Bottling Computation Patterns

Polymorphism and HOFs are the Secret Sauce

Refactor arbitrary *repeated* code patterns ...

... into precisely *specified* and *reusable* **functions**

```
List a = Nil
        | Cons a (List a)
```

```
doTwice f x = f (f x)
```

EXERCISE: Iteration

Write a function that *squares* a list of `Int`

```
squares :: [Int] -> [Int]
squares ns = ???
```

When you are done you should see

```
>>> squares [1,2,3,4,5]
[1,4,9,16,25]
```

Pattern: Iteration

Next, lets write a function that converts a `String` to uppercase.

```
>>> shout "hello"
"HELLO"
```

Recall that in Haskell, a `String` is just a `[Char]`.

```
shout :: [Char] -> [Char]
shout = ???
```

Hoogle (http://haskell.org/hoogle) to see how to transform an individual `Char`

Iteration

Common strategy: *iteratively* transform *each element* of input list

Like humans and monkeys, `shout` and `squares` share 93% of their DNA (http://www.livescience.com/health/070412_rhesus_monkeys.html)

Super common *computation pattern*!

Abstract Iteration "Pattern" into Function

Remember D.R.Y. (Don't repeat yourself)

Step 1 Rename all variables to remove accidental *differences*

```
-- rename 'squares' to 'foo'
foo []     = []
foo (x:xs) = (x * x)     : foo xs

-- rename 'shout' to 'foo'
foo []     = []
foo (x:xs) = (toUpper x) : foo xs
```

Step 2 Identify what is *different*

- In `squares` we *transform* `x` to `x * x`
- In `shout` we *transform* `x` to `Data.Char.toUpper x`

Step 3 Make *differences* a parameter

- Make *transform* a parameter `f`

```
foo f []     = []
foo f (x:xs) = (f x) : foo f xs
```

Done We have *bottled* the computation pattern as `foo` (aka `map`)

```
map f []     = []
map f (x:xs) = (f x) : map f xs
```

`map` bottles the common pattern of iteratively transforming a list:

Fairy In a Bottle

QUIZ

What is the type of `map` ?

```
map :: ???
map f []     = []
map f (x:xs) = (f x) : map f xs
```

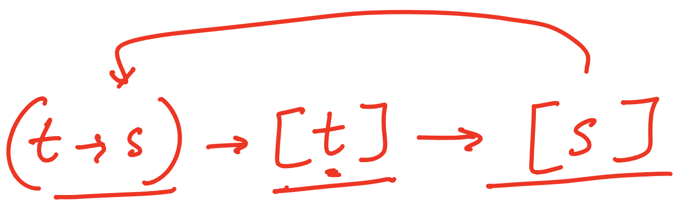
A. `(Int -> Int) -> [Int] -> [Int]`

B. `(a -> a) -> [a] -> [a]`

C. `[a] -> [b]`

D. `(a -> b) -> [a] -> [b]`

E. `(a -> b) -> [a] -> [a]`



The type precisely describes `map`

```
>>> :type map
map :: (a -> b) -> [a] -> [b]
```

That is, `map` takes two inputs

- a *transformer* of type `a -> b`
- a *list* of values `[a]`

and it returns as output

- a list of values `[b]`

that can only come by applying `f` to each element of the input list.

Reusing the Pattern

Lets reuse the pattern by *instantiating* the transformer

shout

```
-- OLD with recursion
shout :: [Char] -> [Char]
shout []     = []
shout (x:xs) = Char.toUpper x : shout xs

-- NEW with map
shout :: [Char] -> [Char]
shout xs = map (???) xs
```

squares

```haskell
-- OLD with recursion
squares :: [Int] -> [Int]
squares []     = []
squares (x:xs) = (x * x) : squares xs

-- NEW with map
squares :: [Int] -> [Int]
squares xs = map (???) xs
```

EXERCISE

Suppose I have the following type

```haskell
type Score = (Int, Int) -- pair of scores for Hw0, Hw1
```

Use `map` to write a function

```
total :: [Score] -> [Int]
total xs = map (???) xs
```

such that

```
>>> total [(10, 20), (15, 5), (21, 22), (14, 16)]
[30, 20, 43, 30]
```

The Case of the Missing Parameter

Note that we can write `shout` like this

```
shout :: [Char] -> [Char]
shout = map Char.toUpper
```

Huh. No parameters? Can someone explain?

The Case of the Missing Parameter

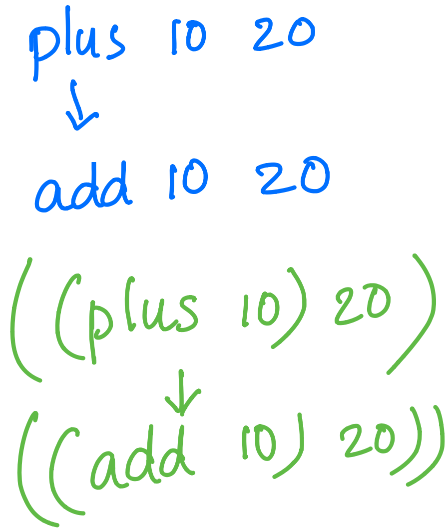
In Haskell, the following all mean the same thing

Suppose we define a function

```haskell
add :: Int -> Int -> Int
add x y = x + y
```

Now the following all *mean the same thing*

```haskell
plus x y = add x y
plus x   = add x
plus     = add
```



Why? *equational reasoning!* In general

```haskell
foo x = e x

-- is equivalent to

foo   = e
```

as long as `x` doesn't appear in `e`.

Thus, to save some typing, we *omit* the extra parameter.

Pattern: Reduction

Computation patterns are *everywhere* lets revisit our old `sumList`

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

Next, a function that *concatenates* the `String` s in a list

```
catList :: [String] -> String
catList []     = ""
catList (x:xs) = x ++ (catList xs)
```

Lets spot the pattern!

Step 1 Rename

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

(A)

```
foo []     = ""
foo (x:xs) = x ++ foo xs
```

(B)

Step 2 Identify what is *different*

1. ??? 0 vs ""
2. ??? + vs ++

Step 3 Make *differences* a parameter

```
foo p1 p2 []     = ???
foo p1 p2 (x:xs) = ???
```