FizzBuzz In Haskell

Owen Lynch

April 25th 2018

Introducing Haskell

```haskell
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

Equivalent python code:

```python
def fact(n):
  if n == 0:
    return 1
  else:
    return n*(fact(n-1))
```

Introducing Haskell

```haskell
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

Equivalent python code:

```python
def fact(n):
  if n == 0:
    return 1
  else:
    return n*(fact(n-1))
```

Notable Features

Introducing Haskell

```haskell
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

Equivalent python code:

```python
def fact(n):
  if n == 0:
    return 1
  else:
    return n*(fact(n-1))
```

Notable Features

- Types

Introducing Haskell

```haskell
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

Equivalent python code:

```python
def fact(n):
  if n == 0:
    return 1
  else:
    return n*(fact(n-1))
```

Notable Features

- Types
- Pattern Matching

The Anatomy of a Haskell Definition

Type Signature

```
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

The Anatomy of a Haskell Definition

Name

```
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

The Anatomy of a Haskell Definition

Type

```
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

The Anatomy of a Haskell Definition

Definition

```
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

The Anatomy of a Haskell Definition

Argument

```
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

The Anatomy of a Haskell Definition

Value

```
fact :: Int -> Int
fact 0 = 1
fact n = n * fact (n-1)
```

Myths about Haskell

- Haskell is hard

Myths about Haskell

- Haskell is hard
  - *Learning* Haskell is hard, *programming* Haskell is easy!

Myths about Haskell

- Haskell is hard
  - *Learning* Haskell is hard, *programming* Haskell is easy!
  - Haskell lets you choose the level of abstraction that you are comfortable with, and you can slowly increase this while being productive the whole time

Myths about Haskell

- Haskell is hard
  - *Learning* Haskell is hard, *programming* Haskell is easy!
  - Haskell lets you choose the level of abstraction that you are comfortable with, and you can slowly increase this while being productive the whole time
- Haskell is for techbro superprogrammers

Myths about Haskell

- Haskell is hard
  - *Learning* Haskell is hard, *programming* Haskell is easy!
  - Haskell lets you choose the level of abstraction that you are comfortable with, and you can slowly increase this while being productive the whole time
- Haskell is for techbro superprogrammers
  - Haskell is for people who can't keep lots of stuff in their head at once and want the compiler to make sure they aren't messing things up

Myths about Haskell

- Haskell is hard
  - *Learning* Haskell is hard, *programming* Haskell is easy!
  - Haskell lets you choose the level of abstraction that you are comfortable with, and you can slowly increase this while being productive the whole time
- Haskell is for techbro superprogrammers
  - Haskell is for people who can't keep lots of stuff in their head at once and want the compiler to make sure they aren't messing things up
  - The Haskell community is one of the nicest and friendliest online communities I've been a part of, in part because there is so much to learn that everyone is comparatively a noob

Myths about Haskell

- Haskell is hard
  - *Learning* Haskell is hard, *programming* Haskell is easy!
  - Haskell lets you choose the level of abstraction that you are comfortable with, and you can slowly increase this while being productive the whole time
- Haskell is for techbro superprogrammers
  - Haskell is for people who can't keep lots of stuff in their head at once and want the compiler to make sure they aren't messing things up
  - The Haskell community is one of the nicest and friendliest online communities I've been a part of, in part because there is so much to learn that everyone is comparatively a noob
- Haskell is for academic ivory-towerists who do too much category theory for their own good

Myths about Haskell

- Haskell is hard
  - *Learning* Haskell is hard, *programming* Haskell is easy!
  - Haskell lets you choose the level of abstraction that you are comfortable with, and you can slowly increase this while being productive the whole time
- Haskell is for techbro superprogrammers
  - Haskell is for people who can't keep lots of stuff in their head at once and want the compiler to make sure they aren't messing things up
  - The Haskell community is one of the nicest and friendliest online communities I've been a part of, in part because there is so much to learn that everyone is comparatively a noob
- Haskell is for academic ivory-towerists who do too much category theory for their own good
  - Haskell is actually a very practical language for all sorts of tasks, and it has been battletested in industry for decades

However...

- In this talk we will not be doing anything practical.

However...

- In this talk we will not be doing anything practical.
- This is a silly tour of some neat features in Haskell.

However...

- In this talk we will not be doing anything practical.
- This is a silly tour of some neat features in Haskell.
- I am not expecting all of this talk to make sense to you right away.

However...

- In this talk we will not be doing anything practical.
- This is a silly tour of some neat features in Haskell.
- I am not expecting all of this talk to make sense to you right away.
- When you see something you don't understand, don't think "Agghhh Haskell is way to hard", think "Cool, I have something to figure out!"

Introducing FizzBuzz

- Make a list of the numbers from 1 to 100, except...

Introducing FizzBuzz

- Make a list of the numbers from 1 to 100, except...
  - For every number divisible by 3, put “Fizz” instead

Introducing FizzBuzz

- Make a list of the numbers from 1 to 100, except...
  - For every number divisible by 3, put “Fizz” instead
  - For every number divisible by 5, put “Buzz” instead

Introducing FizzBuzz

- Make a list of the numbers from 1 to 100, except...
  - For every number divisible by 3, put "Fizz" instead
  - For every number divisible by 5, put "Buzz" instead
  - For every number divisible by 5 and 3, put "FizzBuzz" instead

Introducing FizzBuzz

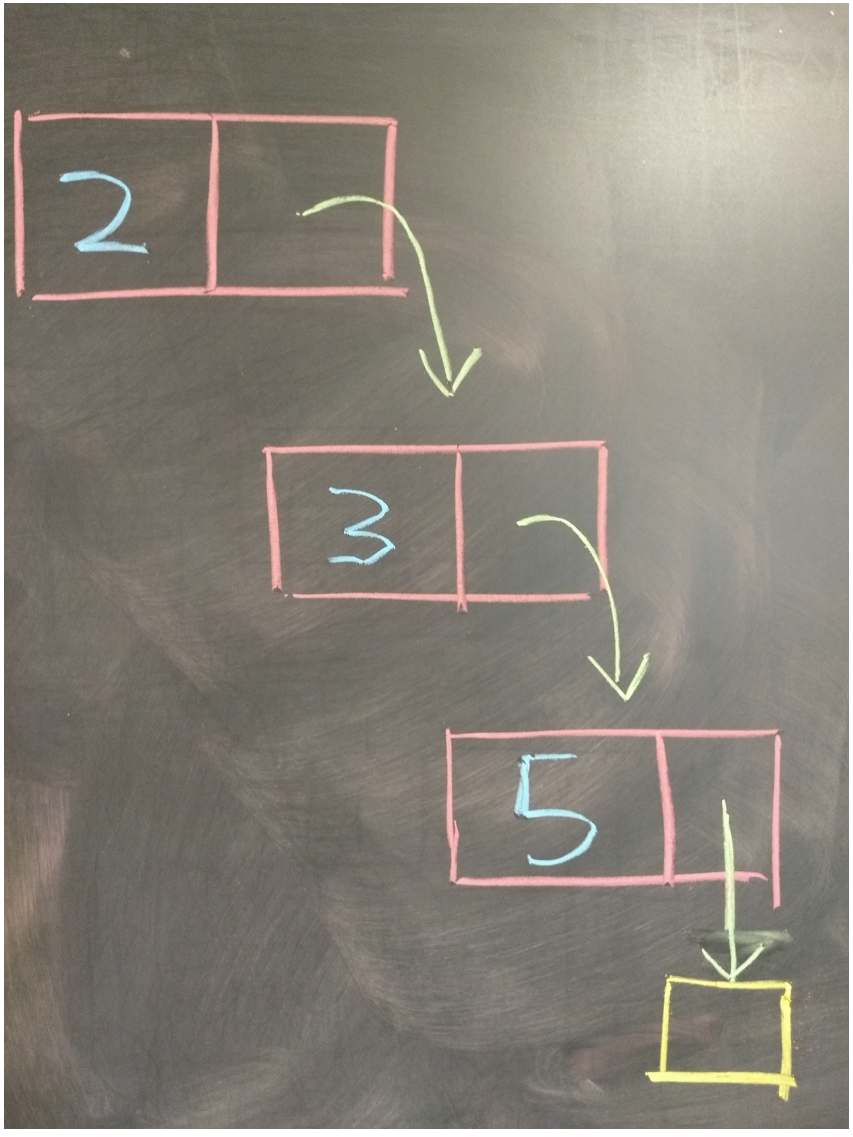
- Make a list of the numbers from 1 to 100, except...
  - For every number divisible by 3, put "Fizz" instead
  - For every number divisible by 5, put "Buzz" instead
  - For every number divisible by 5 and 3, put "FizzBuzz" instead
- How would you solve FizzBuzz?

Lists

How can we make a list until we know what a list *is*??

Lists

How can we make a list until we know what a list *is*??



Lists in Python

```
class ConsCell:
  def __init__(head, tail)
    self.head = head
    self.tail = tail

class EmptyList:
  def __init__():
    return

oneTwo = ConsCell(1, ConsCell(2, EmptyList))
```

Lists in Haskell

```haskell
data [a] = [] | a : [a]
-- data List a = Empty | Cons a (List a)
-- (:) x xs == x : xs
-- ([]) a = [a]

firstFourPrimes :: [Int]
firstFourPrimes = 2:(3:(5:(7:[])))

type String = [Char]
-- "abc" = 'a':('b':('c':[]))

everyFlavoredBeanFlavors :: [String]
everyFlavoredBeanFlavors =
  ["earwax", "marmalade", "spinach"]
```

How do we work with it?

Recursion!

Our first step is generating all of the numbers from 1 to 100.

```
range :: Int -> Int -> [Int]
range n m
  | n == m     = [n]
  | otherwise = n:(range (n+1) m)
-- range n m == [n..m]
```

How do we work with it?

Recursion!

Our first step is generating all of the numbers from 1 to 100.

```
range :: Int -> Int -> [Int]
range n m
  | n == m     = [n]
  | otherwise = n:(range (n+1) m)
-- range n m == [n..m]
```

- New stuff:

How do we work with it?

Recursion!

Our first step is generating all of the numbers from 1 to 100.

```
range :: Int -> Int -> [Int]
range n m
  | n == m     = [n]
  | otherwise = n:(range (n+1) m)
-- range n m == [n..m]
```

- New stuff:
  - Currying

How do we work with it?

Recursion!

Our first step is generating all of the numbers from 1 to 100.

```
range :: Int -> Int -> [Int]
range n m
  | n == m     = [n]
  | otherwise = n:(range (n+1) m)
-- range n m == [n..m]
```

- New stuff:
  - Currying
  - Guard Notation

List Transformations

Now, we need to do something to each of those numbers.

```
map :: (a -> b) -> [a] -> [b]
map f [] = []
map f (x:xs) = (f x):(map f xs)
```

List Transformations

Now, we need to do something to each of those numbers.

```
map :: (a -> b) -> [a] -> [b]
map f [] = []
map f (x:xs) = (f x):(map f xs)
```

- New stuff:

List Transformations

Now, we need to do something to each of those numbers.

```
map :: (a -> b) -> [a] -> [b]
map f [] = []
map f (x:xs) = (f x):(map f xs)
```

- New stuff:
  - Functions applied to functions!

The first solution

```haskell
fizzbuzz1 :: Int -> String
fizzbuzz1 n
  | rem n 15 == 0 = "FizzBuzz"
  | rem n  5 == 0 = "Buzz"
  | rem n  3 == 0 = "Fizz"
  | otherwise     = show n

sol1 :: [String]
sol1 = map fizzbuzz1 [1..100]
```

Discuss first solution

- What did we like?

Discuss first solution

- What did we like?
  - Recursion!

Discuss first solution

- What did we like?
  - Recursion!
  - Combinators that allowed us to not do recursion!

Discuss first solution

- What did we like?
  - Recursion!
  - Combinators that allowed us to not do recursion!
  - Case syntax!

Discuss first solution

- What did we like?
  - Recursion!
  - Combinators that allowed us to not do recursion!
  - Case syntax!
- What did we not like?

Discuss first solution

- What did we like?
  - Recursion!
  - Combinators that allowed us to not do recursion!
  - Case syntax!
- What did we not like?
  - Not extensible enough! (What about Bazz??)

FizzBuzzBazz

```
fizzbuzzbazz1 :: Int -> String
fizzbuzzbazz1 n
  | rem n 105 == 0 = "FizzBuzzBazz"
  | rem n  35 == 0 = "BuzzBazz"
  | rem n  21 == 0 = "FizzBazz"
  | rem n  15 == 0 = "FizzBuzz"
  | rem n   7 == 0 = "Bazz"
  | rem n   5 == 0 = "Buzz"
  | rem n   3 == 0 = "Fizz"
  | otherwise      = show n
```

FizzBuzzBazz

```
fizzbuzzbazz1 :: Int -> String
fizzbuzzbazz1 n
  | rem n 105 == 0 = "FizzBuzzBazz"
  | rem n  35 == 0 = "BuzzBazz"
  | rem n  21 == 0 = "FizzBazz"
  | rem n  15 == 0 = "FizzBuzz"
  | rem n   7 == 0 = "Bazz"
  | rem n   5 == 0 = "Buzz"
  | rem n   3 == 0 = "Fizz"
  | otherwise      = show n
```

This is terrible!

How should we solve this?

- First of all, let's make it generic over the descriptions

How should we solve this?

- First of all, let's make it generic over the descriptions

How should we solve this?

- First of all, let's make it generic over the descriptions

```
fizzbuzz2 :: [(Int, String)] -> Int -> String
```

How should we solve this?

- First of all, let's make it generic over the descriptions

```
fizzbuzz2 :: [(Int, String)] -> Int -> String
```

- Now, what are going to do with each `(Int,String)`?

How should we solve this?

- First of all, let's make it generic over the descriptions

```
fizzbuzz2 :: [(Int, String)] -> Int -> String
```

- Now, what are going to do with each `(Int,String)`?

How should we solve this?

- First of all, let's make it generic over the descriptions

```
fizzbuzz2 :: [(Int, String)] -> Int -> String
```

- Now, what are going to do with each `(Int,String)`?

```
data NumberDescription = Description String | NoComment

describe :: Int -> (Int, String) -> NumberDescription
describe n (k, s)
  | rem n k == 0 = Description s
  | otherwise    = NoComment

fizzbuzz2 conds n =
  <something> (map (\c -> describe n c) conds)
```

How do we compose number descriptions?

- We need to be able to compose different number descriptions.

How do we compose number descriptions?

- We need to be able to compose different number descriptions.
- What does compose mean? (Think and talk about it)

How do we compose number descriptions?

- We need to be able to compose different number descriptions.
- What does compose mean? (Think and talk about it)

How do we compose number descriptions?

- We need to be able to compose different number descriptions.
- What does compose mean? (Think and talk about it)

```
compose :: [NumberDescription] -> NumberDescription
compose [] = NoComment
compose (NoComment:rest) = rest
compose ((Description s):rest) = case compose rest of
  NoComment -> NumberDescription s
  NumberDescription s' -> NumberDescription (s ++ s')

(++) :: [a] -> [a] -> [a]
[] ++ ys = ys
(x:xs) ++ ys = x:(xs ++ ys)
```

A slight problem

We end up with a NumberDescription and we want a string

A slight problem

We end up with a NumberDescription and we want a string

```
withDefault :: Int -> NumberDescription -> String
withDefault n NoComment = show n
withDefault n (Description s) = s

fizzbuzz2 conds n = withDefault n
  (compose (map (\c -> describe n c) conds))
```

The Long March of refactoring

Currying

The Long March of refactoring

Currying

```
describe :: Int -> (Int, String) -> NumberDescription
(\c -> describe n c) :: (Int, String) -> NumberDescription
describe n :: (Int, String) -> NumberDescription

fizzbuzz2 conds n = withDefault n
  (compose (map (describe n) conds))
```

Maybe types

```haskell
data Maybe a = Just a | Nothing

compose :: [Maybe a] -> Maybe a
compose [] = Nothing
compsoe (Nothing:rest) = compose rest
compose ((Just x):rest) = case compose rest of
  Nothing -> Just x
  Just y -> ??????????
```

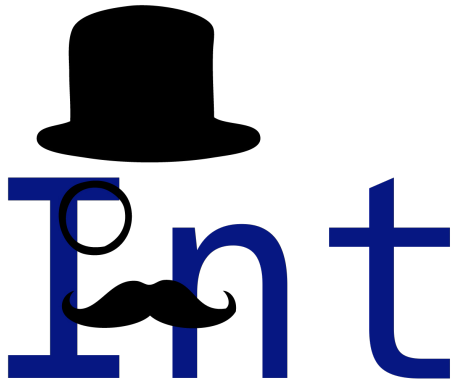
Maybe types

```haskell
data Maybe a = Just a | Nothing

compose :: [Maybe a] -> Maybe a
compose [] = Nothing
compsoe (Nothing:rest) = compose rest
compose ((Just x):rest) = case compose rest of
  Nothing -> Just x
  Just y -> ??????????
```

We need to compose x and y! When they are strings, this is fine, but what if they are something else?

TypeClasses: Types with Class




```
class Composable a where
  compose :: [a] -> a

instance (Composable a) => Composable (Maybe a) where
  compose [] = Nothing
  compose ((Just x):rest) = case compose rest of
    Nothing -> Just x
    Just y -> Just (compose [x,y])
```

Waste not Want not

To write compose, we only really need two things

- Something to return in the empty list case

Waste not Want not

To write compose, we only really need two things

- Something to return in the empty list case
- A way of composing *two* elements

Waste not Want not

To write compose, we only really need two things

- Something to return in the empty list case
- A way of composing *two* elements

Waste not Want not

To write compose, we only really need two things

- Something to return in the empty list case
- A way of composing *two* elements

In math this is called a Monoid, because it sounds cool that's why

Waste not Want not

To write compose, we only really need two things

- Something to return in the empty list case
- A way of composing *two* elements

In math this is called a Monoid, because it sounds cool that's why

```
class Monoid a where
  mempty :: a
  (<>) :: a -> a -> a

mconcat :: (Monoid a) => [a] -> a
mconcat [] = mempty
mconcat (x:xs) = x <> (mconcat xs)
```

Well-behavedness

We want:

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

We can get this property if we require that

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

We can get this property if we require that

- `mempty <> x == x == x <> mempty`

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

We can get this property if we require that

- `mempty <> x == x == x <> mempty`
  - this is because `[] ++ xs == xs == xs ++ []`

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

We can get this property if we require that

- `mempty <> x == x == x <> mempty`
  - this is because `[] ++ xs == xs == xs ++ []`
  - This is called the "Identity Law"

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

We can get this property if we require that

- `mempty <> x == x == x <> mempty`
  - this is because `[] ++ xs == xs == xs ++ []`
  - This is called the "Identity Law"
- `x <> (y <> z) == (x <> y) <> z`

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

We can get this property if we require that

- `mempty <> x == x == x <> mempty`
  - this is because `[] ++ xs == xs == xs ++ []`
  - This is called the "Identity Law"
- `x <> (y <> z) == (x <> y) <> z`
  - this is because `[a,b] ++ [c] == [a] ++ [b,c]`

Well-behavedness

We want:

- `mconcat (xs ++ ys) == (mconcat xs) <> (mconcat ys)`

We can get this property if we require that

- `mempty <> x == x == x <> mempty`
  - this is because `[] ++ xs == xs == xs ++ []`
  - This is called the "Identity Law"
- `x <> (y <> z) == (x <> y) <> z`
  - this is because `[a,b] ++ [c] == [a] ++ [b,c]`
  - This is called the "Associativity Law"

Monoid Hype

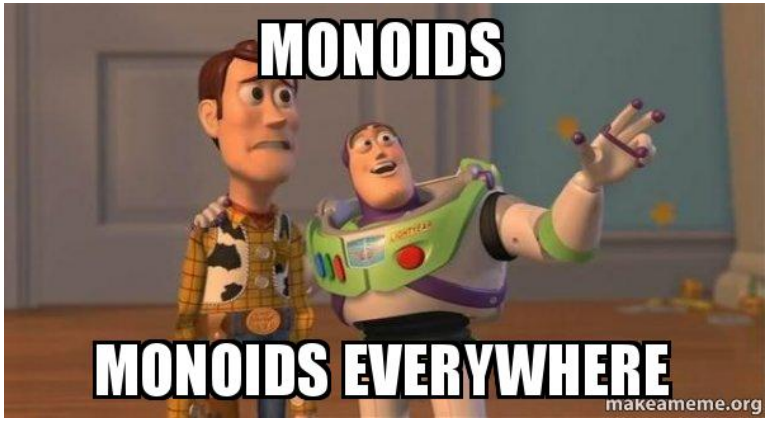
"Monoids are ubiquitous throughout programming. The difference is that in Haskell we recognize and talk about them."

– Real World Haskell

Monoid Hype

"Monoids are ubiquitous throughout programming. The difference is that in Haskell we recognize and talk about them."

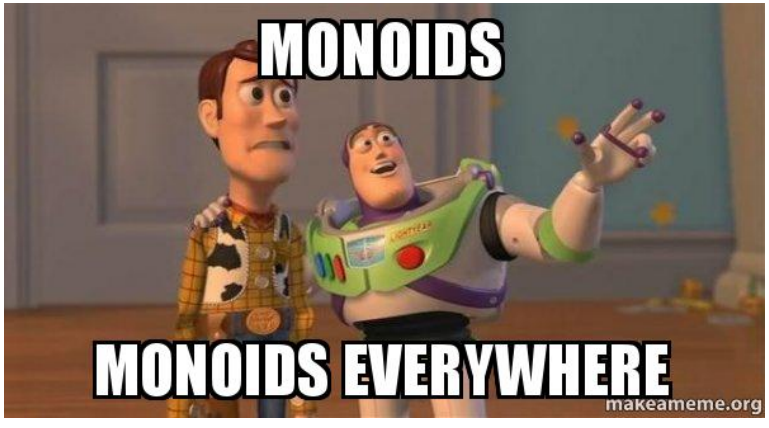
– Real World Haskell



Monoid Hype

"Monoids are ubiquitous throughout programming. The difference is that in Haskell we recognize and talk about them."

– Real World Haskell



Monoid Mary
@argumatronic

A lways
B e
C onsidering monoids

You already know lots of monoids!

Take a couple minutes and think of monoids

You already know lots of monoids!

Take a couple minutes and think of monoids

- Strings or lists with concatenation

You already know lots of monoids!

Take a couple minutes and think of monoids

- Strings or lists with concatenation
- Bytes with `AND` and `11111111`

You already know lots of monoids!

Take a couple minutes and think of monoids

- Strings or lists with concatenation
- Bytes with `AND` and `11111111`
- Bytes with `OR` and `00000000`

You already know lots of monoids!

Take a couple minutes and think of monoids

- Strings or lists with concatenation
- Bytes with `AND` and `11111111`
- Bytes with `OR` and `00000000`
- Functions `f :: a -> a` along with composition and the identity function

You already know lots of monoids!

Take a couple minutes and think of monoids

- Strings or lists with concatenation
- Bytes with `AND` and `11111111`
- Bytes with `OR` and `00000000`
- Functions `f :: a -> a` along with composition and the identity function
- Any type of number ($\mathbb{N}$, $\mathbb{Z}$, $\mathbb{Q}$, $\mathbb{R}$, $\mathbb{C}$) along with addition

You already know lots of monoids!

Take a couple minutes and think of monoids

- Strings or lists with concatenation
- Bytes with `AND` and `11111111`
- Bytes with `OR` and `00000000`
- Functions `f :: a -> a` along with composition and the identity function
- Any type of number ($\mathbb{N}$, $\mathbb{Z}$, $\mathbb{Q}$, $\mathbb{R}$, $\mathbb{C}$) along with addition
- Any type of number along with multiplication

You already know lots of monoids!

Take a couple minutes and think of monoids

- Strings or lists with concatenation
- Bytes with `AND` and `11111111`
- Bytes with `OR` and `00000000`
- Functions `f :: a -> a` along with composition and the identity function
- Any type of number ($\mathbb{N}$, $\mathbb{Z}$, $\mathbb{Q}$, $\mathbb{R}$, $\mathbb{C}$) along with addition
- Any type of number along with multiplication
- Any ordered set along with max and a "negative infinity" element as identity

You already know lots of monoids!

Take a couple minutes and think of monoids

- Strings or lists with concatenation
- Bytes with `AND` and `11111111`
- Bytes with `OR` and `00000000`
- Functions `f :: a -> a` along with composition and the identity function
- Any type of number ($\mathbb{N}$, $\mathbb{Z}$, $\mathbb{Q}$, $\mathbb{R}$, $\mathbb{C}$) along with addition
- Any type of number along with multiplication
- Any ordered set along with max and a "negative infinity" element as identity
- Any ordered set along with min and a "positive infinity" element as identity

Back to FizzBuzz...

```haskell
instance Monoid [a] where
  mempty = []
  (<>) = (++)

instance (Monoid a) => Monoid (Maybe a) where
  mempty = Nothing
  Nothing <> Nothing = Nothing
  (Just a) <> Nothing = Just a
  Nothing <> (Just b) = Just b
  (Just a) <> (Just b) = Just (a <> b)
```

FizzBuzz Refactored

```haskell
fromMaybe :: a -> Maybe a -> a
fromMaybe def Nothing = def
fromMaybe _ (Just y) = y

describe :: Int -> (Int, String) -> Maybe String
describe n (k, s)
  | rem n k == 0 = Just s
  | otherwise = Nothing

fizzbuzz2 :: [(Int, String)] -> Int -> String
fizzbuzz2 conds n
  = fromMaybe (show n) (mconcat (map (describe n) conds))

sol2 :: [String]
sol2 = map (fizzbuzz2 conds) [1..100]
  where conds = [(3, "Fizz"), (5, "Buzz")]
```

Reflections on take 2

- What do we like?

Reflections on take 2

- What do we like?
  - Monoids!

Reflections on take 2

- What do we like?
  - Monoids!
  - Currying!

Reflections on take 2

- What do we like?
  - Monoids!
  - Currying!
  - Much more extensible!

Reflections on take 2

- What do we like?
  - Monoids!
  - Currying!
  - Much more extensible!
- What do we not like?

Reflections on take 2

- What do we like?
  - Monoids!
  - Currying!
  - Much more extensible!
- What do we not like?
  - Still not extensible enough!

FizzBuzz: Hard Mode

- FizzBuzz, but...

FizzBuzz: Hard Mode

- FizzBuzz, but...
  - For every prime number, put “Buzz” instead

FizzBuzz: Hard Mode

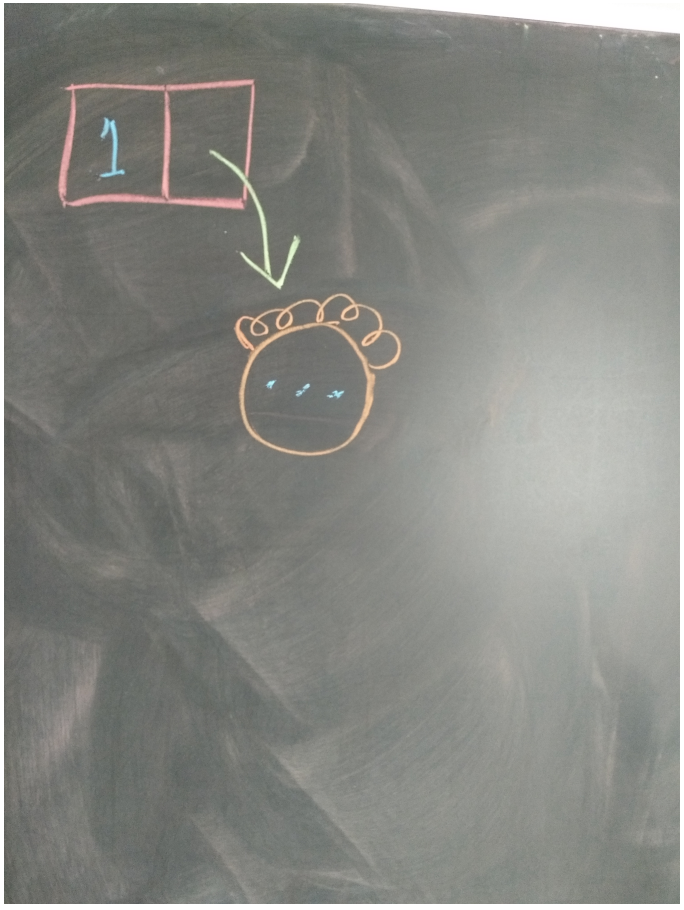
- FizzBuzz, but...
  - For every prime number, put “Buzz” instead
  - For every fibonacci number, put “Fizz” instead

FizzBuzz: Hard Mode

- FizzBuzz, but...
  - For every prime number, put "Buzz" instead
  - For every fibonacci number, put "Fizz" instead
  - For every number that is a fibonacci number and a prime number, put "FizzBuzz" instead

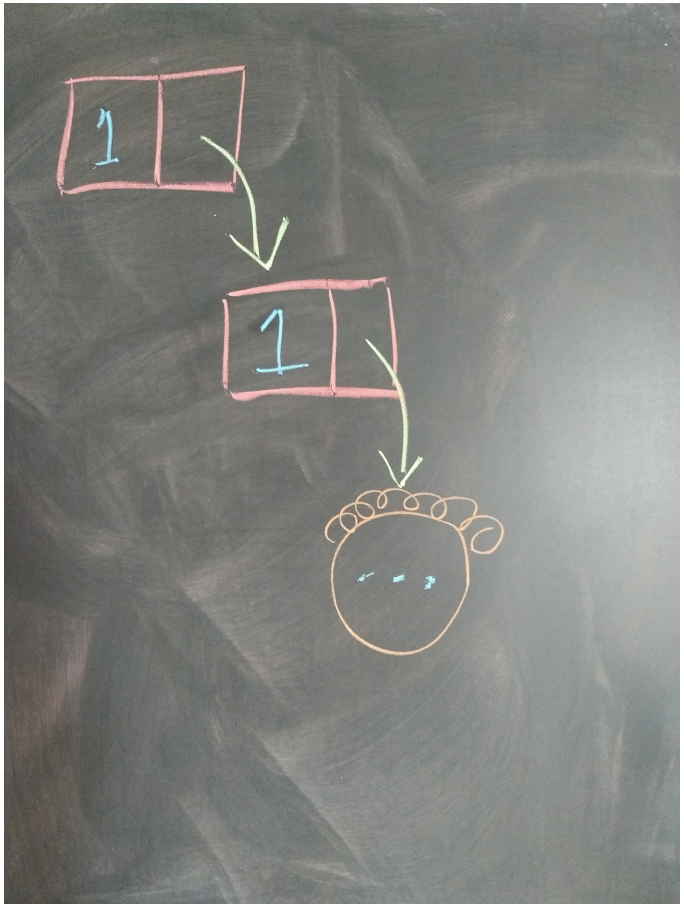
Infinity and Beyond!

```
repeat :: a -> [a]
repeat x = x:(repeat x)
-- take 3 (repeat 1) = [1,1,1]
```



Infinity and Beyond!

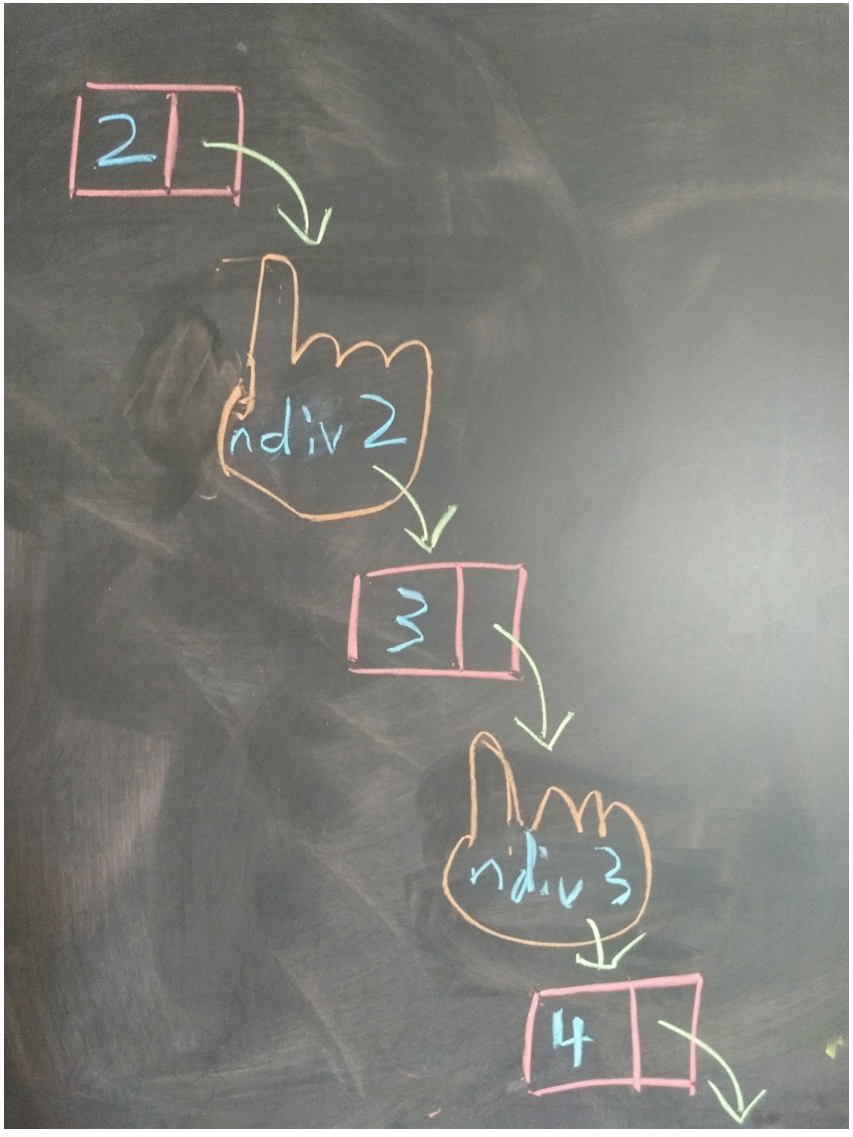
```
repeat :: a -> [a]
repeat x = x:(repeat x)
-- take 3 (repeat 1) = [1,1,1]
```



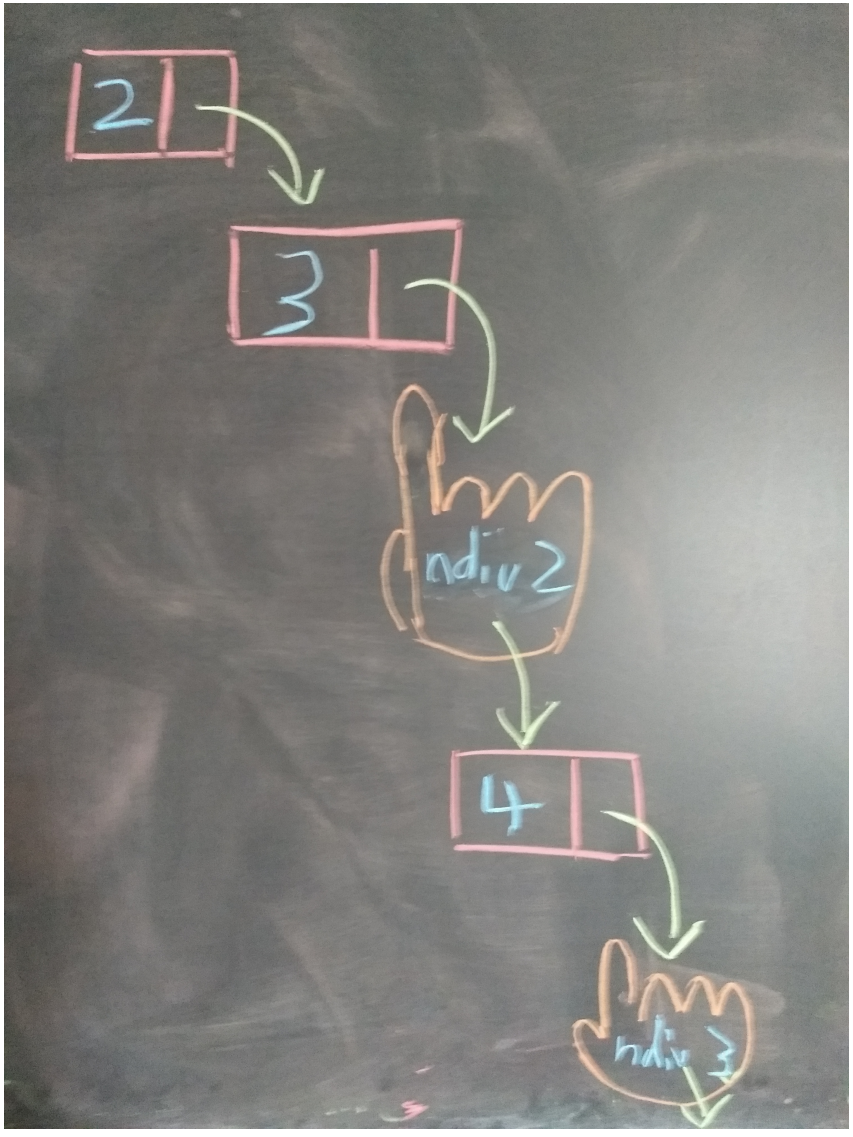
Generating prime numbers

```haskell
primes :: [Int]
primes = from 2
  where
    from k = k:(filter (ndiv k) (from (k+1)))
    ndiv k n = rem n k /= 0
-- take 4 primes == [2,3,5,7]
```

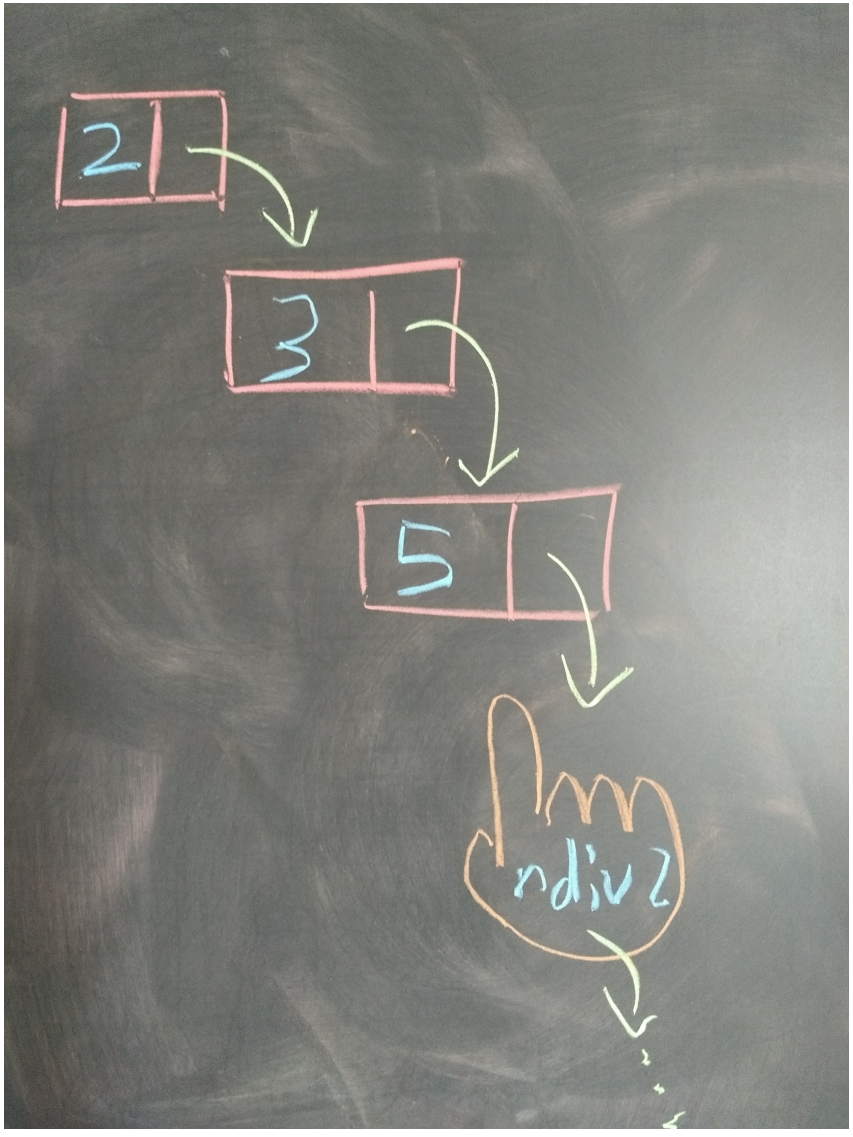
An illustration of `primes`



An illustration of `primes`



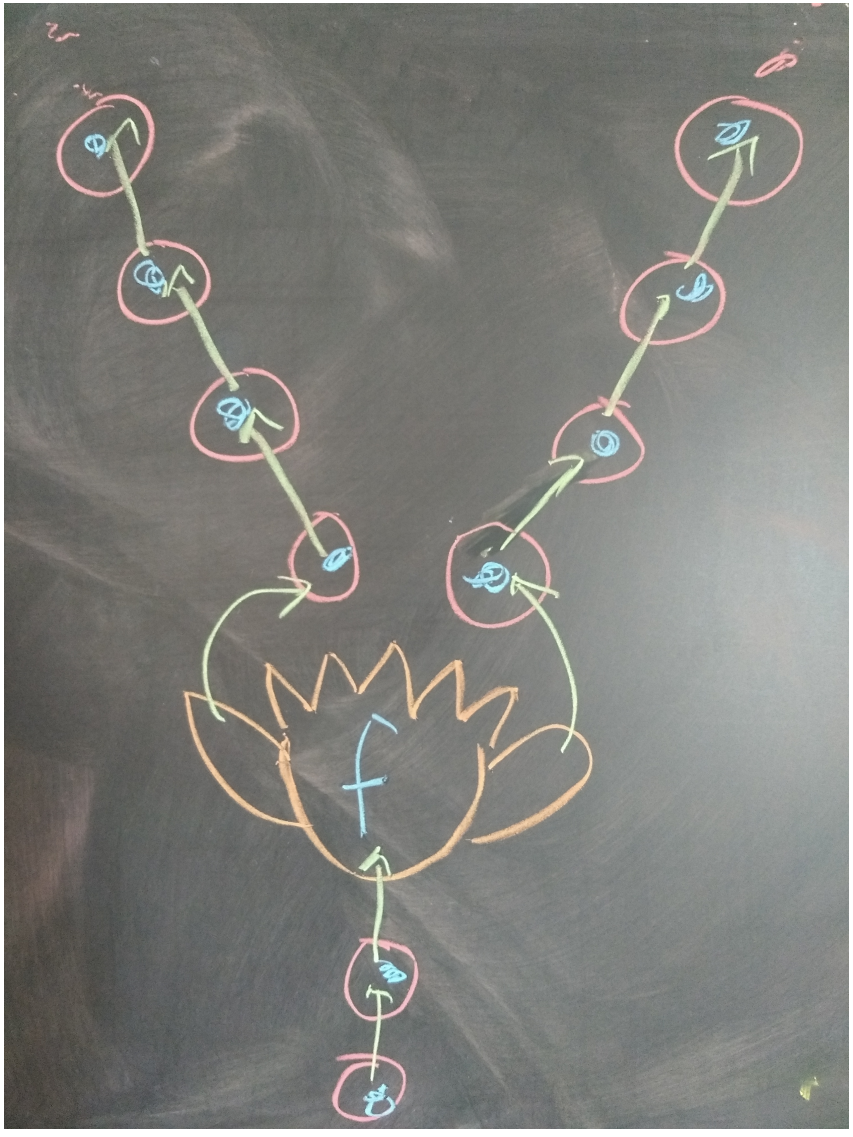
An illustration of `primes`



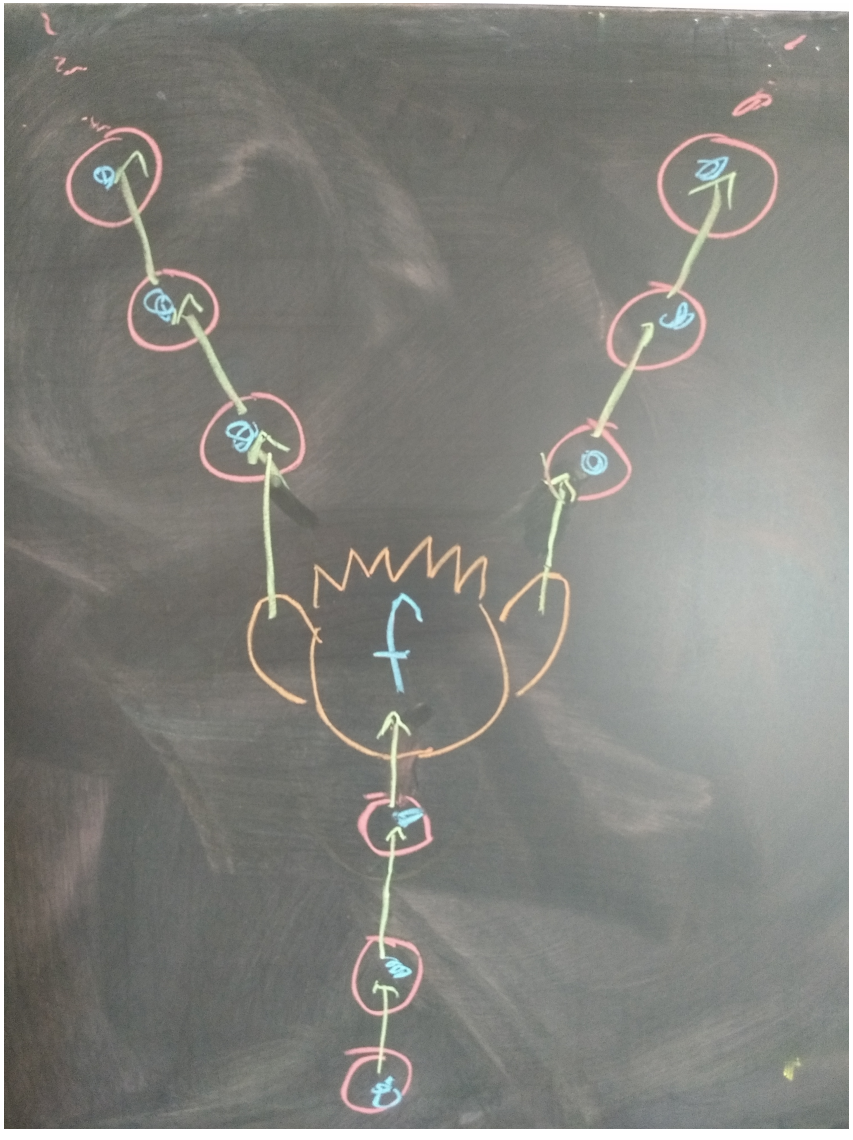
Zipping Lists

```
zipWith :: (a -> b -> c) -> [a] -> [b] -> [c]
zipWith _ [] _ = []
zipWith _ _ [] = []
zipWith f (x:xs) (y:ys) =
  (f x y):(zipWith f xs ys)
```

The zipWith Monster!



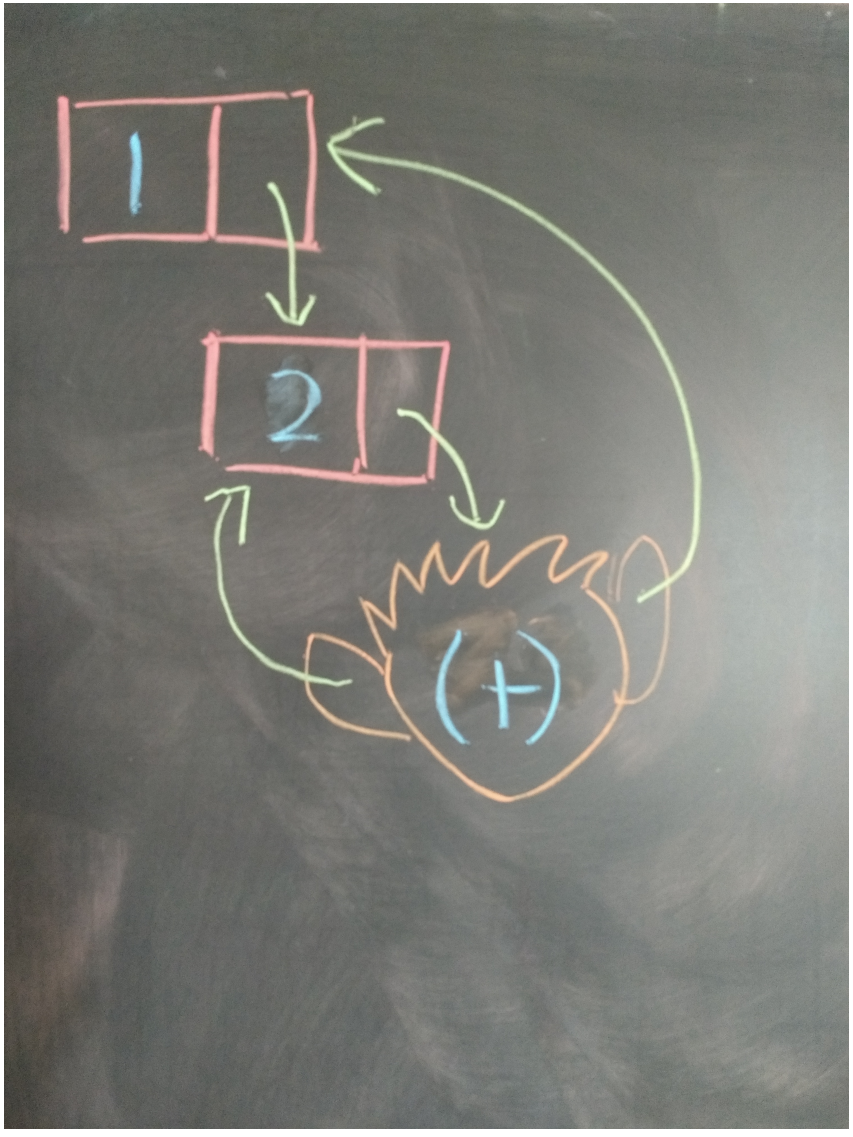
The zipWith Monster!



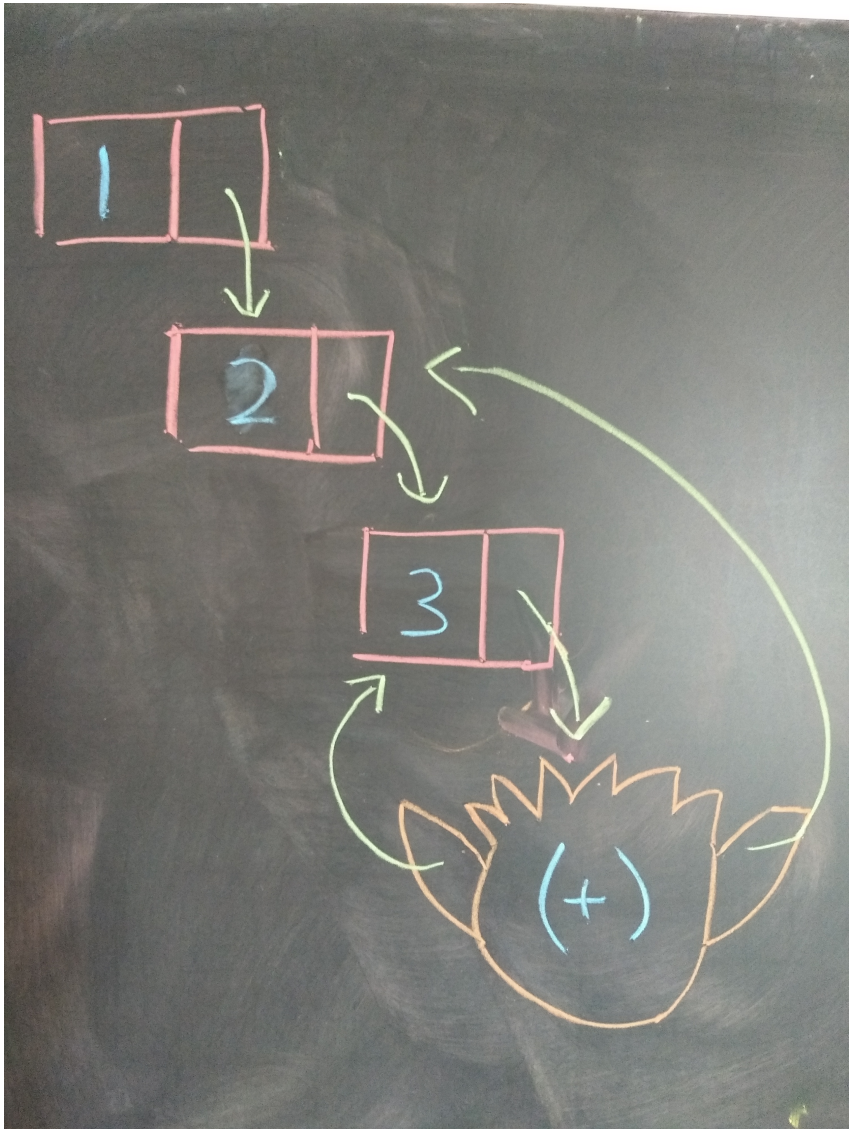
Fibonacci numbers

```haskell
fibs :: [Int]
fibs = 1:2:(zipWith (+) fibs (tail fibs))
-- This one's a braintwister!
```

The Fibonacci zipWith Monster!



The Fibonacci zipWith Monster!



Lists as Monoids Revisited

```haskell
newtype Stream a = S [a]

unS :: Stream a -> [a]
unS (S xs) = xs

instance Monoid a => Monoid (Stream a) where
  mempty = S []
  (S []) <> (S ys) = S ys
  (S xs) <> (S []) = S xs
  (S (x:xs)) <> (S (y:ys)) = S ((x <> y):rest)
    where (S rest) = (S xs) <> (S ys)
```

Conceptually, when the list ends, we treat the rest as an infinite stream of `memptys` (this might make more sense in the context of the next slide)

Thoughts on Streams

`Stream Double` is a vector space, where Double is the type of real numbers (OK, floating point numbers) in Haskell.

```
scalarMult :: Double -> Stream Double -> Stream Double
scalarMult r (S xs) = S (map (r*) xs)

addV :: Stream Double -> Stream Double -> Stream Double
addV = (<>)
-- The monoid instance for Double uses addition

negV :: Stream Double -> Stream Double
negV = scalarMult (-1)
```

This is the same thing as the vector space of polynomials of one variable over $\mathbb{R}$.

$[1, 0, \pi] \approx 1 + \pi x^2$

FizzBuzz: The Final Showdown (Part 1)

```haskell
spacer :: [Int] -> a -> [Maybe a]
spacer (n:ns) x = loop (n-1) (n:ns)
  where
    loop 0 (k1:k2:ns) =
      (Just x):(loop (k2-k1-1) (k2:ns))
    loop k ns = Nothing:(loop (k-1) ns)

-- spacer [1,3,4,7,...] 'x' ==
--   [Just 'x', Nothing, Just 'x', Just 'x', Nothing
--    Nothing, Just 'x',...]
```

FizzBuzz: The Final Showdown (Part 2)

```haskell
(.) :: (b -> c) -> (a -> b) -> (a -> c)
(f . g) x = f (g x)
-- We need the Monoid instance for a because we need
-- a monoid instance for Stream (Maybe a), which we
-- need because of mconcat
combine :: (Monoid a) => [([Int], a)] -> [Maybe a]
combine = unS . mconcat . map (S . uncurry spacer)
-- uncurry spacer :: ([Int], a) -> [Maybe a]

sol3 :: [String]
sol3 = zipWith fromMaybe (map show [1..100]) descs
  where descs = combine [(primes,"Fizz"), (fibs,"Buzz")]
```

Reflecting on the Final Showdown

- What we liked

Reflecting on the Final Showdown

- What we liked
  - Really really extensible!

Reflecting on the Final Showdown

- What we liked
  - Really really extensible!
  - Argument-free function definition!

Reflecting on the Final Showdown

- What we liked
  - Really really extensible!
  - Argument-free function definition!
- What we didn't like

Reflecting on the Final Showdown

- What we liked
  - Really really extensible!
  - Argument-free function definition!
- What we didn't like
  - Very dense, hard to come up with on the fly

Reflecting on the Final Showdown

- What we liked
  - Really really extensible!
  - Argument-free function definition!
- What we didn't like
  - Very dense, hard to come up with on the fly
- There should always be a balance, no matter what your programming language is. The difference is, in Haskell you have many more choices about how you balance.

Resources

- Resources for learning Haskell

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles
    - REALLY GOOD, NOT FREE, online at haskellbook.com

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles
    - REALLY GOOD, NOT FREE, online at haskellbook.com
  - Real World Haskell

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles
    - REALLY GOOD, NOT FREE, online at haskellbook.com
  - Real World Haskell
    - PRETTY GOOD, FREE, google for pdf or email me

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles
    - REALLY GOOD, NOT FREE, online at haskellbook.com
  - Real World Haskell
    - PRETTY GOOD, FREE, google for pdf or email me
- Resources for using Haskell

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles
    - REALLY GOOD, NOT FREE, online at haskellbook.com
  - Real World Haskell
    - PRETTY GOOD, FREE, google for pdf or email me
- Resources for using Haskell
  - stack, a package manager for Haskell

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles
    - REALLY GOOD, NOT FREE, online at haskellbook.com
  - Real World Haskell
    - PRETTY GOOD, FREE, google for pdf or email me
- Resources for using Haskell
  - stack, a package manager for Haskell
    - haskellstack.org

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles
    - REALLY GOOD, NOT FREE, online at haskellbook.com
  - Real World Haskell
    - PRETTY GOOD, FREE, google for pdf or email me
- Resources for using Haskell
  - stack, a package manager for Haskell
    - haskellstack.org
  - haskell.org, the center of all things Haskell

Resources

- Resources for learning Haskell
  - Learn You a Haskell for Great Good
    - FREE online at learnyouahaskell.com
  - Haskell Programming From First Principles
    - REALLY GOOD, NOT FREE, online at haskellbook.com
  - Real World Haskell
    - PRETTY GOOD, FREE, google for pdf or email me
- Resources for using Haskell
  - stack, a package manager for Haskell
    - haskellstack.org
  - haskell.org, the center of all things Haskell
  - hoogle, a search engine for functions, data types, etc. (REALLY USEFUL)

Thank You

Thank You

Shout out to my beta testers Max and Megan, without whom this talk would be far less comprehensible.

Thank You

Shout out to my beta testers Max and Megan, without whom this talk would be far less comprehensible.

Shriram sponsored this talk and helped me rework the section on Monoids – if you understand Monoids now, you have him to blame.

Thank You

Shout out to my beta testers Max and Megan, without whom this talk would be far less comprehensible.

Shriram sponsored this talk and helped me rework the section on Monoids – if you understand Monoids now, you have him to blame.

Monoid Mary (Julie Moronuki) allowed me to quote her and also gave me the quote from Real World Haskell.

Thank You

Shout out to my beta testers Max and Megan, without whom this talk would be far less comprehensible.

Shriram sponsored this talk and helped me rework the section on Monoids – if you understand Monoids now, you have him to blame.

Monoid Mary (Julie Moronuki) allowed me to quote her and also gave me the quote from Real World Haskell.

Thank you all for coming and being curious!