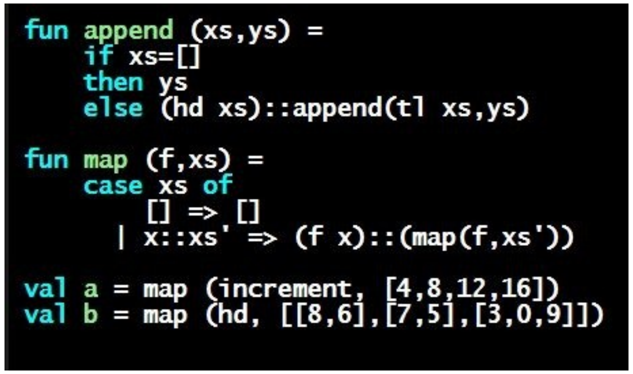

```
fun append (xs,ys) =
    if xs=[]
    then ys
    else (hd xs)::append(tl xs,ys)

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

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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