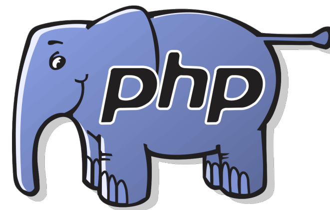
CS 360
Programming Languages
Day 8



Swift

JavaScript

Review

- A first-class citizen is a data type that can be
  - Passed as an argument to a function.
  - Returned as a value from a function.
  - Assigned to a variable.
  - (Stored in a data structure.)
  - (Created at run-time [dynamically, on-the-fly])
- First three are always part of the definition; last two sometimes.

Review

- Lambda expression: creates and returns an ***anonymous function***.

```
(lambda (arg1 arg2 ...) expression)
```

Term comes from the ***lambda calculus***.

- Developed by Alonzo Church.
- A formal way of studying the properties of computation, like Turing machines.

Review

- Higher order functions:
  - Take functions as arguments, or
  - Return functions.

- Map and filter both take functions as arguments.

  - Map: Applies a function to every (top-level) item within a list.

    ```
    (map func lst)
    ```

  - Filter: Takes a list L and a predicate P; returns a list of all the values in L that satisfy P.

    ```
    (filter pred lst)
    ```

Map examples

```
(define (map func lst)
  (if (null? lst) '()
      (cons (func (car lst)) (map func (cdr lst)))))

(define (double x) (* x 2))
(map double '(1 2 3)) => '(2 4 6)

(map (lambda (x) (* x 2)) '(1 2 3)) => '(2 4 6)

(map car '((1 2 3) (4 5) (6) (7 8 9))) => '(1 4 6 7)

(define (scale factor lst)
  (map (lambda (x) (* x factor)) lst)

(scale 2 '(1 2 3)) => '(2 4 6)
```

Map examples

```
(map (lambda (x) (+ x 1)) '(1 2 3)) => ?

(map (lambda (x) (cons x '()) '(1 2 3)) => ?

(map (lambda (x) (list x)) '(1 2 3)) => ?

(map (lambda (x)
       (if (> x 0) (* x 2) (* x 3))) '(1 -2 -3 4))
```

Key to using map with lambda expression: the argument to the lambda expression (x) represents each element of the list in turn.

Filter examples

```
(define (filter func lst)
  (cond ((null? lst) '()
        ((func (car lst))
          (cons (func (car lst)) (filter func (cdr lst))))
        (#t
          (filter func (cdr lst)))))

(filter odd? '(1 2 3)) => '(1 3)

(define (keep-odds lst)
  (filter odd? lst)

(filter (lambda (x) (> x 0)) '(-1 2 -3 4)) => '(2 4)
```

Filter examples

```
(filter (lambda (x) (= 1 (remainder x 2))) '(1 2 3)) => ?

(define (keep-divisible factor lst)
  (filter ______ lst))

(filter (lambda (lst) (even? (car lst)))
           '((1 2 3) (4 5) (6 7))) => ?

(filter (lambda (lst) (even? (car lst)))
           '((1 2 3) (4 5) (6 7) ())) => ?

(define (keep-longer-than n lst)
  (filter ______ lst))
```

STARK

- Recall that Racket has a **`expt`** function:
  - **`(expt x y)`** => x raised to the y power

- We can define a square function like this:

```
(define (square x) (expt x 2))
```

- Or a cube function like this:

```
(define (cube x) (expt x 3))
```

- But this gets rather repetitive.

- What if we wanted to create a lot of these "raise to a power" functions?

Functions that return functions!

```
(define (to-the-power exponent)
      (lambda (x) (expt x exponent)))
```

Functions that return functions!

```
(define (to-the-power exponent)
        (lambda (x) (expt x exponent)))
```

Define a function called to-the-power that takes a variable called exponent…

…that returns an anonymous function of a single variable x…

…that raises x to the power of the exponent variable.

How to use this

- Old way:
  - **`(define (square x) (expt x 2))`**
  - **`(define (cube x) (expt x 3))`**

- New way:
  - **`(define square (to-the-power 2))`**
  - **`(define cube (to-the-power 3))`**

- Notice that the new way doesn't use extra parentheses around the name of the function
  - Don't need 'em: what would we do with the argument?

Another example

- `(define (add3 num) (+ 3 num))`
- `(define (add17 num) (+ 17 num))`

- New way:

```
(define (create-add-function inc)
   (lambda (num) (+ inc num)))
(define add3 (create-add-function 3))
(define add17 (create-add-function 17))
```

Getting more complicated

- How about a function that takes functions as arguments and returns a new function?

```
• (define (compose f g)
     (lambda (x) (f (g x))))
• (define second (compose car cdr))
• (define third (compose car
                     (compose cdr cdr)))
• (map third '((2013 5 6) (2012 1 8)
                (2000 7 7)))
```

Transformations on functions

- Imagine you have a function that must take a non-empty list argument:

```
• (define (make-safe func)
    (lambda (lst)
      (if (or (not (list? lst))
              (null? lst))
          "No can do!"
          (func lst))))
```

More families of functions

```
(define (divisible n)
     (lambda (x) (= 0 (remainder x n))))

(define (make-quad-polynomial a b c)
    (lambda (x)
      (+ (* a x x) (* b x) c)))
```

A little syntax

- How to call a function:
  - **`(f e1 e2 e3…)`**
  - **`f`** is a function name and **`e1`**, **`e2`**… are expressions that will be evaluated and passed as the values of the arguments to f.

- Turns out **`f`** doesn't have to be a function name.

- **`f`** can be any expression that evaluates to a function!

A little syntax

- All of these evaluate to a function:
  - the name of a function (e.g., cons, car, +, …)
  - a lambda expression
  - a function call that returns a function

One more abstraction. Compare:

```
(define (length lst)
  (if (null? lst) 0
    (+ 1 (length (cdr lst)))))

(define (sum-list lst)
  (if (null? lst) 0
    (+ (car lst) (sum-list (cdr lst)))))

(define (map func lst)
  (if (null? lst) '()
    (cons (func (car lst)) (map func (cdr lst)))))
```

One more abstraction. Compare:

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(define (length lst)
  (if (null? lst) 0
    (+ 1 (length (cdr lst)))))

(define (sum-list lst)
  (if (null? lst) 0
    (+ (car lst) (sum-list (cdr lst)))))

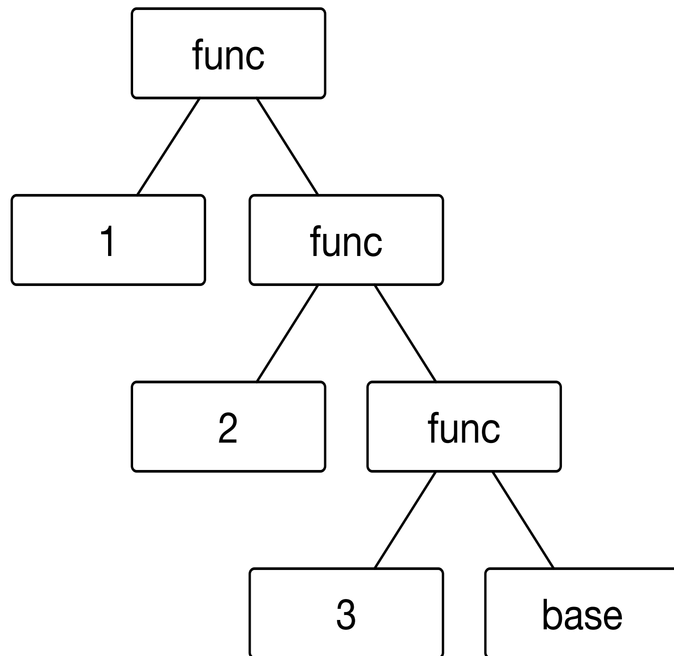
(define (map func lst)
  (if (null? lst) '()
    (cons (func (car lst)) (map func (cdr lst)))))
```

One function to rule them all

```
(define (foldr func base lst)
  (if (null? lst) base
    (func (car lst)
                 (foldr func base (cdr lst)))))
```

(foldr func base lst)

Say `lst = '(1 2 3)`



- **Foldr applies `func` repeatedly to pairs of items, starting from the right end of the list.**
- **The first two items are the last item in the list and the base element.**
- **The function must be a function of two items.**

`(f 1 (f 2 (f 3 base)))`

- **In general, for `lst = (x1 x2 … xn)`**
- **`(f x1 (f x2 (f x3 (f … (f xn base)))…)`**

```
(define (sum-list-new lst)
      (foldr + 0 lst))

(define (length-new lst)
  (foldr
    (lambda (elt cdr-len) (+ 1 cdr-len))
    0 lst))

(define (my-map func lst)
  (foldr
    (lambda (car cdr) (cons (func car) cdr))
    '() lst))
```