# CSCI 275: Programming Abstractions

## Lecture 07: Function Design - Part 2

## Fall 2024

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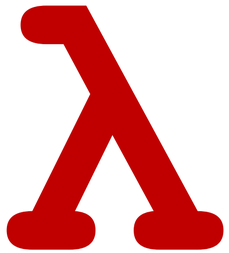
**Slides gratefully borrowed from Molly Q Feldman**



# Questions? Comments?

# Goals for Today's Class

- Local variables: `let`
- Environments: how do we store bindings?
- [If time] Tail Recursion, or how to be efficient

# Let

# Storing Local Information

```
(let ([id1 s-exp1] [id2 s-exp2]…) body)
```

`let` enables us to create some new bindings that are visible only inside `body`

```
(let ([x 37]                ; binds 37 to x
      [y (foo 42)])         ; binds the result of (foo 42) to y
  (if (< x y)
      (bar x)
      (bar y)))
```

`x` and `y` are only bound inside the body of the let expression

That is, the *scope* of the identifiers bound by `let` is `body`

# What happens when you want a binding in terms of an existing one?

When writing programs, it's not uncommon to define some local variables in terms of other local variables

```
(define (all-larger? lst)
  (let ([head (first lst)]
        [streamlined
     (filter (lambda (x) (> x head)) (rest lst))])
      (pair? streamlined)))
```

Given a list, is everything after the first element larger than the first element?

This doesn't work; we can't use `head` in the definition of `streamlined`

# The Fix? Sequential let

**`(let* ([id1 s-exp1] [id2 s-exp2]…) body)`**

Later s-exps can use earlier ids!

Example:

```
(let* ([x 5]
       [y (foo x)]
       [z (+ x y)])
  (bar z y))
```

# Environments

# How we know what `x` means?

Recall that when Racket evaluates a variable, the result is the value that the variable is bound to

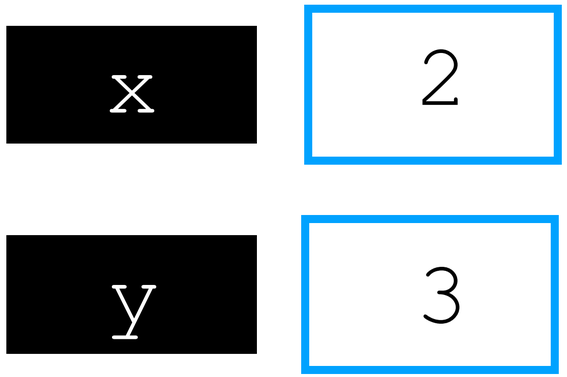
If we have `(define x 10)`, then evaluating `x` gives us the value `10`

If we have `(define (foo x) (- x y))`, then evaluating `foo` gives us the procedure `(lambda (x) (- x y))`, along with a way to get the value of `y` (which is hopefully defined!)

Racket needs a way to look up values that correspond to variables: an **environment**

# Environments: Examples

```
(let ([x 2]
      [y 3])
  (+ x y))
```



# When we execute the following, what is the result?

```
(let ([x 2]
      [y 3])
  (let ([x 4])
    (+ x y)))
```

A. 6

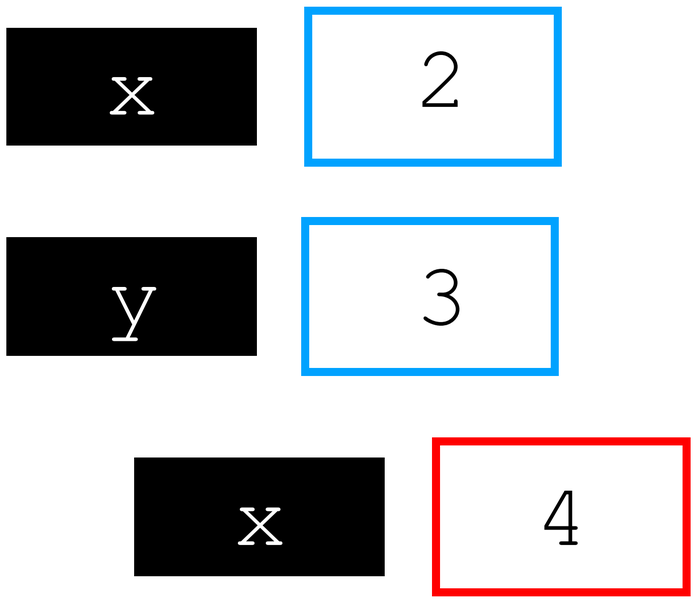
B. 9

C. 7

D. Something else

# Environments: Examples

```
(let ([x 2]
      [y 3])
  (let ([x 4])
    (+ x y)))
```



# When we execute the following, what is the result?

```
(let ([x 2]
      [y 3])
  (let ([f (lambda (x) (+ x y))])
    (f 5)))
```

A. 8

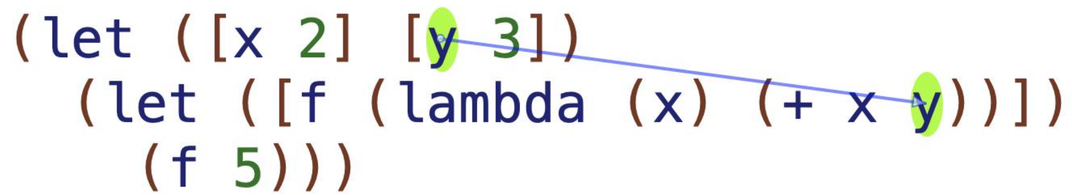
B. 7

C. 5

D. Something else

# DrRacket shows variable bindings

Mouse over an identifier in DrRacket

# Environment Operations

Two basic operations on environments:

1. **Look something up**
   - What is the binding of `x` right now?

2. **Add something to the environment**
   - Specifically, we'll do this by *extending* a previously known environment

# Look Up in Environments

The first is we need to look up the value bound to a symbol:

```
(let ([x 3])
  (let ([x 4])
    (+ x 5)))
```

should return 9 since the innermost binding of x is 4

# Extending Environments: Let

Consider

```
(let ([x (+ 3 4)]
      [y 5]
      [z (foo 8)])
  body)
```

We have three symbols `x`, `y`, and `z` and three values, 7, 5, and whatever the result of `(foo 8)` is, let's say it's 12

If `E` is the environment of the whole `let` expression, then the body should be evaluated in the environment

`E[x ↦ 7, y ↦ 5, z ↦ 12]`

# Reminder: closures

The expression of `(lambda parameters body…)` evaluates to a *closure* consisting of

- The parameter list (a list of identifiers)
- The body as un-evaluated expressions (often just one expression)
- The environment (the mapping of identifiers to values) **at the time the lambda expression is evaluated**

# Even More Let

# A realistic example

Let's write a procedure `(split-by pred lst)` that splits lst into two lists, the first contains all of the elements that match pred, the second contains all the elements that do not match pred

```
(split-by even? (range 10)) => '((0 2 4 6 8) (1 3 5 7 9))

(split-by (lambda (x) (< x 3)) (range 5)) =>
                    '((0 1 2) (3 4))
```

# Recursion

Often, we're going to want to define a recursive procedure in a `let`. For example,

```
(let ([fact (lambda (n)
              (if (<= n 1)
                  1
                  (* n (fact (sub1 n)))))])
  (fact 5))
```

Unfortunately, we can't use `fact` in the definition of `fact`

# Recursive let

**`(letrec ([id1 s-exp1] [id2 s-exp2]…) body)`**

*All* of the s-exps can refer to *all* of the ids

This is used to make recursive procedures

```
(letrec ([fact (lambda (n)
                 (if (<= n 1)
                     1
                     (* n (fact (sub1 n)))))])
  (fact 5))
```

# Can’t we just always use letrec then?

Nope, a subtle point: the values of the identifiers we're binding can't be used in the bindings

**Invalid** (the value of `x` is used to define `y`)

```
(letrec ([x 1]
         [y (+ x 1)])
  y)
```

**Valid** (the *value* of `x` isn't used to define `y`, it's only used when `y` is *called*)

```
(letrec ([x 1]
         [y (lambda () (+ x 1))])
  (y))
```

# Next Up

Weekly Reflections due at 11:59pm Tonight

HW1 due at 11:59pm Friday – first commit due **tonight**