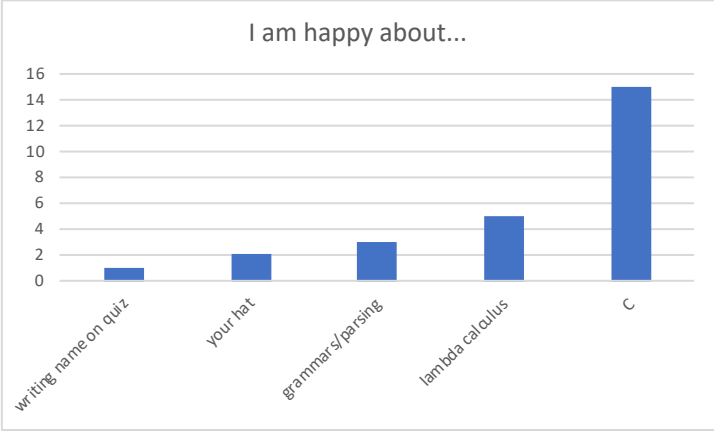
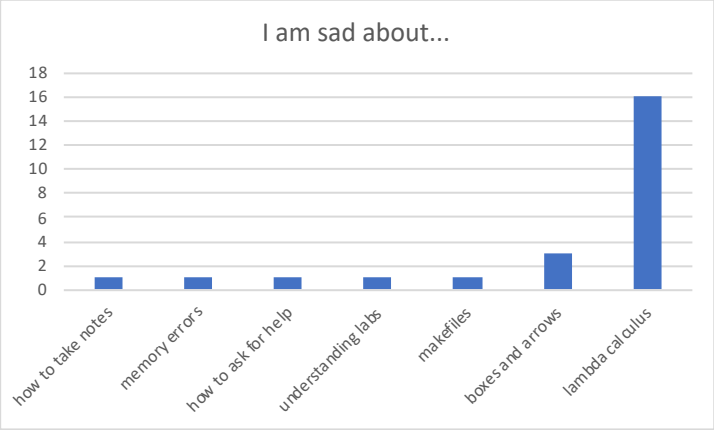
CSCI 334:
Principles of Programming Languages

Lecture 6: Lisp

Instructor: Dan Barowy

Williams





`(λx.xx)(λy.yx)z`
reduces to: **`xxz`**

Quiz

Life tip

"Growth" mindset

"In a fixed mindset students believe their basic abilities, their intelligence, their talents, are just fixed traits. They have a certain amount and that's that, and then their goal becomes to look smart all the time and never look dumb. In a growth mindset students understand that their talents and abilities can be developed through effort, good teaching and persistence."

— Carol Dweck (Lewis and Virginia Eaton Professor of Psychology at Stanford University)

Individuals with a "growth" mindset are more likely to continue working hard—and succeed—despite setbacks.

Why am I telling you this?

This course is about priming your brain with different ways of thinking about programming.

Why am I telling you this?

You can **be a programmer** without these ideas.

But make the effort to internalize these concepts and you will see their application everywhere.

You will be a ***clearer*** **thinker** and a ***better*** **programmer**.

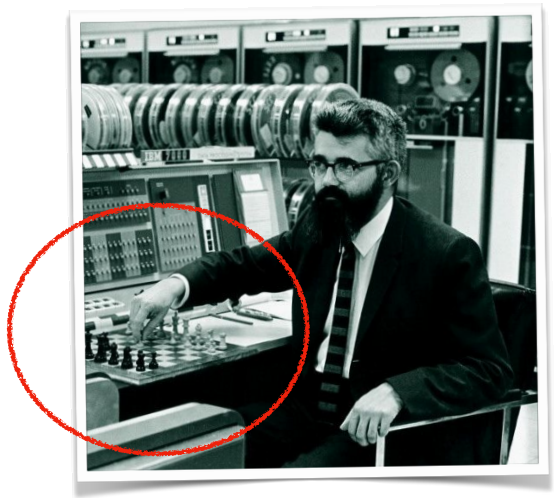
How this course works

- Lots of **new languages**
- **Not enough class time** to cover all features (e.g., Java over the course of 134-136: 1 year!)
- **Do the assigned reading** and **seek additional material** on your own (on teh Googles)
- **Help hours!!!**

LISP

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)

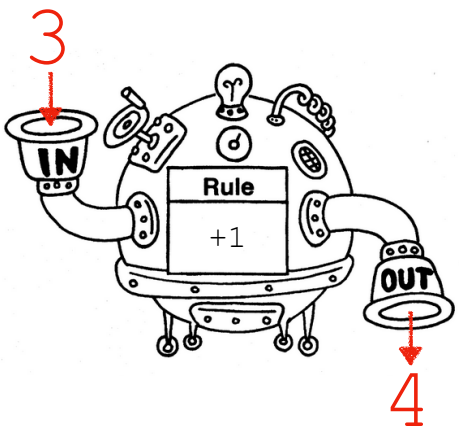
```
(defun fact (n)
    (cond ((eq n 0) 1)
          (t (* n (fact (- n 1))))))
```

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.

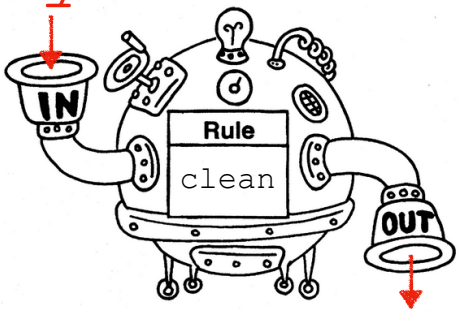
LISP is a “functional” language




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

LISP is a “functional” language

dirty house

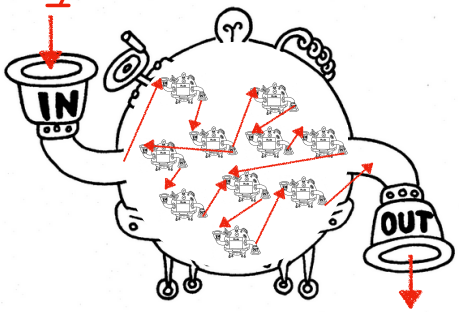


clean house

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

Big functions are “composed” of little functions

dirty house

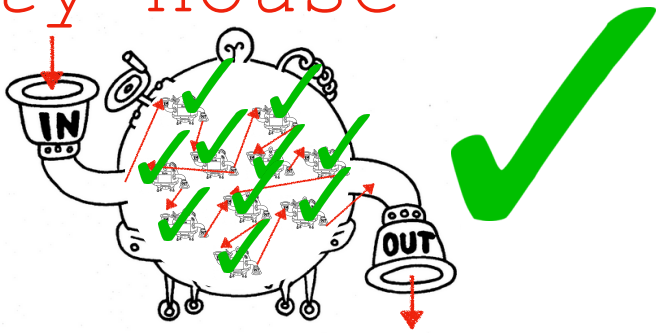


clean house

```
(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 deeply influenced by the lambda calculus

- all code is either a **value**, a **function**, or a **function application**

  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 values and operations that yields a new value

  Lisp: `(+ i 1)`

  evaluating + with i and 1 returns i + 1
- Lisp **has only expressions**.

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**
- 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

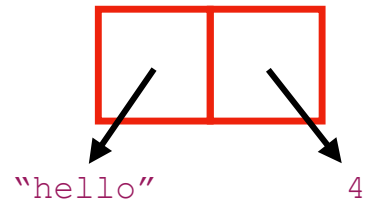
- An **atom** is the most basic unit of **data** in Lisp

`4`	Number
`112.75`	Number
`"hello"`	String
`'foo`	Quoted symbol
`t`	Boolean
`nil`	Empty list

Lisp syntax: data structure

- Historically, Lisp has exactly one data structure: the **cons cell**.
- The "cons cell" allows "composing" values

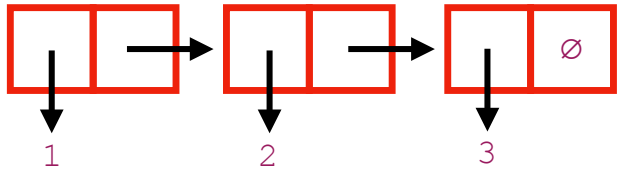
```
(cons "hello" 4)
```



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)
```

"Recursive Functions [...]" (McCarthy)

Lisp	C
`car`	`head`
`cdr`	`tail`
`cons`	`prepend`

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))
```

Recap & Next Class

Today we covered:

LISP

Next class:

More LISP

Garbage collection