CSCI 334:
Principles of Programming Languages

Lecture 2: Lisp

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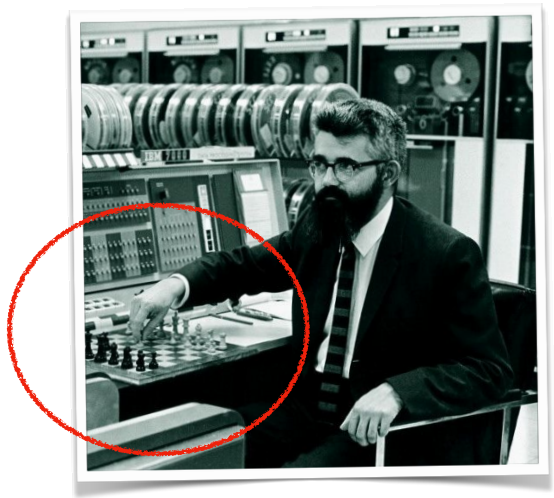
Williams

How this course works

- Lots of new languages
- Not enough class time to cover all features (e.g., Java over the course of 134-136: 1 year!)
- Read the assigned book chapters, read course tutorials, and even seek additional material on your own (on teh Googles)
- TAs/office hours

John McCarthy

IBM 704



Lisp was invented for AI research

```
                        04000       ORG 2048
04000 -0 53400 5 04011              LXD P1,J+K

04001 -0 63400 4 04020  P4          SXD P2,K
04002  0 50000 1 04022              CLA A+1,J
04003  1 77777 1 04004              TXI P6,J,-1
04004 -2 00001 4 04017  P6          TNX P5,K,1
04005  0 76500 0 00043  P3          LRS 35
04006  0 26000 0 04046              FMP X
04007  0 30000 1 04022              FAD A+1,J
04010  1 77777 1 04011              TXI P1,J,-1
04011  2 00001 4 04005  P1          TIX P3,K,1
04012  0 60100 0 04051              STO S
04013  0 56000 0 04050              LDQ Z
04014  0 26000 0 04047              FMP Y
04015  0 30000 0 04051              FAD S
04016 -3 77754 1                    TXL OUT, J,
                                      -R/2+1
04017  0 60100 0 04050  P5          STO Z
04020  1 00000 4 04001  P2          TXI P4,K
                        00005  N    EQU 5
                        00052  R    EQU N*N+3*N+2
                        04021  A    BSS R/2
04046  0 00000 0 00000  X
04047  0 00000 0 00000  Y
04050  0 00000 0 00000  Z
04051  0 00000 0 00000  S
                        00001  J    EQU 1
                        00004  K    EQU 4
                        04000       END P4-1
                        00000  OUT
```

704 Assembly (circa 1954)
(From Coding the MIT-IBM 704 Computer)

```
C                                                                       0114
C     READ IN INPUT DATA                                                0115
C                                                                       0116
      IF (ISYS-99) 401,403,401                                          0117
  403 READ TAPE 3,(G(I),I=1,8044)                                       0118
      REWIND 3                                                          0119
      IF (SENSE SWITCH 6) 651,719                                       0120
  401 ISYS=99                                                           0121
      IFROZ=0                                                           0122
      PAUSE 11111                                                       0123
  429 CALL INPUT                                                        0124
      IF (L) 651,651,433                                                0125
  433 WRITE OUTPUT TAPE 6,443, HX,VXPLS,VXMIN,HF,VFPLS,VFMIN            0126
     1, (ELMT(I),BOX(I),BOF(I),I=1,L)                                   0127
  443 FORMAT (10H1OXIDANT  3E16.6/10H FUEL      3E16.6/(1H A6,2E20.8))  0128
C                                                                       0129
C     RIGHT ADJUST ELEMENT SYMBOLS                                      0130
C                                                                       0131
      DO 447 K=1,L                                                      0132
      TMLM = ELMT(K)                                                    0133
      ELMT(K) = ARSF(24, TMLM)                                          0134
```

FORTRAN (circa 1956)
(From NASA Technical Note D-1737)

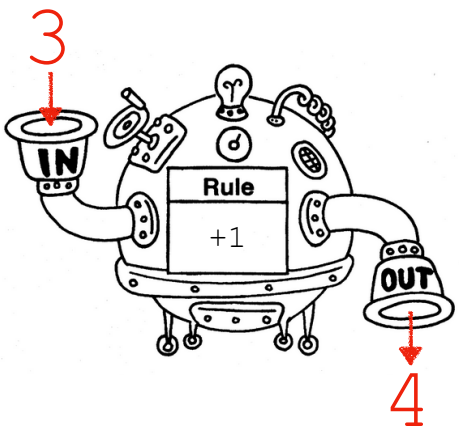
```
(defun fact (n)
    (cond ((eq n 0) 1)
          (t (* n (fact (- n 1))))))
```

LISP (circa 1958)

LISP is a “functional” language

- programs are modeled after math. functions
- no statements, only expressions
- no “mutable” variables, only declarations
- therefore, the effect of running a program (“evaluation”) is purely the effect of applying a function to an input.

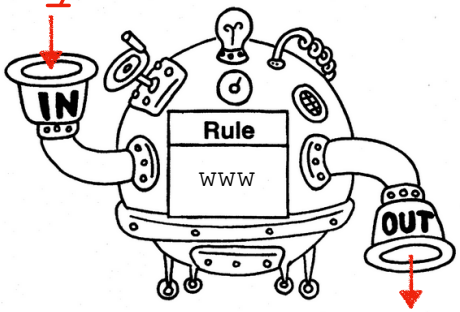
LISP is a “functional” language




```
(defun add-one (n) n + 1)
```

LISP is a “functional” language

dirty house

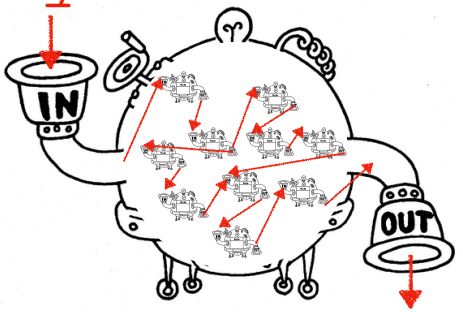


clean house

```
(defun cleaning-robot (dirt) …)
```

Big functions are “composed” of little functions

dirty house

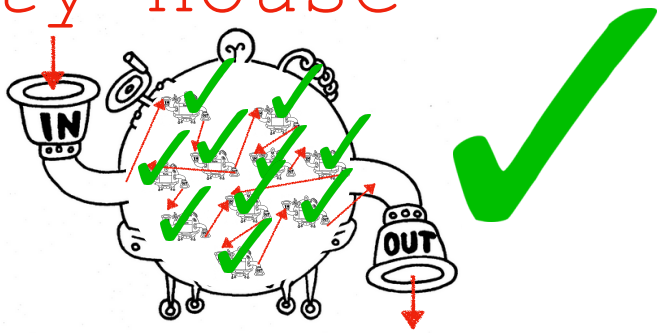


clean house

```
(defun cleaning-robot (dirt) …)
```

Program correctness is easier to achieve

dirty house



clean house

I.e., whole is correct if pieces are correct.

LISP is inspired by the lambda calculus

- everything either a value or a funct. of a value

  value: `1`

  function of two values: `(+ 1 1)`
- syntax is (mind-numbingly) regular

  functions: `(function-name arguments …)`

  values: anything that is not a function
- evaluating a function produces a value:

  `(+ 1 1)=2`

Statements vs. expressions

- A *statement* is an operation that changes the state of the computer

  Java: `i++`

  value stored at location i incremented by one
- An *expression* is a combination of functions and values that yields a new value

  Lisp: `(+ i 1)`

  evaluating + with i and 1 returns i + 1

REPL
(read-eval-print loop)

Batch mode

Mutable variables

- If you can update a variable in a language, you have mutable variables

  Java:
  ```
  int i = 3;
  i = 4;
  ```
- Notice that both lines of code are statements
- (pure) Lisp does not have mutable variables

Immutable variables

- Variables cannot be updated in Lisp

  Lisp:
  ```
  (defun my-func (i) …)
      (my-func 3)
  ```
  or the shorter
  ```
      ((lambda (i) …) 3)
  ```
- Notice that all of the above are expressions
- In fact, functions are the only way to bind values to names in (pure) Lisp

Lisp syntax: atoms

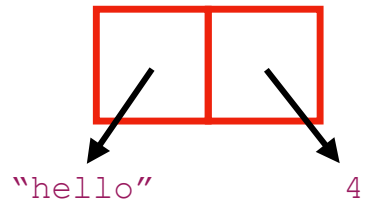
- An atom is the most basic unit in Lisp: data

```
4
112.75
“hello”
‘foo
t
nil
```

Lisp syntax: cons cells

- The "cons cell" allows "composing" values

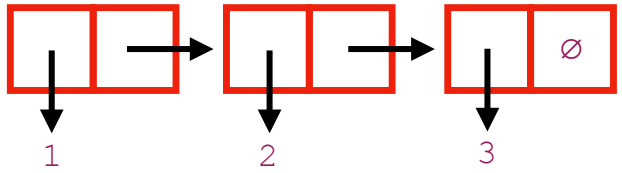
```
(cons "hello" 4)
```



Lisp syntax: lists

- E.g., lists in Lisp are just made out of cons cells

```
(cons 1 (cons 2 (cons 3 nil)))
```



- Lisp has a shorthand for this:

```
'(1 2 3)
```

Lisp syntax: car and cdr

- Access the first element of a cons cell with `car`

```
(car (cons 1 2)) = 1
```

- Access the second element with `cdr`

```
(cdr (cons 1 2)) = 2
```

- What's the value of the following expression?

```
(car '(1 2 3))
```

- What about this?

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

Lisp syntax: functions

- Everything else is a function (or special form)
- There are a bunch of built-in functions

```
(car …)
(cdr …)
(append …)
```

, etc.

- And you can define your own

```
(defun my-func (arg) (value))
```

Lisp syntax: conditionals

- In Lisp, there is no `if/else`

```
(cond ((test) (value)) …)
```

- E.g.,

```
(cond ((eq 1 x) (cons x xs)) …)
```

- Does the same as the Java

```
if (x == 1) {
  xs.add(x);
}
```

Lisp syntax: conditionals

- `cond` is more general than `if/else`.

```
(cond ((test1) (value1))
      ((test2) (value2)
      …)
```

```
(defun insert (x l)
  (cond ((eq l nil) (cons x nil))
        ((< x (car l)) (cons x l))
        (t (cons
             (car l)
             (insert x (cdr l))))))
```

That's pretty much it!

- Note that the book uses slightly different syntax
- You should use:

  `t` instead of `true`

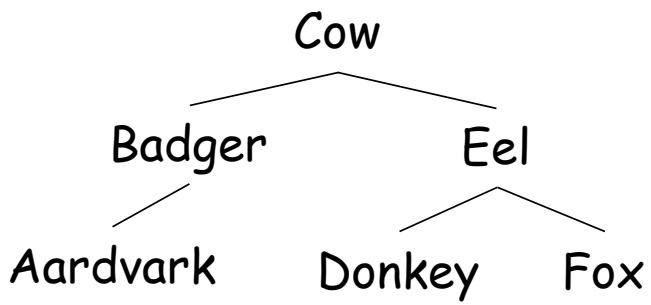
  `(defun …)` instead of `(define …)`

  `(mapcar #'f xs)` instead of `(maplist f xs)`
- See "334 Lisp FAQ" for all the syntax you need to know on course webpage

Activity

list length

Activity



Memory management

- C:

  When you want to use a variable, you have to *allocate* it first, then *decallocate* it when done.

```
MyObject *m = malloc(sizeof(MyObject));
m->foo = 2;
m->bar = 3;
… do stuff with m …
free(m);
```

Memory management

- Lisp and Java:

  You barely need to think about this at all.

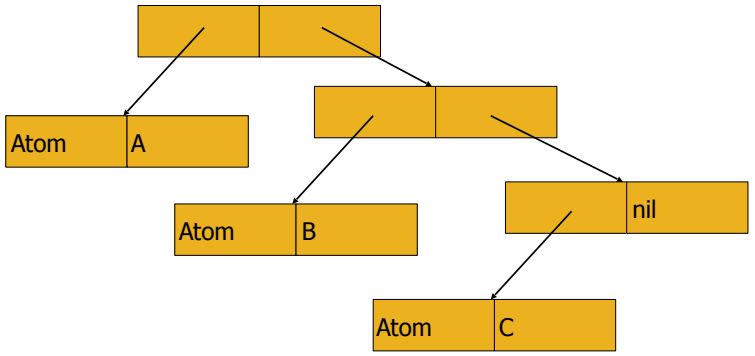
```
MyObject m = new MyObject(2,3);
… do stuff with m …
(cons 2 3)
```

Lisp memory model

Cons cell: Address | Decrement

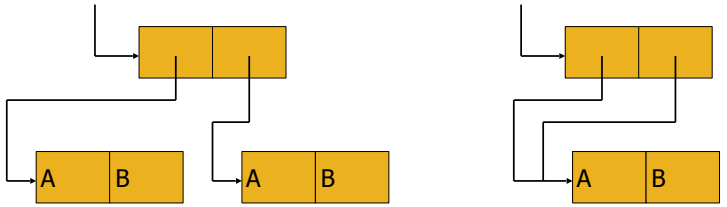
Atom: Atom | value

```
(cons 'A (cons 'B (cons 'C nil)))
```



Sharing data

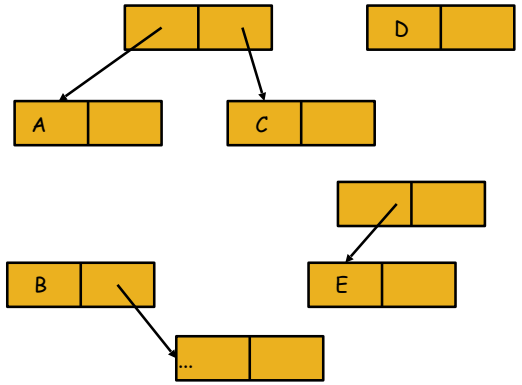
(a) (b)



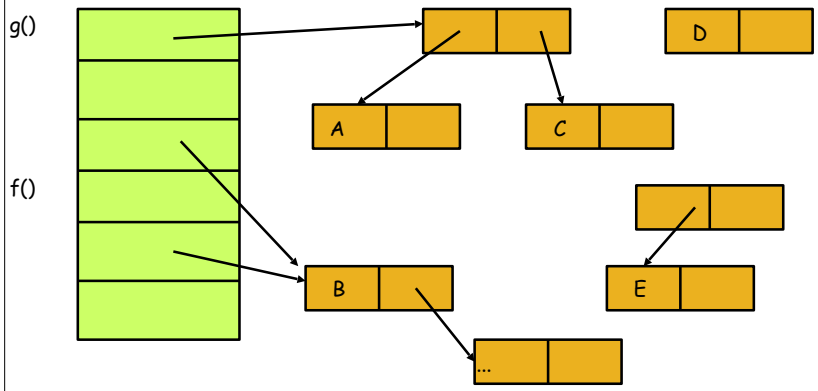
- Both structures could be printed as `(A.B).(A.B)`
- What is result of evaluating

```
(cons (cons 'A 'B) (cons 'A 'B)) ?
```

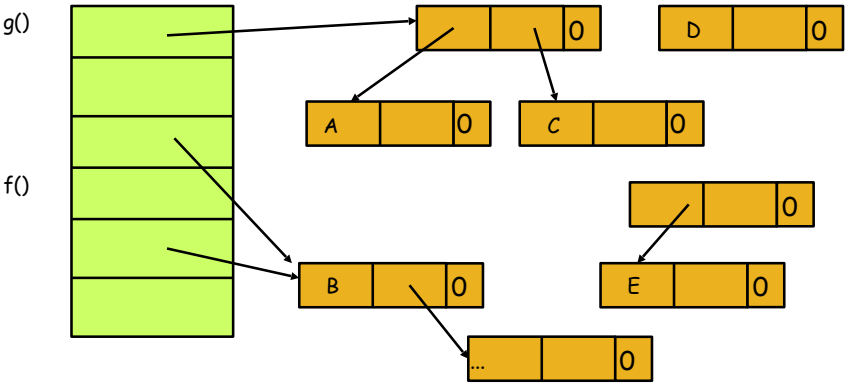
Garbage collection



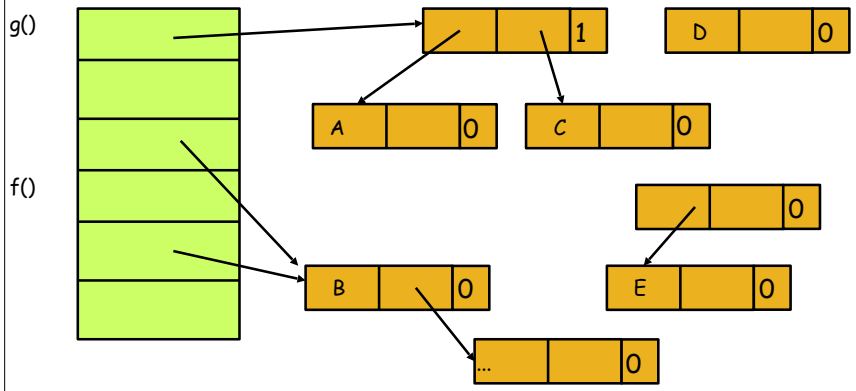
Garbage collection



1. Clear tags



2. Mark reachable cells



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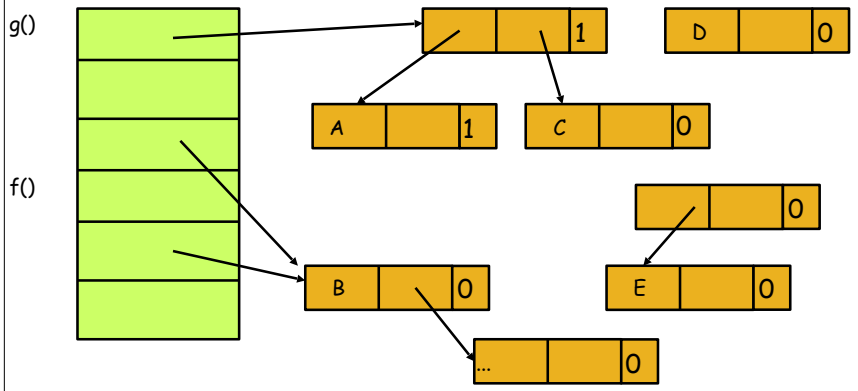

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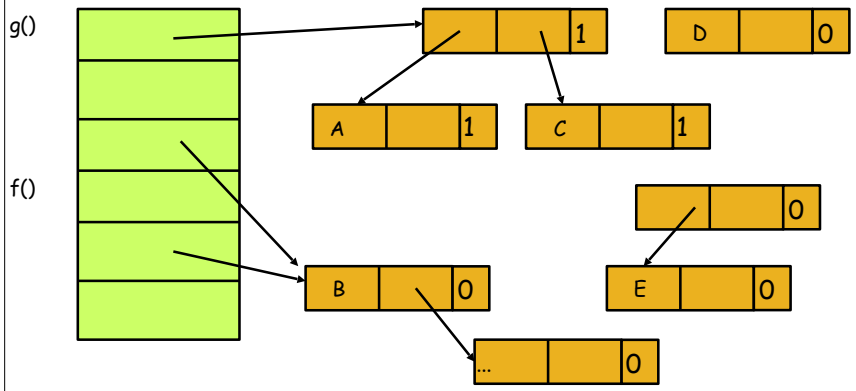

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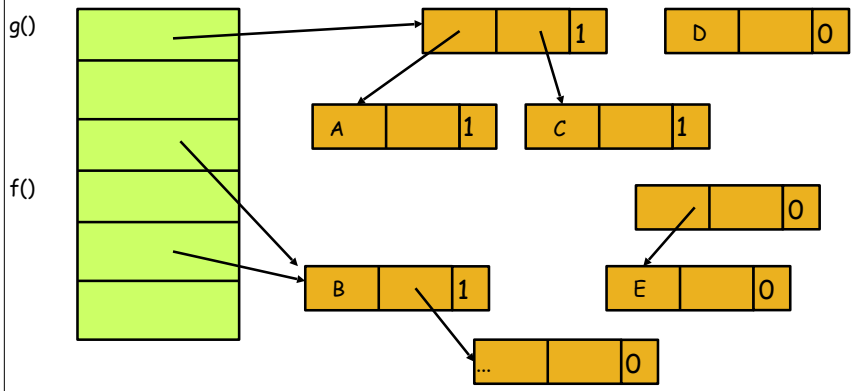

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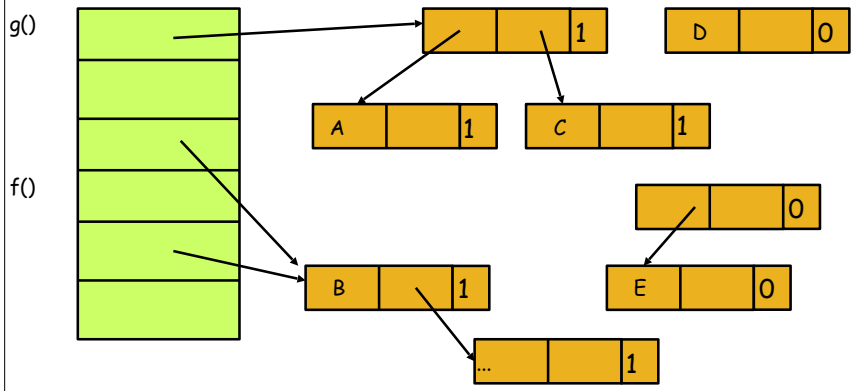

3. Free unreachable cells