

```
fun append (xs,ys) =  
  if xs=[]  
  then ys  
  else (hd xs)::append(tl xs,ys)  
  
fun map (f,xs) =  
  case xs of  
    [] => []  
  | x::xs' => (f x)::(map(f,xs'))  
  
val a = map (increment, [4,8,12,16])  
val b = map (hd, [[8,6],[7,5],[3,0,9]])
```

Programming Languages

Dan Grossman

Delayed Evaluation and Thunks

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