An Invitation to Haskell

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My name is Emily Pillmore.
I am a programmer, and a math enthusiast.

- Author/Maintainer of more than 30 packages, some bigger than others
- Served on the Haskell Core Libraries and .Org committees
- Twitter (@yandereidiot)
- Meetups in NYC: NY Homotopy Type Theory, NY Category Theory, and the NY Haskell User Group.
- All of my slides, general scribbles, research, and meetup content are hosted at cohomolo.gy.

If you ever want to talk math or programming, I'm around.

I helped start the Haskell Foundation and served on the executive leadership team as a duo (CTO) with Andrew Boardman (ED).

I now work at a company called **Kadena**, as the lead of the language, its ecosystem, and its execution layers.

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- A programming style? (emphasis on recursion, "math", small static combinators, shunting as many errors to the compiler as possible)
- A cult?

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In 1977, John Backus wrote everything we needed to know about FP.

Compositionality! Equational Reasoning! Sound foundational principles!

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Haskell builds a equational foundation on purity.

This means that functions may not have *side effects*. In conjunction with not allowing side effects anywhere, this allows expressions to be completely deterministic, and therefore *referentially transparent*.

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- It has generics

Haskell has a global notion of parametricity everywhere you want it which may be reasoned about equationally, and therefore free theorems you can reason about.

It has a form of ad-hoc polymorphism for generics called "Typeclasses".

For more, see:

- Wadler - Theorems for Free
- My talk - Type Arithmetic

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- This requires a different take on analysis (thunk counting techniques etc.) which causes you to think in a whole new paradigm.

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- Laziness (a limited form of mutation) turns out to be enough to recover amortized analysis.
- This requires a different take on analysis (thunk counting techniques etc.) which causes some tension.

Immutability + Laziness, though, is a super power. Friedman-Wise posed an important question back in 1976.

Inherently easy to spread about on multiple cores. With commutative, associative, and unital (see: commutative monoidal) functions, map-reduce is possible.

It also makes scheduling parallelism and concurrency a simpler.

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```haskell
-- a function
square :: Int -> Int -- a type signature
square x = x ^ x

-- Constants
pi_trunc :: Double
pi_trunc = 3.14159265359

charizard :: Char
charizard = 'c'

stringy :: String
stringy = "Hi, SEMIBUG!"
```

In haskell, we write the definition for functions and constants like this:

```haskell
-- builtin lists
oneTwoThree :: [Int]
oneTwoThree = [1,2,3]

-- builtin tuples
ab :: a -> b -> (a,b)
ab a b = (a,b)
```

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

-- Int -> Int -> Int is the
-- same as Int -> (Int -> Int)
plus' :: Int -> Int -> Int
plus' x = \y -> x + y
```

Function types are defined syntactically by enclosing parens

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```haskell
apply :: (a -> b) -> a -> b
-- apply = id
apply f a = f a

compose
  :: (b -> c)
  -> (a -> b)
  -> (a -> c)
compose f g = \a -> f (g a)
```

Defining infix notation is easy as well (not pictured: fixity):

```haskell
(^+) :: Int -> Int -> Int
(^+) x y = x + y
-- usage: x ^+ y
```

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We can define data as follows:

```haskell
-- data DataType <tyvars>
--   = Case1
--   | Case2
--   | ...
data MyAdt = Thing1 | Thing2

data MyRec = MyRecordName
  { foo :: Int
    -- ^ foo :: MyRecordName -> Int
  , bar :: String
    -- ^ bar :: MyRecordName -> String
  }
```

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```

Pattern matching is the means by which one destructs sum types.

```
let
  x :: MyDataType
  x = Case1

in case x of
  Case1 -> "hi!"
  Case2 -> "Death!"
```

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As mentioned in the beginning of the talk, immutable data structures let us achieve some remarkable properties.

We can write recursive data definitions for things like Lists:

We can write recursive data definitions for things like Lists:

```haskell
data List a = Nil | Cons a (List a)
-- builtin: data [a] = [] | (:) a [a]
-- usage: Cons 1 (Cons 2 (Cons 3 Nil))
-- usage: [1,2,3] := 1:(2:(3:[]))
```

Noodle baker: why does this work?

```
-- List(a) = 1 + a * List(a)
-- List(a) - a*List(a) = 1
-- List(a)(1 - a) = 1
-- List(a) = 1 / (1 - a)
-- List(a) = 1 + a + a^2 + a^3 ...
```

```haskell
reduce :: (a -> b -> b) -> b -> [a] -> b
reduce step accum lst = case lst of
  [] -> accum
  first:rest ->
    let stepped = step first accum
    in reduce step stepped rest
```

reduce is commonly referred to as a "fold". In fact, it's a *"right fold"* in the sense that the values are accumulated thusly:

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```
reduce (+) 0 [1,2,3]
-- ~ reduce (+) 0 (1:(2:(3:[])))
-- ~ 1 + reduce (+) 0 (2:(3:[]))
-- ~ 1 + (2 + (reduce (+) 0 (3:[])))
-- ~ 1 + (2 + (3 + reduce (+) 0 []))
-- ~ 1 + (2 + (3 + 0))
-- ~ 1 + (2 + 3)
-- ~ 1 + 5
-- ~ 6
```

Claim: this function corresponds with a kind of "canonical way to reduce a list recursively". As a result, one may define many interesting properties of a list in terms of this formulation.

```haskell
sum :: [Int] -> Int
sum lst = reduce (+) 0 lst

product :: [Int] -> Int
product lst = reduce (*) 1 lst

filter :: (a -> Bool) -> [a] -> [a]
filter p lst = reduce
  (\a acc -> if p a then a:acc else acc)
  [] lst

map :: (a -> b) -> [a] -> [b]
map f lst = reduce
 (\a acc -> (f a):acc) [] lst
```

```haskell
-- data Bool = True | False
all :: [Bool] -> Bool
all bs = reduce (&&) True bs

any :: [Bool] -> Bool
any bs = reduce (||) False bs
```

Graham Hutton's paper A tutorial on the universality and expressiveness of fold is a great resource on the subject.

These are definable in any language for any list. But in haskell, with the right foundation, they're understandable one-liners.

Further, we have laziness. This implies a thing called *shortcircuiting*.

Typeclasses are a means of layering ad-hoc behaviors.

```haskell
class Functor (f :: Type -> Type) where
  fmap :: (a -> b) -> f a -> f b

instance Functor List where
  -- fmap :: (a -> b) -> List a -> List b
  fmap f Nil = Nil
  fmap f (Cons h t) = Cons (f h) (fmap f h)
```

```haskell
functorFloor :: Functor f => f Double -> f Int
functorFloor dubs = fmap floor dubs

-- class Show a where show :: a -> String
stringify :: [Int] -> [String]
stringify = fmap show
```

```haskell
-- instances:
-- Int, <> = +, <> = *, etc.
class Semigroup a where
  (<>) :: a -> a -> a

-- instances:
-- Int, unit = 0, unit = 1
class Semigroup a => Monoid a where
  unit :: a
```

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You can get everything you need from a tool called "ghcup".

GHCup is the canonical toolchain installer. It will install the LSP, the compiler, and the build tools.

Get it here: get-ghcup

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Cabal is the Haskell project structure spec (as well as other tools), and cabal-install is the tool we use to build Haskell projects.

Useful commands:

- init
- build
- repl
- test
- run
- publish

Dependencies are located by default in a community service called "Hackage". Cabal-install knows how to talk to this service.

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Without spending too much on the dreaded "m-word" (it's monad), we have a monad called "IO".

IO is a means of sequencing real world state changes.

In fact, it is "just" a state monad, for the curious reader.

```haskell
main :: IO ()
main = putStrLn "Hello, World!"
```

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We're out of time, but this is a teaser for you.

Takeaways:

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- Laziness + Purity = Performance + Reasoning
- Reasoning + Consistency = Laws
- Laws + Types = Fewer Bugs
- Fewer Bugs = Less Stressful Programs

Haskell: lose your hair *before* you run the program.

...and then probably after too (it's still programming).