# Types and Typeclasses

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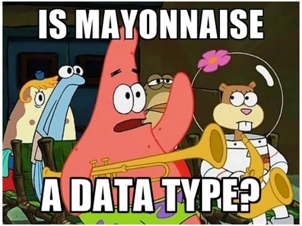

# Types in Haskell

Haskell is statically typed: every expression's type known at compile-time

Haskell has type inference: the compiler can deduce most types itself

Type names start with a capital letter (Int, Bool, Char, etc.)

GHCi's `:t` command reports the type of any expression

Read "`::`" as "is of type"

```
Prelude> :t 'a'
'a' :: Char

Prelude> :t True
True :: Bool

Prelude> :t "Hello"
"Hello" :: [Char]

Prelude> :t (True, 'a')
(True, 'a') :: (Bool, Char)

Prelude> :t 42 == 17
42 == 17 :: Bool
```

# Some Common Types

| | |
|---|---|
| `Bool` | Booleans: `True` or `False` |
| `Char` | A single Unicode character, about 25 bits |
| `Int` | Word-sized integers; the usual integer type. E.g., 64 bits on my x86_64 Linux desktop |
| `Integer` | Unbounded integers. Less efficient, so only use if you need *really* big integers |
| `Float` | Single-precision floating point |
| `Double` | Double-precision floating point |

# The Types of Functions

In a type, -> indicates a function

```
Prelude> welcome x = "Hello " ++ x
Prelude> welcome "Stephen"
"Hello Stephen"
Prelude> :t welcome
welcome :: [Char] -> [Char]
```

“Welcome is a function that takes a list of characters and produces a list of characters”

# Multi-argument functions are Curried

Haskell functions have exactly one argument.
Functions with "multiple arguments" are actually functions that return functions that return functions.

Such "currying" is named after Haskell Brooks Curry, who is also known for the Curry-Howard Correspondence ("programs are proofs").

```
Prelude> say x y = x++" to "++y
Prelude> :t say
say :: [Char] -> [Char] -> [Char]
Prelude> say "Hello" "Stephen"
"Hello to Stephen"

Prelude> :t say "Hello"
say "Hello" :: [Char] -> [Char]
```

```
Prelude> hello s = say "Hello" s
Prelude> hello "Fred"
"Hello to Fred"
Prelude> :t hello
hello :: [Char] -> [Char]
Prelude> hello = say "Hello"
Prelude> hello "George"
"Hello to George"
Prelude> :t hello
hello :: [Char] -> [Char]
```

# Top-level Type Declarations

It is good style in `.hs` files to include type declarations for top-level functions

Best documentation ever: a precise, compiler-verified function summary

```haskell
-- addThree.hs
addThree :: Int -> Int -> Int -> Int
addThree x y z = x + y + z
```

```
Prelude> :l addThree
[1 of 1] Compiling Main             ( addThree.hs, interpreted )
Ok, one module loaded.
*Main> :t addThree
addThree :: Int -> Int -> Int -> Int
*Main> addThree 1 2 3
6
```

# Polymorphism and Type Variables

Haskell has excellent support for polymorphic functions

Haskell supports *parametric polymorphism*, where a value may be of any type

Haskell also supports *ad hoc polymorphism*, where a value may be one of a set of types that support a particular group of operations

Parametric polymorphism: the `head` function

```
Prelude> :t head
head :: [a] -> a
```

Here, `a` is a type variable that ranges over every possible type.

```
Prelude> :t fst
fst :: (a, b) -> a
```

Here, `a` and `b` are distinct type variables, which may be equal or different

# Ad Hoc Polymorphism and Type Classes

Haskell's ad hoc polymorphism is provided by Type Classes, which specify a group of operations that can be performed on a type (think Java Interfaces)

```
Prelude> :t (==)
(==) :: Eq a => a -> a -> Bool
```

"The `(==)` function takes two arguments of type `a`, which must be of the `Eq` class, and returns a `Bool`"

Members of the `Eq` class can be compared for equality

A type may be in multiple classes; multiple types may implement a class

# Common Typeclasses

| | |
|---|---|
| `Eq` | Equality: `==` and `/=` |
| `Ord` | Ordered: `Eq` and `>`, `>=`, `<`, `<=`, `max`, `min`, and `compare`, which gives an `Ordering`: `LT`, `EQ`, or `GT` |
| `Enum` | Enumerable: `succ`, `pred`, `fromEnum`, `toEnum` (conversion to/from `Int`), and list ranges |
| `Bounded` | `minBound`, `maxBound` |
| `Num` | Numeric: `(+)`, `(-)`, `(*)`, `negate`, `abs`, `signum`, and `fromInteger` |
| `Real` | `Num`, `Ord`, and `toRational` |
| `Integral` | `Real`, `Enum`, and `quot`, `rem`, `div`, `mod`, `toInteger`, `quotRem`, `divMod` |
| `Show` | Can be turned into a string: `show`, `showList`, and `showsPrec` (operator precedence) |
| `Read` | Opposite of `Show`: string can be turned into a value: `read` et al. |

# Ord, Enum, and Bounded Typeclasses

```
Prelude> :t (>)
(>) :: Ord a => a -> a -> Bool
Prelude> :t compare
compare :: Ord a => a -> a -> Ordering

Prelude> :t succ
succ :: Enum a => a -> a

Prelude> maxBound :: Int
9223372036854775807
Prelude> minBound :: Char
'\NUL'
Prelude> maxBound :: Char
'\1114111'
Prelude> minBound :: (Char, Char)
('\NUL','\NUL')
```

# The Num Typeclass

```
Prelude> :t 42
42 :: Num p => p            -- Numeric literals are polymorphic
Prelude> :t (+)
(+) :: Num a => a -> a -> a -- Arithmetic operators are, too

Prelude> :t 1 + 2
1 + 2 :: Num a => a
Prelude> :t (1 + 2) :: Int
(1 + 2) :: Int :: Int      -- Forcing the result type
Prelude> :t (1 :: Int) + 2
(1 :: Int) + 2 :: Int      -- Type of one argument forces the type

Prelude> :t (1 :: Int) + (2 :: Double)
<interactive>:1:15: error:
    * Couldn't match expected type 'Int' with actual type 'Double'
    * In the second argument of '(+)', namely '(2 :: Double)'
      In the expression: (1 :: Int) + (2 :: Double)
```

# The Integral and Fractional Typeclasses

```
Prelude> :t div
div :: Integral a => a -> a -> a          -- div is integer division
Prelude> :t toInteger
toInteger :: Integral a => a -> Integer      -- E.g., Int to Integer
Prelude> :t fromIntegral
fromIntegral :: (Integral a, Num b) => a -> b -- Make more general
Prelude> 1 + 3.2
4.2                                           -- Fractional
Prelude> (1 :: Int) + 3.2
  * No instance for (Fractional Int) arising from the literal '3.2'
  * In the second argument of '(+)', namely '3.2'
    In the expression: (1 :: Int) + 3.2
    In an equation for 'it': it = (1 :: Int) + 3.2
Prelude> fromIntegral (1 :: Integer) + 3.2
4.2                                          -- Num + Fractional
Prelude> :t (/)
(/) :: Fractional a => a -> a -> a          -- Non-integer division
```

# The Show Typeclass

Show is helpful for debugging

```
Prelude> :t show
show :: Show a => a -> String
Prelude> show 3
"3"
Prelude> show 3.14159
"3.14159"
Prelude> show pi
"3.141592653589793"
Prelude> show True
"True"
Prelude> show (True, 3.14)
"(True,3.14)"
Prelude> show ["he","llo"]
"[\"he\",\"llo\"]"
```

# The Read Typeclass

Simple parsing. You may need to tell it what type to look for

```
Prelude> :t read
read :: Read a => String -> a
Prelude> read "17" + 25
42                                    -- Deduced type from context
Prelude> read "4"
*** Exception: Prelude.read: no parse -- Not enough information
Prelude> read "4" :: Int
4
Prelude> read "4" :: Integer
4
Prelude> read "4" :: Float
4.0
Prelude> read "(True, 42)" :: (Bool, Int)
(True,42)                             -- Tuples can be read
Prelude> read "[\"hello\",\"world\"]" :: [String]
["hello","world"]                     -- Lists can be read
```