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csci54 – discrete math & functional programming  
lambdas and folds

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# Studying for the checkpoint (a week from today)

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- ▶ Checkpoint will be closed everything (including, for example, calculators) **except** you can have one double-sided 8.5"x11" page of notes and something to write with (pen, pencil).
- ▶ Suggestions for reviewing
  - ▶ Look over material
    - ▶ topics from lecture/problem sets; more detail in textbook
    - ▶ do problems on the material: worksheets, group assignments, problem set problems
  - ▶ Practice writing down solutions on paper in full
    - ▶ duplicate the feeling of seeing a completely new problem and having to write something down
    - ▶ come up with variations of problems you've seen (e.g. different problems or solving the same problem in different way)
- ▶ Will post study guide later today

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## practice problem from last time

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- ▶ The `mapish` function takes a list of functions and a single element `x`. It then returns a list of the results of applying each function to `x`.

```
ghci> mapish [(+1), (*3)] 10
[11, 30]
```

- ▶ Implement the `mapish` function. What is the type of the `mapish` function?

```
mapish :: [a->b] -> a -> [b]
mapish [] _ = []
mapish (f:fs) x = (f x) : (mapish fs x)
```

```
mapish' :: [(a->b)] -> a -> [b]
mapish' fs x = [f x | f <- fs]
```

use `mapish` to implement a function `f` that takes a number `x` and computes:

$$f1(x) = x^2 + 1$$

$$f2(x) = 4x - 10$$

# lambdas (aka anonymous functions)

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- ▶ functions that don't have names
- ▶ functions that you use once in the context of some other function

```
ghci> headA x = (head x) == 'a'  
ghci> filter headA ["ab", "aaaaa", "b"]
```

```
ghci> filter (\y -> (head y) == 'a') ["ab", "aaaaa", "b"]
```

- ▶ syntax: `\a b -> (a * b + 10)`

starts with `\` (meant to resemble  $\lambda$ ).

- ▶ `->` separates parameters from what the function evaluates to
- 



## lambdas (aka anonymous functions)

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- ▶ note that if we wanted a function `headA` such that it would take out the elements that started with the character 'A', we could define it as follows:

```
ghci> headA = filter (\y -> (head y) == 'A')
```

- ▶ practice: what is the type of the function `foo`? what does it do?

```
foo y zs = map (\x -> x^y) zs
```



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# One more built-in higher order function

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- ▶ map, filter, reduce
- ▶ How would you write a function `sumList` that returned the sum of a list of integers? `prodList` the returned the product of a list of integers?

```
sumList [] = 0
sumList (x:xs) = x + (sumList xs)
```

```
prodList [] = 1
prodList (x:xs) = x * (prodList xs)
```

- ▶ what is similar?
- ▶ what is different?
- ▶ in Haskell "reduce" is referred to as "fold"



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```
foldr' :: (b -> b -> b) -> b -> [b] -> b
```



## Right fold (foldr)

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```
foldr' :: (b -> b -> b) -> b -> [b] -> b
```

- ▶ `foldr (+) 0 [3,2,6]`
  - ▶ very, very informally can think:
    - ▶ `[3,2,6]` is really `3:2:6:[]`.
    - ▶ Replace `[]` with the base case `0` (sometimes called “seed” value)
    - ▶ Replace `:` with the operator `(+)`
  - ▶ associate to the right
  - ▶ `3 + (2 + (6 + 0))`
- ▶ how would you write `sumList` and `prodList` using `foldr`?



# foldr and foldl

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```
foldr' :: (b -> b -> b) -> b -> [b] -> b
```

- ▶ `foldr (+) 0 [3,2,6]`
  - ▶ informally can think of as: `[3,2,6]` is really `3:2:6:[]`. Replace `[]` with the base case and the `:` with the operator
  - ▶ associate to the right
  - ▶ `3 + (2 + (6 + 0))`
- ▶ `foldl` - same idea but associates to the left



## foldr and foldl

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`foldr' :: (a -> a -> a) -> a -> [a] -> a`

▶ `foldr f x [y1, y2, ... yk] = f y1 (f y2 (... (f yk x) ... ))`

`foldl' :: (a -> a -> a) -> a -> [a] -> a`

▶ `foldl f x [y1, y2, ... yk] = f (... (f (f x y1) y2) ... ) yk`

▶ `foldr (+) 0 [3,2,6]`

▶ `foldl (+) 0 [3,2,6]`



## practice with folds

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```
foldr f x [y1, y2, ... yk] = f y1 (f y2 (... (f yk x) ... ))
```

```
foldl f x [y1, y2, ... yk] = f (... (f (f x y1) y2) ...) yk
```

- ▶ The following evaluate to two different values:
  - ▶ `foldr (^) 1 [2,3]`
  - ▶ `foldl (^) 1 [2,3]`
- ▶ What do they evaluate to and why?



## and a hint of something more . . .

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- ▶ `foldr f x [y1, y2, ... yk] = f y1 (f y2 (... (f yk x) ... ))`
- ▶ what does the following do?

```
foldr (\_ s -> 1 + s) 0 "abcde"
```

- ▶ what does this tell you about the type signature?

```
foldr' :: (a -> b -> b) -> b -> [a] -> b
```

- ▶ (but really it's this:

```
foldr :: Foldable t => (a -> b -> b) -> b -> t a -> b  
)
```

