PAUL G. ALLEN SCHOOL
OF COMPUTER SCIENCE & ENGINEERING

CSE341: Programming Languages

Section 6
What does mutation mean?
When do function bodies run?

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Set!

- Unlike ML, Racket really has assignment statements
  - But used *only-when-really-appropriate!*

```
(set! x e)
```

- For the **x** in the current environment, subsequent lookups of **x** get the result of evaluating expression **e**
  - Any code using this **x** will be affected
  - Like `x = e` in Java, C, Python, etc.

- Once you have side-effects, sequences are useful:

```
(begin e1 e2 … en)
```

Example

Example uses **`set!`** at top-level; mutating local variables is similar

```
(define b 3)
(define f (lambda (x) (* 1 (+ x b))))
(define c (+ b 4)) ; 7
(set! b 5)
(define z (f 4))   ; 9
(define w c)       ; 7
```

Not much new here:

- Environment for closure determined when function is defined, but body is evaluated when function is called
- Once an expression produces a value, it is irrelevant how the value was produced

The truth about **cons**

cons just makes a pair

- Often called a *cons cell*
- By convention and standard library, lists are nested pairs that eventually end with **null**

```
(define pr (cons 1 (cons #t "hi"))) ; '(1 #t . "hi")
(define lst (cons 1 (cons #t (cons "hi" null))))
(define hi (cdr (cdr pr)))
(define hi-again (car (cdr (cdr lst))))
(define hi-another (caddr lst))
(define no (list? pr))
(define yes (pair? pr))
(define of-course (and (list? lst) (pair? lst)))
```

Passing an *improper list* to functions like **length** is a run-time error

The truth about **cons**

So why allow improper lists?

- Pairs are useful
- Without static types, why distinguish **`(e1,e2)`** and **`e1::e2`**

Style:

- Use proper lists for collections of unknown size
- But feel free to use **`cons`** to build a pair
  - Though structs (like records) may be better

Built-in primitives:

- **`list?`** returns true for proper lists, including the empty list
- **`pair?`** returns true for things made by cons
  - All improper and proper lists except the empty list

cons cells are immutable

What if you wanted to mutate the *contents* of a cons cell?

- In Racket you cannot (major change from Scheme)
- This is good
  - List-aliasing irrelevant
  - Implementation can make **`list?`** fast since listness is determined when cons cell is created

Set! does not change list contents

This does *not* mutate the contents of a cons cell:

```
(define x (cons 14 null))
(define y x)
(set! x (cons 42 null))
(define fourteen (car y))
```

– Like Java's **`x = new Cons(42,null)`**, *not* **`x.car = 42`**

mcons cells are mutable

Since mutable pairs are sometimes useful (will use them soon), Racket provides them too:

- **`mcons`**
- **`mcar`**
- **`mcdr`**
- **`mpair?`**
- **`set-mcar!`**
- **`set-mcdr!`**

Run-time error to use **`mcar`** on a cons cell or **`car`** on an mcons cell

Delayed evaluation

For each language construct, the semantics specifies when subexpressions get evaluated. In ML, Racket, Java, C:

- Function arguments are *eager* (call-by-value)
  - Evaluated once before calling the function
- Conditional branches are not eager

It matters: calling **`factorial-bad`** never terminates:

```
(define (my-if-bad x y z)
  (if x y z))

(define (factorial-bad n)
  (my-if-bad (= n 0)
             1
             (* n (factorial-bad (- n 1)))))
```

Thunks delay

We know how to delay evaluation: put expression in a function!

– Thanks to closures, can use all the same variables later

A zero-argument function used to delay evaluation is called a *thunk*

– As a verb: *thunk the expression*

This works (but it is silly to wrap **`if`** like this):

```
(define (my-if x y z)
  (if x (y) (z)))

(define (fact n)
    (my-if (= n 0)
           (lambda() 1)
           (lambda() (* n (fact (- n 1))))))
```

The key point

- Evaluate an expression **e** to get a result:

```
e
```

- A function that *when called*, evaluates **e** and returns result
  - Zero-argument function for “thunking”

```
(lambda () e)
```

- Evaluate **e** to some thunk and then call the thunk

```
(e)
```

- Next: Powerful idioms related to delaying evaluation and/or avoided repeated or unnecessary computations
  - Some idioms also use mutation in encapsulated ways

Avoiding expensive computations

Thunks let you skip expensive computations if they are not needed

Great if take the true-branch:

```
(define (f th)
  (if (…) 0 (…  (th) …)))
```

But worse if you end up using the thunk more than once:

```
(define (f th)
  (… (if (…) 0 (… (th) …))
     (if (…) 0 (… (th) …))
     …
     (if (…) 0 (… (th) …))))
```

In general, might not know many times a result is needed

Best of both worlds

Assuming some expensive computation has no side effects, ideally we would:

- Not compute it *until needed*
- *Remember the answer* so future uses complete immediately

Called *lazy evaluation*

Languages where most constructs, including function arguments, work this way are *lazy languages*

- Haskell

Racket predefines support for *promises*, but we can make our own

- Thunks and mutable pairs are enough… [Friday]