CSCI 334:
Principles of Programming Languages

Lecture 7: Lisp, part II

Instructor: Dan Barowy

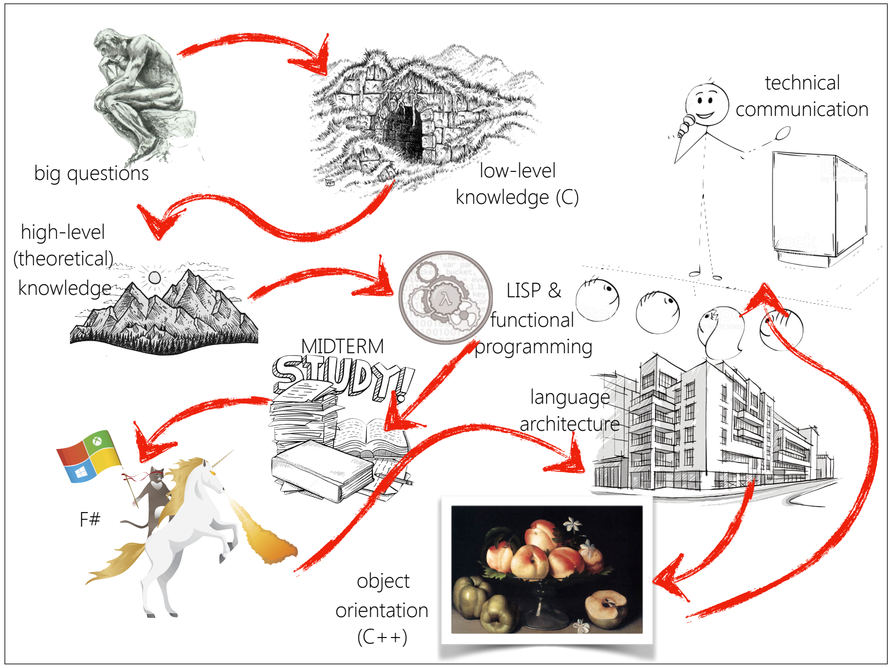
Williams

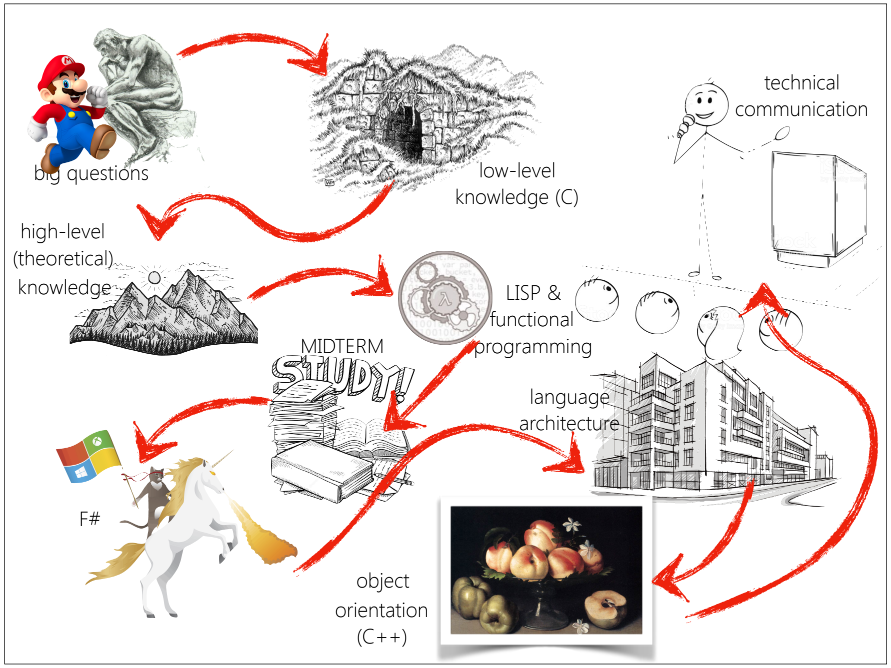
Announcements

- Lab 4 due Sunday by 11:59pm
- Scheduled power outage: this Sunday at 10pm until Monday at 9am
  - **All CS lab machines**
  - All CS servers
- Colloquium: 2:30pm in Wege Auditorium (TCL 123)
  - "Adventures in Hybrid Architectures for Intelligent Systems," Nate Derbinsky, Northeastern

Outline

1. Happy/sad cards
2. More LISP
3. Garbage Collection

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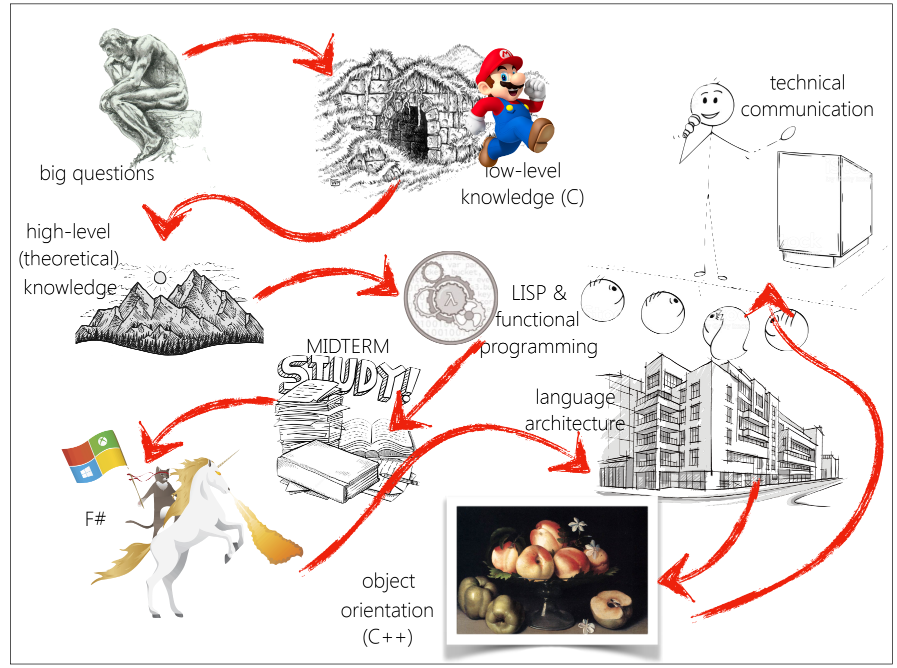
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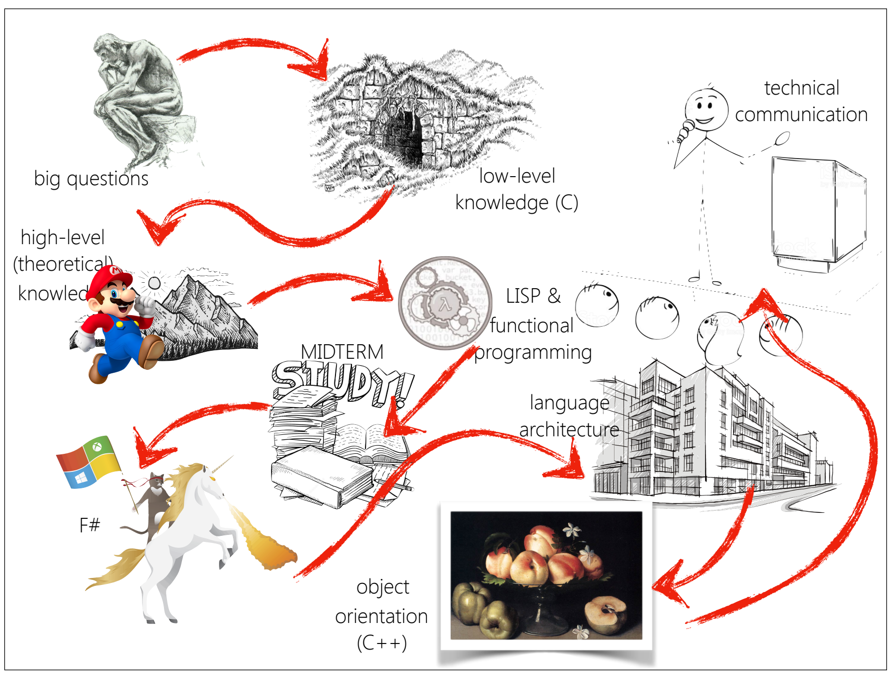
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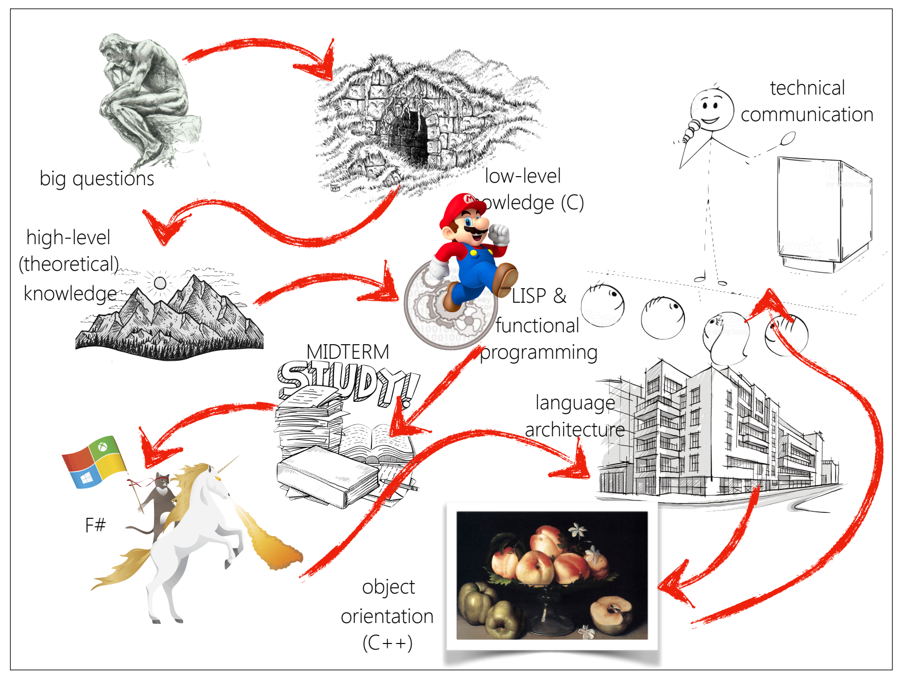
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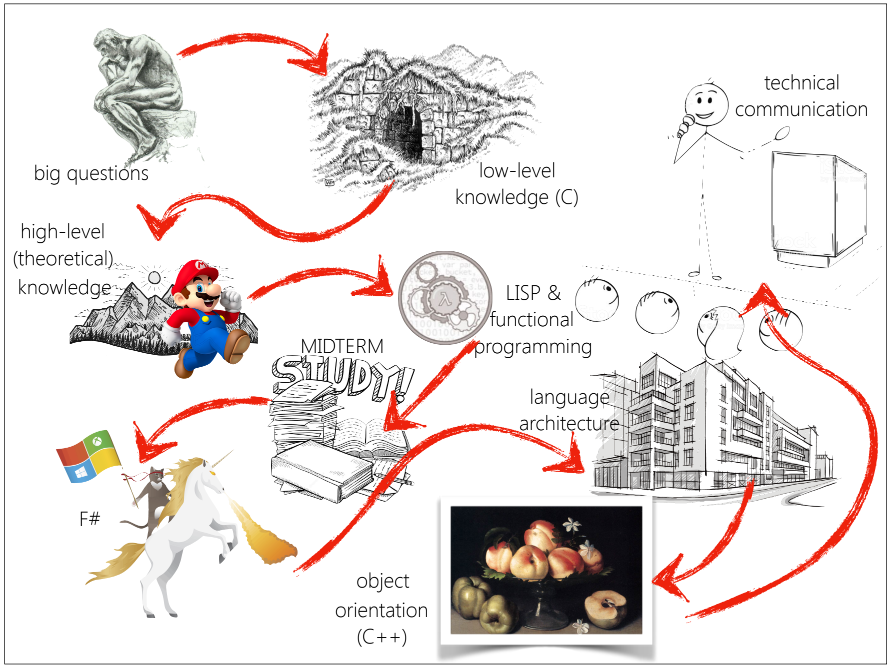
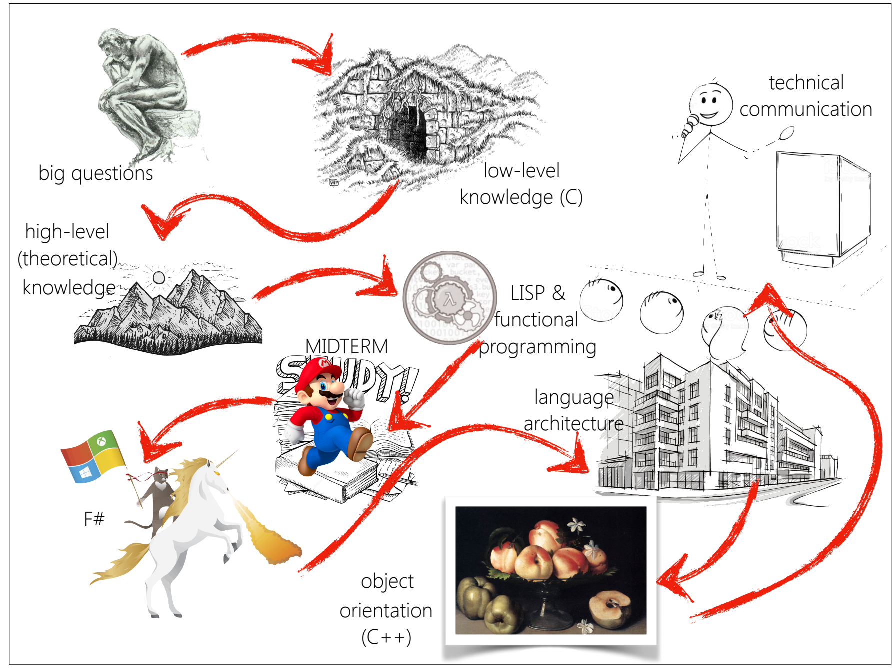




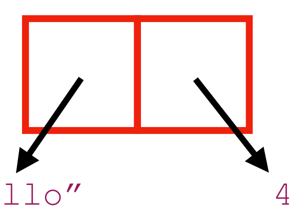
Midterm Exam

- Friday, March 20, in class

Lisp syntax: data structure

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

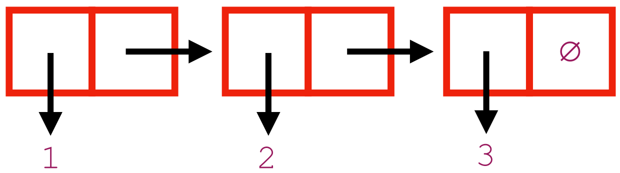
```
(cons “hello” 4)
```



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))
```

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, `if`/`else` is called `cond`

  ```
  (cond (test₁ value₁)
   …)
  ```

- 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)
   …)
  ```

demo

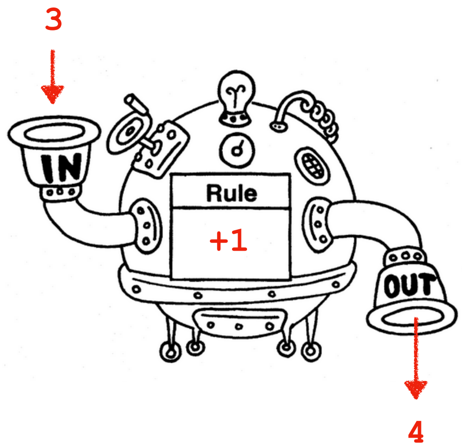
Lisp syntax: conditionals

```
(defun only-positives (xs)
  (cond
    ; empty list
    ((eq xs nil) nil)
    ; element is positive
    ( (> (car xs) 0)
      (cons (car xs) (only-positives (cdr xs)))
    )
    ; element is not positive
    ( t
      (only-positives (cdr xs))
    )
  )
)
```

Three amazing concepts from LISP

- First-class functions
- Higher-order functions
  - map
  - fold

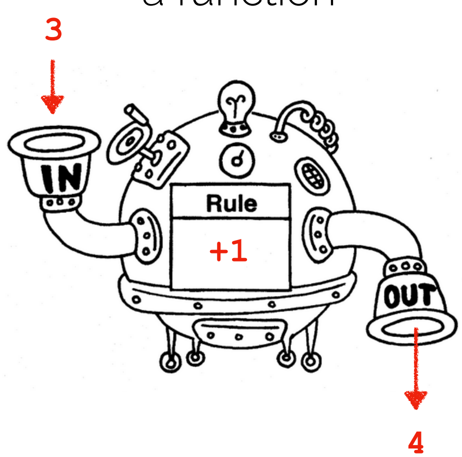
a function



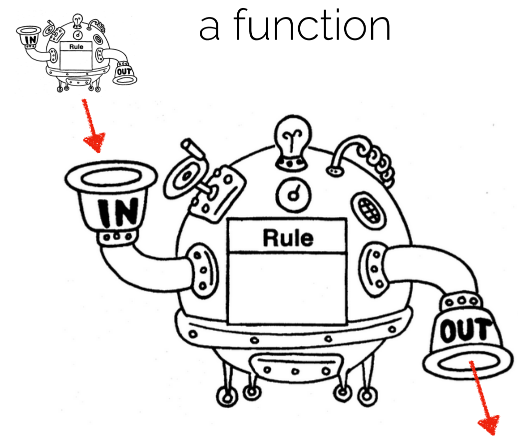
“first class” function

Functions are **values** in a functional programming language

a function

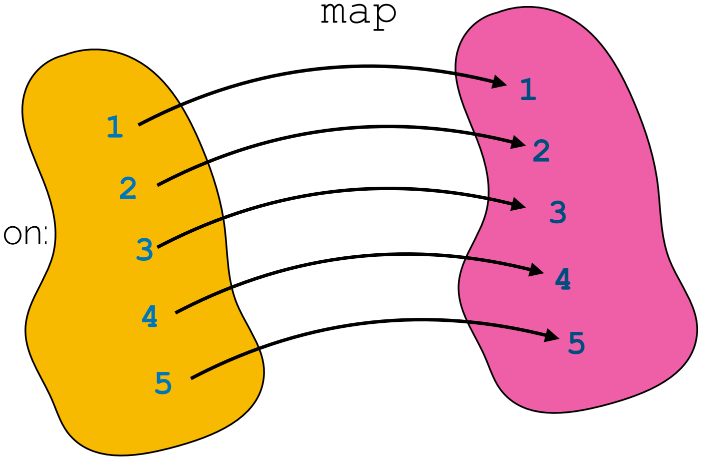


a function



map

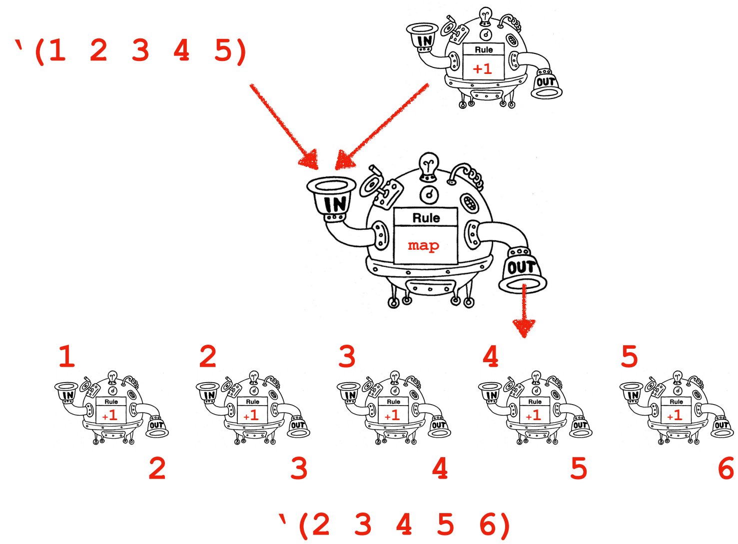
Intuition:



Like a `for` loop, but without mutable variables

```
(mapcar (lambda (x) (+ x 1)) '(1 2 3 4 5))
```

map



fold

Intuition:

fold left

```
(reduce #'+ '(1 2 3) :initial-value 0)
```

```
acc = 0, '(1 2 3)
acc = 0+1, '(2 3)
acc = 1+2, '(3)
acc = 3+3, nil
returns acc = 6
```

fold right

```
(reduce #'+ '(1 2 3):initial-value 0
                    :from-end t)
```

```
'(1 2 3), acc = 0
'(1 2), acc = 0+3
'(1), acc = 2+3
nil acc = 5+1
returns acc = 6
```

what does this print?

```
(reduce #'append '((2) (0))
    :initial-value '(w i l l i a m s))
```

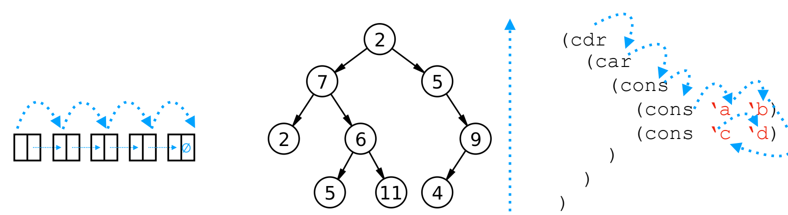
how about?

```
(reduce #'append '((2) (0))
    :initial-value '(w i l l i a m s)
    :from-end t)
```

fold

structural recursion → fold it!

(in a nutshell: any problem that recurses on a subset of input)



list length   tree height   evaluation

That's pretty much it!

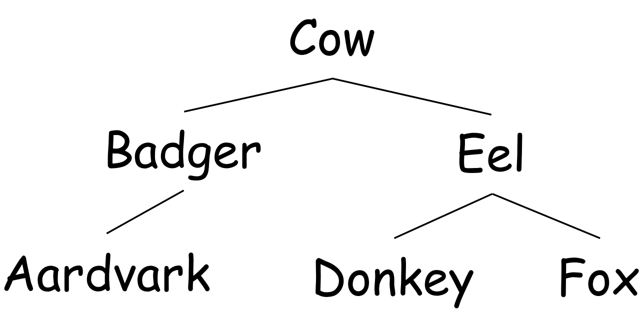
- See "LISP Notes" for all the syntax you need to know on course webpage

Activity

list length

```
(length-list '(1 2 3 4 5 6)) ↠ 6
```

Activity



Activity

Write a function (using `mapcar`) that replaces the number 3 in a list with the
number 6

```
(mapcar #'my-replace '(1 2 3 4 5 6))
          '(1 2 6 4 5 6)
```

Activity

Write a function (using `mapcar`) that replaces the number 3 in a list with the

number 6

```
       (defun my-replace (x)
         (cond
           ((equal x 3) 6)
           (t x)
         )
       )
(mapcar #'my-replace '(1 2 3 4 5 6))
            '(1 2 6 4 5 6)
```

Automatic Memory Management

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

- Java:

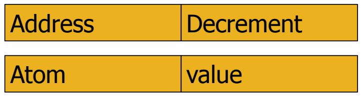
  You barely need to think about this at all.

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

- Same with LISP!

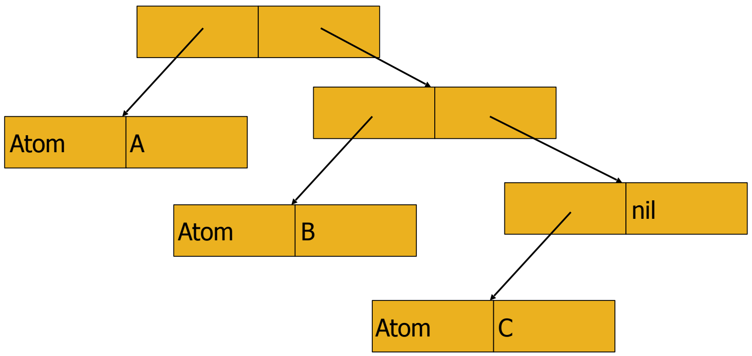
```
(cons 2 3)
```

Lisp memory model

Cons cell:


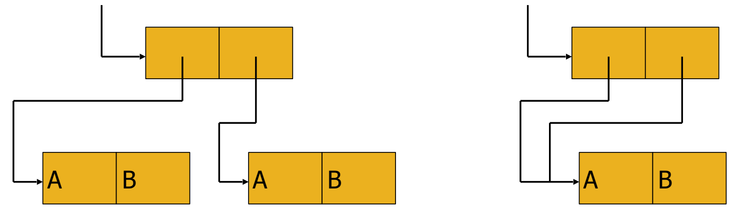
Atom:

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



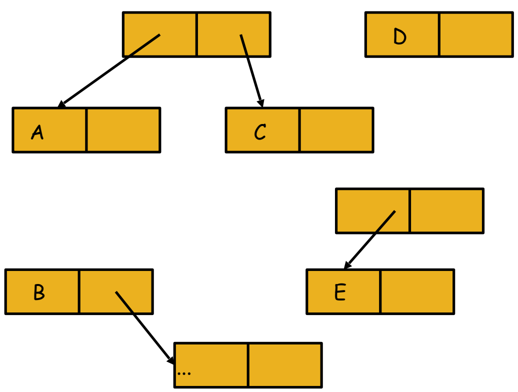
Sharing data

(a) (b)



- Which is the result of evaluating
  `(cons (cons 'A 'B) (cons 'A 'B))` ?

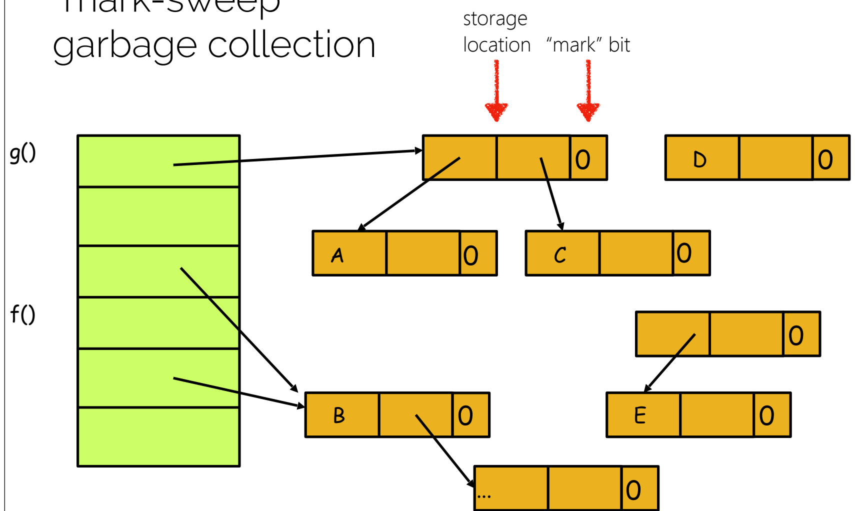
Garbage collection



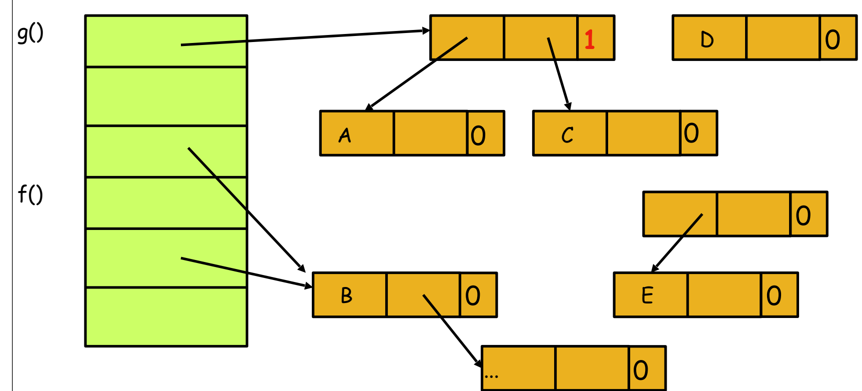
Garbage collection

A **garbage collection algorithm** is an algorithm that determines whether the storage, occupied by a value used in a program, can be reclaimed for future use. Garbage collection algorithms are often tightly integrated into a programming language **runtime**.

“mark-sweep” garbage collection



1. Mark reachable cells



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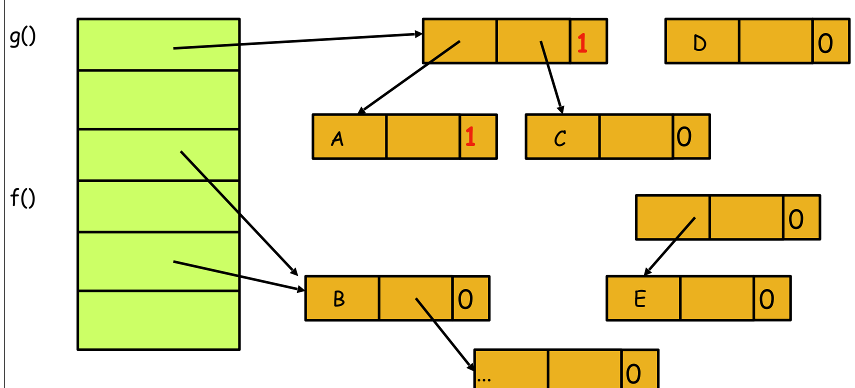

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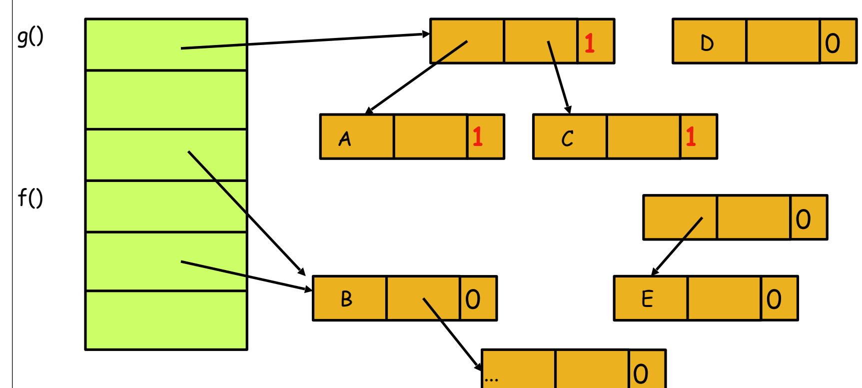

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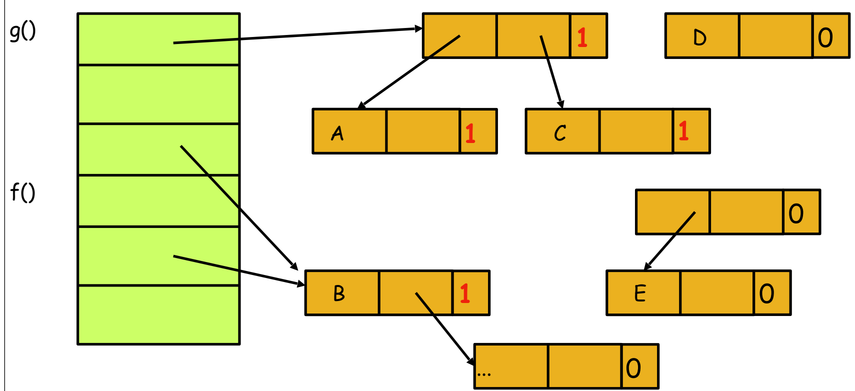

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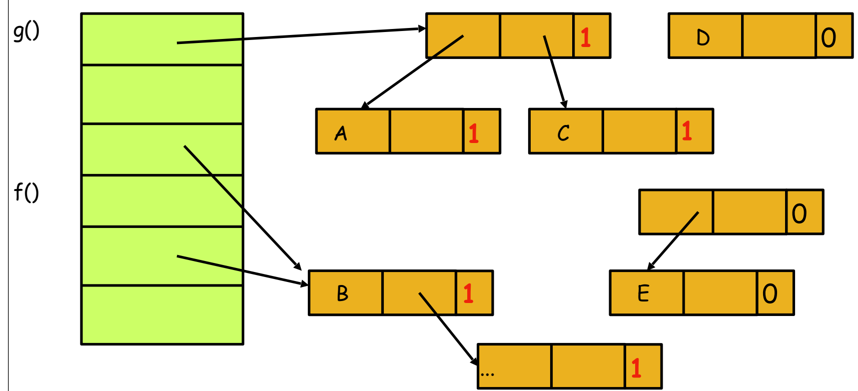
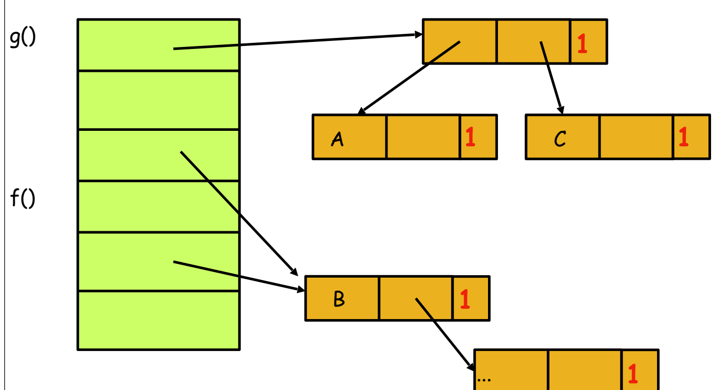
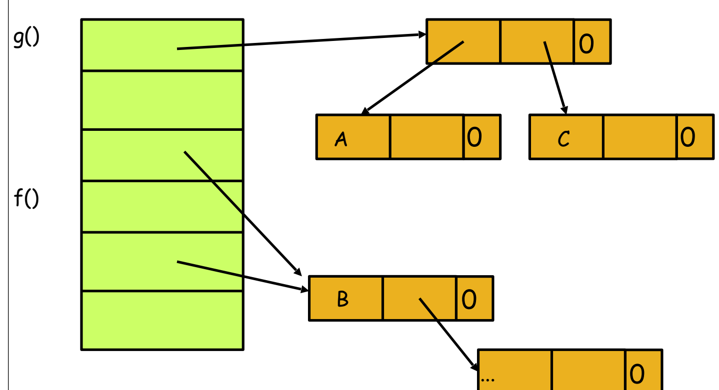


2. Free ("sweep") unreachable cells



3. Clear tags



More lambda calculus practice?

1. `(λx.x)(λx.xx)(λx.xa)`
   reduces to: **`aa`**
2. `(λx.x)(λy.yy)(λz.za)`
   reduces to: **`aa`**
3. `(λx.λy.xyy)(λa.a)b`
   reduces to: **`bb`**
4. `(λx.xx)(λy.yx)z`
   reduces to: **`xxz`**
5. `(λx.(λy.(xy))y)z`
   reduces to: **`zy`**

Recap & Next Class

Today we covered:

More LISP

Garbage collection

Next class:

Halting Problem