What is a Type?

A type is a name for a collection of related values. For example, in Haskell the basic type


```
Bool
```


contains the two logical values:

```
False
```

```
True
```

Type Errors

Applying a function to one or more arguments of the wrong type is called a type error.


```
> 1 + False
Error
```


1 is a number and False is a logical value, but + requires two numbers.

Types in Haskell

- If evaluating an expression e would produce a value of type t, then e has type t, written


```
e :: t
```


- Every well formed expression has a type, which can be automatically calculated at compile time using a process called type inference.

- All type errors are found at compile time, which makes programs safer and faster by removing the need for type checks at run time.

- In GHCi, the :type command calculates the type of an expression, without evaluating it:


```
> not False
True

> :type not False
not False :: Bool
```

Basic Types

Haskell has a number of basic types, including:

`Bool`	- logical values
`Char`	- single characters
`String`	- strings of characters
`Int`	- fixed-precision integers
`Integer`	- arbitrary-precision integers
`Float`	- floating-point numbers

List Types

A list is sequence of values of the same type:


```
[False,True,False] :: [Bool]
```



```
['a','b','c','d']  :: [Char]
```


In general:

[t] is the type of lists with elements of type t.

Note:

- The type of a list says nothing about its length:

```
[False,True] :: [Bool]

[False,True,False] :: [Bool]
```


- The type of the elements is unrestricted. For example, we can have lists of lists:

```
[['a'],['b','c']] :: [[Char]]
```

Tuple Types

A tuple is a sequence of values of different types:


```
(False,True)      :: (Bool,Bool)
```



```
(False,'a',True)  :: (Bool,Char,Bool)
```


In general:

(t1,t2,…,tn) is the type of n-tuples whose ith components have type ti for any i in 1…n.

Note:

- The type of a tuple encodes its size:

```
(False,True)       :: (Bool,Bool)

(False,True,False) :: (Bool,Bool,Bool)
```


- The type of the components is unrestricted:

```
('a',(False,'b'))  :: (Char,(Bool,Char))

(True,['a','b'])   :: (Bool,[Char])
```

Function Types

A function is a mapping from values of one type to values of another type:


```
not      :: Bool → Bool

isDigit  :: Char → Bool
```


In general:

t1 → t2 is the type of functions that map values of type t1 to values to type t2.

Note:

- The arrow → is typed at the keyboard as ->.
- The argument and result types are unrestricted. For example, functions with multiple arguments or results are possible using lists or tuples:


```
add         :: (Int,Int) → Int
add (x,y)    = x+y

zeroto      :: Int → [Int]
zeroto n     = [0..n]
```

Curried Functions

Functions with multiple arguments are also possible by returning functions as results:


```
add' :: Int -> (Int -> Int)
add' x y = x+y
```


add' takes an integer x and returns a function add' x. In turn, this function takes an integer y and returns the result x+y.

Note:

- add and add' produce the same final result, but add takes its two arguments at the same time, whereas add' takes them one at a time:


```
add  :: (Int,Int) → Int

add' :: Int → (Int → Int)
```

- Functions that take their arguments one at a time are called curried functions, celebrating the work of Haskell Curry on such functions.

- Functions with more than two arguments can be curried by returning nested functions:

```
mult       :: Int → (Int → (Int → Int))
mult x y z = x*y*z
```


mult takes an integer x and returns a function mult x, which in turn takes an integer y and returns a function mult x y, which finally takes an integer z and returns the result x*y*z.

Why is Currying Useful?

Curried functions are more flexible than functions on tuples, because useful functions can often be made by partially applying a curried function.

For example:

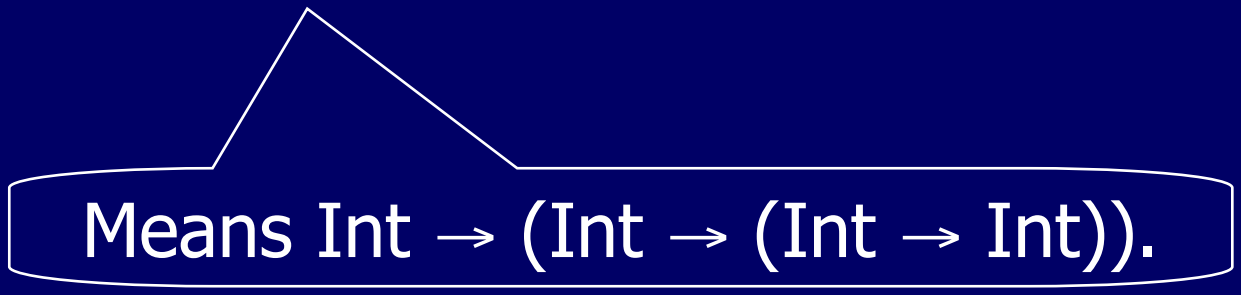

```
add' 1 :: Int → Int

take 5 :: [Int] → [Int]

drop 5 :: [Int] → [Int]
```

Currying Conventions

To avoid excess parentheses when using curried functions, two simple conventions are adopted:

- The arrow → associates to the right.


```
Int → Int → Int → Int
```



- As a consequence, it is then natural for function application to associate to the left.

```
mult x y z
```


Means ((mult x) y) z.

Unless tupling is explicitly required, all functions in Haskell are normally defined in curried form.

Polymorphic Functions

A function is called polymorphic ("of many forms") if its type contains one or more type variables.


```
length :: [a] → Int
```

for any type a, length takes a list of values of type a and returns an integer.

Note:

- Type variables can be instantiated to different types in different circumstances:


```
> length [False,True]
2
```


a = Bool


```
> length [1,2,3,4]
4
```

a = Int

- Type variables must begin with a lower-case letter, and are usually named a, b, c, etc.

- Many of the functions defined in the standard prelude are polymorphic. For example:

```
fst  :: (a,b) → a

head :: [a] → a

take :: Int → [a] → [a]

zip  :: [a] → [b] → [(a,b)]

id   :: a → a
```

Overloaded Functions

A polymorphic function is called overloaded if its type contains one or more class constraints.


```
sum :: Num a ⇒ [a] → a
```


for any numeric type a, sum takes a list of values of type a and returns a value of type a.

Note:

- Constrained type variables can be instantiated to any types that satisfy the constraints:


```
> sum [1,2,3]
6

> sum [1.1,2.2,3.3]
6.6

> sum ['a','b','c']
ERROR
```

a = Int

a = Float

Char is not a numeric type

- Haskell has a number of type classes, including:

  `Num` - Numeric types

  `Eq` - Equality types

  `Ord` - Ordered types

- For example:

```
(+)  :: Num a ⇒ a → a → a

(==) :: Eq a  ⇒ a → a → Bool

(<)  :: Ord a ⇒ a → a → Bool
```

Hints and Tips

- When defining a new function in Haskell, it is useful to begin by writing down its type;
- Within a script, it is good practice to state the type of every new function defined;
- When stating the types of polymorphic functions that use numbers, equality or orderings, take care to include the necessary class constraints.