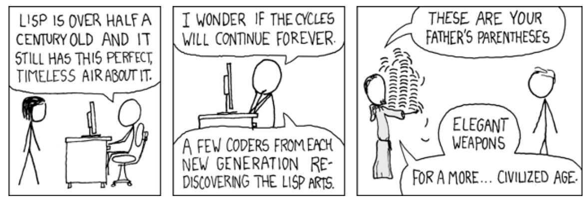
# 61A Lecture 25

Friday, October 26

## Scheme is a Dialect of Lisp

What are people saying about Lisp?

- "The greatest single programming language ever designed."
  -Alan Kay, co-inventor of Smalltalk and OOP
- "The only computer language that is beautiful."
  -Neal Stephenson, John's favorite sci-fi author
- "God's programming language."
  -Brian Harvey, Berkeley CS instructor extraordinaire




http://imgs.xkcd.com/comics/lisp_cycles.png



## Scheme Fundamentals

Scheme programs consist of expressions, which can be:

- Primitive expressions: 2, 3.3, true, +, quotient, ...
- Combinations: (quotient 10 2), (not true), ...

Numbers are self-evaluating; symbols are bound to values.

Call expressions have an operator and 0 or more operands.

```
> (quotient 10 2)
5
> (quotient (+ 8 7) 5)
3
> (+ (* 3
        (+ (* 2 4)
           (+ 3 5)))
     (+ (- 10 7)
        6))
```

"quotient" names Scheme's built-in integer division procedure (i.e., function)

Combinations can span multiple lines (spacing doesn't matter)

Demo



## Special Forms

A combination that is not a call expression is a *special form*:

- **If** expression: (if <predicate> <consequent> <alternative>)
- **And** and **or**: (and <e1> ... <en>), (or <e1> ... <en>)
- Binding names: (define <name> <expression>)
- New procedures: (define (<name> <formal parameters>) <body>)

```
> (define pi 3.14)
> (* pi 2)
6.28
```

The name "pi" is bound to 3.14 in the global frame

```
> (define (abs x)
    (if (< x 0)
        (- x)
        x))
> (abs -3)
3
```

A procedure is created and bound to the name "abs"

Demo



## Lambda Expressions

Lambda expressions evaluate to anonymous functions.

(lambda (<formal-parameters>) <body>)

λ

Two equivalent expressions:

```
(define (plus4 x) (+ x 4))

(define plus4 (lambda (x) (+ x 4)))
```

An operator can be a call expression too:

```
((lambda (x y z) (+ x y (square z))) 1 2 3)
```

Evaluates to the *add-x-&-y-&-z²* procedure



## Pairs and Lists

In the late 1950s, computer scientists used confusing names.

- **cons**: Two-argument procedure that **creates a pair**
- **car**: Procedure that returns the **first element** of a pair
- **cdr**: Procedure that returns the **second element** of a pair
- **nil**: The empty list

They also used a non-obvious notation for recursive lists.

- A (recursive) Scheme list is a pair in which the second element is nil or a Scheme list.
- Scheme lists are written as space-separated combinations.
- A dotted list has an arbitrary value for the second element of the last pair. Dotted lists may not be well-formed lists.

```
> (define x (cons 1 2))
> x
(1 . 2)
> (car x)
1
> (cdr x)
2
> (cons 1 (cons 2 (cons 3 (cons 4 nil))))
(1 2 3 4)
```

Not a well-formed list!

Demo

## Symbolic Programming

Symbols normally refer to values; how do we refer to symbols?

```
> (define a 1)
> (define b 2)
> (list a b)
(1 2)
```

No sign of “a” and “b” in the resulting value

Quotation is used to refer to symbols directly in Lisp.

```
> (list 'a 'b)
(a b)
> (list 'a b)
(a 2)
```

Symbols are now values

Quotation can also be applied to combinations to form lists.

```
> (car '(a b c))
a
> (cdr '(a b c))
(b c)
```



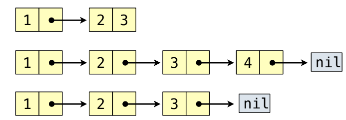
## Scheme Lists and Quotation

Dots can be used in a quoted list to specify the second element of the final pair.

```
> (cdr (cdr '(1 2 . 3)))
3
```

However, dots appear in the output only of ill-formed lists.

```
> '(1 2 . 3)
(1 2 . 3)
> '(1 2 . (3 4))
(1 2 3 4)
> '(1 2 3 . nil)
(1 2 3)
```

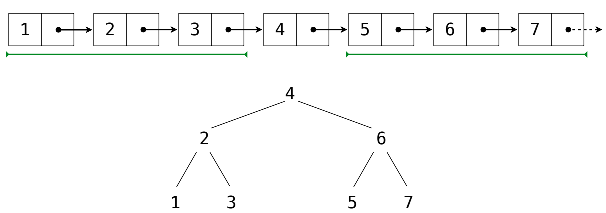



What is the printed result of evaluating this expression?

```
> (cdr '((1 2) . (3 4 . (5))))
(3 4 5)
```



## Coercing a Sorted List to a Binary Search Tree




Divide length n into 3 parts: [ (n-1)/2 , 1 , (n-1)/2 ]

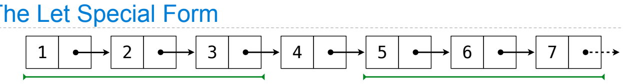
Recursively coerce the left part

The next element is the entry

Recursively coerce the right part



## The Let Special Form




```
(define (entry tree) ...)
(define (left-branch tree) ...)
(define (right-branch tree) ...)
(define (make-tree entry left right) ...)
(define (list->tree elements)
  (car (partial-tree elements (length elements))))

(define (partial-tree elts n)
  (if (= n 0)
      (cons nil elts)
      (let ((left-size (quotient (- n 1) 2)))
        (let ((left-result (partial-tree elts left-size)))
          (let ((left-tree (car left-result))
                (non-left-elts (cdr left-result))
                (right-size (- n (+ left-size 1))))
            (let ((this-entry (car non-left-elts))
                  (right-result (partial-tree (cdr non-left-elts)
                                              right-size)))
              (let ((right-tree (car right-result))
                    (remaining-elts (cdr right-result)))
                (cons (make-tree this-entry left-tree right-tree)
                      remaining-elts))))))))
```



## The Begin Special Form

```
(begin <exp1> <exp2> ... <expn>)
```

Demo