

Haskell: Notes

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Variables and functions

Variables

- variables are useful

```
a = 3.141592
a^3
```

- code is more readable and modifiable

Haskell source files

- file extension is `.hs`
- to load a file in GHCi type `:l`, to reload type `:r`

Comments

- comments are done like this

```
x = 5      -- a comment
```

- block comments work like this

```
x = 5
{-
    multi-line comment
-}
y = {- inline comment -} 12
```

Variables in imperative languages

- in Haskell, variables can only be declared once and they are immutable
- they must begin with a letter and then can contain letters, numbers, underscores and ticks

Functions

- functions take an argument (or parameter) and gives a resulting value
- they are defined as follows

```
area r = pi * r ^ 2
```

- functions don't use parentheses but they can be used to group expressions and to make code easier to read
- haskell functions can also take multiple arguments

```
areaTriangle b h = (b * h) / 2
```

- functions can also be passed as arguments
- arguments are applied in the order they are given
- functions can be used to define some new functions

Local definitions

- when functions have values local to them, they are declared using `where` – see Heron's formula $A = \sqrt{s(s-a)(s-b)(s-c)}$

```
heron a b c = sqrt (s * (s - a) * (s - b) * (s - c))  
  where  
    s = (a + b + c) / 2
```

- the `where` and local variables are indented by 4 spaces – there can be multiple such statements

Truth values

Equality and other comparisons

- double equal signs are used for comparisons ==
- True and False are the representations of the booleans
- other evaluations are <, >, >=, <=, /=

```
-- defining operators  
x /= y = not (x == y)
```

- types are important

Infix operators

- functions that are written between the arguments

```
4 + 9 == 13  
-- same as  
(==) (4 + 9) 13
```

Boolean operations

- logical and is &&
- logical or is ||
- logical not is not

Guards

- syntactic sugar for piecewise functions

```
-- function for the absolute value of x  
absolute x  
  | x < 0      = 0 - x      -- -x would also work  
  | otherwise = x
```

- the pipe | is followed by a predicate (boolean expression)
- otherwise is used when none of the preceding values are True, it is actually just defined as True
- where works well with guards

```
numOfRealSolutions a b c
| disc > 0 = 2
| disc == 0 = 1
| otherwise = 0
  where
    disc = b^2 - 4*a*c      -- discriminant for above
                           -- descisions
```

Type basics

- all types in haskell have to begin with a capital letter
- types are useful because they define what you can and can't do with them
- `:type` or `:t` checks the type of any expression
- `::` means 'is of type', it indicates the *type signature*
- `True` and `False` are of type `Bool`
- characters are of type `Char`

```
:t 'H'
'H' :: Char
```

- strings are of type list of char

```
:t "hello"
"hello" :: [Char]
```

- type synonyms are different words for the same types

```
[Char] == String
```

Functional types

- functions have types too
- type signature for `not`

```
:t not
not :: Bool -> Bool
-- function from bool to bool
```

- `chr :: Int -> Char` converts int to char ASCII
- `ord :: Char -> Int` converts ASCII to int
- to use these functions you have to use the module `Data.Char` with `:module Data.Char` or `:m Data.Char`
- finding the type signatures of function works by listing all types of the input values in order and then the result value, all separated by `->`

```
xor p q = (p || q) && not (p && q)
:t xor
xor :: Bool -> Bool -> Bool
```


Type signatures in code

- type annotations look exactly like the function signatures

```
xor :: Bool -> Bool -> Bool
xor p q = (p || q) && not (p && q)
```

- this clarifies the function to the compiler and the programmer
- when types are not provided, the compiler infers the types by what data is there
- also, type signatures can help the compiler spot errors for you
- by separating functions with commas we can put multiple ones on the same signature line
- if one writes + instead of ++ for concatenation, the compiler will let you know

Lists and tuples

Lists

- denoted by [and], elements are separated by commas
- all elements must be of the same type

```
numbers = [1,2,3,4]
bools   = [True, False, False]
```

- to add elements to the start of a list, use : (cons), evaluated from right to left

```
[1,2,3,4] == 1:2:3:4:[]
```

- you can only cons elements to a list, not vice versa
- strings are also just lists of characters
- lists can also contain lists – a useful feature

Tuples

- store multiple values in a single value
- tuples will always have a set length, you cannot increase their size – good if you know the amount of needed data
- elements of a tuple do not need to be of the same type

```
(True, 1)
("hello", 'c', 123.23)
```

- tuples can also contain other tuples
- `fst` and `snd` return the first and second elements of a 2-tuple or pair
- `head` and `tail` for lists return the first element and the list minus the first element
- `head` and `tail` are pretty bad though, they will fail if passed an empty list
- functions can use polymorphic types, they can represent a bunch of different types with certain similarities
- type variables allow any type to take their place, they are useful for writing functions that can work on many types
- mathematically that's called polymorphism

```
f :: a -> a
-- takes type a and returns same type a
f :: a -> b
-- takes a and may or may not return the same type
```

- for example `fst` and `snd` work like this

```
-- return first of pair
fst :: (a, b) -> a
-- return second of pair
snd :: (a, b) -> b
```

Type basics II

- in maths you can add any type of number together – for computers that does not work too well
- floats and integers are the least types you need
- this means Haskell needs types for at least those two
- still, the (+) works on any type of number

```
(+) :: (Num a) => a -> a -> a
```

- here Num is a typeclass – a restriction on the types that a function can accept
- the most important numeric types are Int, Integer, Float, and Double
- Int is 32 bit, Integer is arbitrarily long, the others are floating point numbers
- a number in a Haskell program is of type number and is only restricted when it is changed, like 7 is anything, 3.12 is restricted to double and then they are added on the lowest denominator
- monomorphic trouble comes when returned types are incompatible
- using a function that returns Int with a function expecting Double will blow up, it requires conversion

```
-- converts an int into a polymorphic number  
fromIntegral (num)
```

Classes beyond numbers

- there is a typeclass for equations Eq
- length is a function that takes a Foldable, a type that includes lists and more

Building vocabulary

Function composition

- means applying one function to a value and then applying another function to the result

```
-- defining functions
f x = x + 3
square x = x ^ 2
square (f 1)      -- returns 16
f (square 2)      -- returns 7
```

- the parentheses are necessary because otherwise the function would try to take another function as input – an error
- we can make one function of multiple commonly used ones

```
squareOfF x = square (f x)
fOfSquare x = f (square x)
```

- another way to do it is with `(.)`, the function composition operator

```
-- functions are applied from right to left
squareOfF x = (square . f) x
fOfSquare x = (f . square) x
```

- one can also leave out the `x`, giving

```
squareOfF = square . f
```

Prelude and the libraries

- the standard library in Haskell is called the prelude
- it provides the types and general functions
- you can import modules into your program

```
import Data.List
```

- in GHCi use `:m +<name>`
- using the standard library can make programs much shorter

```
-- program that reverses the order of strings
revWords :: String -> String
revWords input = (unwords . reverse . words) input
```



Next steps

If then else

- works like in other languages

```
signum x =  
  if x < 0  
    then -1  
    else if x > 0  
      then 1  
      else 0
```

- there *has* to be an **else** statement because there always has to be a result
- if - then - else can also be translated to guards

```
signu x =  
  | x < 0      = -1  
  | x > 0      = 1  
  | otherwise = 0
```

- both options work the same, sometimes one is more readable than the other

Introducing pattern matching

- long if-else statements are convoluted
- defining piece-wise functions is much better and more readable

```
pts :: Int -> Int  
pts 1 = 10  
pts 2 = 6  
pts 3 = 4  
pts 4 = 3  
pts 5 = 2  
pts 6 = 1  
pts _ = 0
```

- the `_` is a wildcard – matching anything of the functions type
- using some logic, we can make `pts` even shorter

```
pts :: Int -> Int  
pts 1 = 10  
pts 2 = 6
```

```
pts x
| s <= 6    = 7 - x
| otherwise = 0
```

- pattern matching can be overlapped and thus inefficient
- patterns should always match all possible cases

Tuple and list patterns

- the patterns work the same, they are more useful actually

```
head    :: [a] -> a
head (x:_) = x
head []    = error "Prelude.head: empty list"

tail    :: [a] -> [a]
tail (_:xs) = xs
tail []    = error "Prelude.head: empty list"
```

Let bindings

- similar to `where`, different formatting
- can help make functions more readable

```
roots a b c =
    ((-b + sqrt(b * b - 4 * a * c)) / (2 * a),
     (-b - sqrt(b * b - 4 * a * c)) / (2 * a))
-- can be transformed to
short_roots a b c =
    let d = sqrt (b ^ 2 - 4 * a * c)
        two_a = 2 * a
    in ((-b + d) / two_a,
        (-b - d) / two_a)
```


Simple input and output

- program have to interact with the world around them

```
putStrLn "Hello, world!"
```

- `putStr` just misses the new line `putStrLn` has
- these functions are of type `IO ()`, that is `IO` action with type `()` – unit type, tuple with 0 elements – basically nothing
- `IO` occurs in `print`, `read`, `write`

Sequencing actions with `do`

- `do` lets you put actions in order of execution

```
main = do
  putStrLn "Please enter your name:"
  name <- getLine
  putStrLn ("Hello, " ++ name ++ ", how are you")
```

- the final action defines the type of the whole `do` block – here the whole program has type `IO ()`
- the `<-` notation assigns the result of `getLine` to the variable – omitting it will just take the input but don't act on it
- `<-` cannot be the last action
- use `read` to convert string to text, `show` to convert number to string

```
double = read "123.3"
```

```
string_of_double = show double
```

- `<-` can be used to get any result value, just some of them are not worth saving
- the two branches of `if/then/else` statements must all have the same type
- for all sequenced commands we need to start a new `do` block
- for action to return what they say they will, you require the `<-`

Recursion

- a function that has the ability to invoke itself
- a recursive function calls itself in certain circumstances and stops in others

Numeric recursion

- see factorials

```
factorial 0 = 1
factorial n = n * factorial (n - 1)
```

- always write the most restrictive type first
- `go` can be used to translate loops from other languages into Haskell
- many functions have recursive versions – multiplication for example TODO: look at the exercises to practice