```
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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Implementing Closures

The best part

- The most interesting and mind-bending part of the homework is that the language being implemented has first-class closures
  - With lexical scope of course

- Fortunately, what you have to implement is what we have been stressing since we first learned about closures…

Higher-order functions

The "magic": How do we use the "right environment" for lexical scope when functions may return other functions, store them in data structures, etc.?

Lack of magic: The interpreter uses a closure data structure (with two parts) to keep the environment it will need to use later

```
(struct closure (env fun) #:transparent)
```

Evaluate a function expression:

- A function is *not* a value; a closure *is* a value
  - Evaluating a function returns a closure
- Create a closure out of (a) the function and (b) the current environment when the function was evaluated

Evaluate a function call:

- …

Function calls

(call e1 e2)

- Use current environment to evaluate **e1** to a closure
  - Error if result is a value that is not a closure
- Use current environment to evaluate **e2** to a value
- Evaluate closure's function's body in the closure's environment, extended to:
  - Map the function's argument-name to the argument-value
  - And for recursion, map the function's name to the whole closure

This is the same semantics we learned a few weeks ago "coded up"

Given a closure, the code part is *only* ever evaluated using the environment part (extended), *not* the environment at the call-site