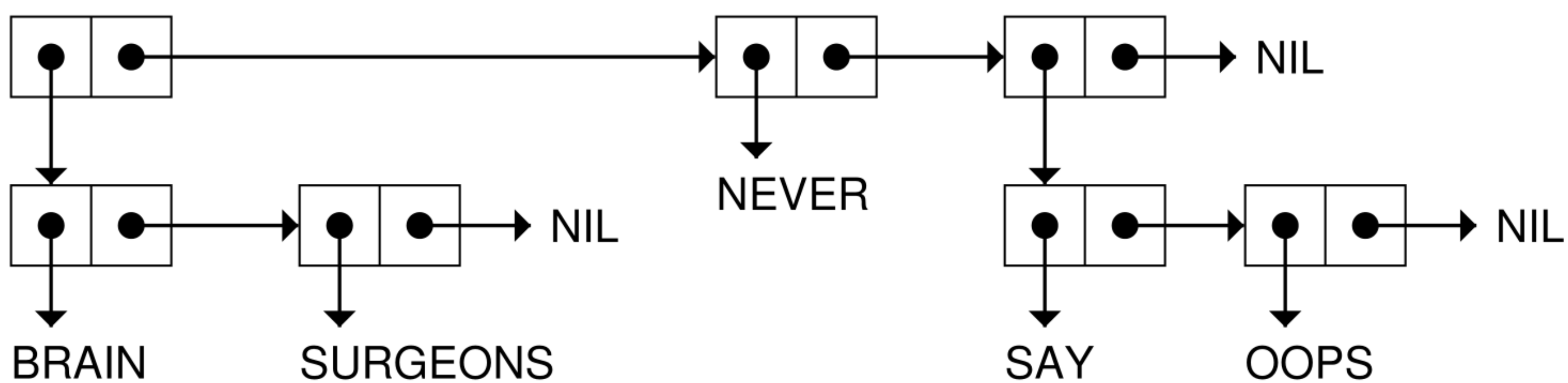
From p. 34 of Touretzky.

((BRAIN SURGEONS) NEVER (SAY OOPS)) represents:



Evaluation of S-Expressions

- To ***evaluate*** an S-expression is to compute its ***value***; evaluation is said to ***return*** the value, and the S-expression is said to ***evaluate to*** that value.
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- If an S-expression can be evaluated, then its value will be a data object that may be an atom or a list.

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Note: The result of evaluating a *dotted* list is undefined!