## PROGRAMMING IN HASKELL



Chapter 4 - Defining Functions

## **Conditional Expressions**

As in most programming languages, functions can be defined using <u>conditional expressions</u>.

```
abs :: Int \rightarrow Int abs n = if n \ge 0 then n = lse -n
```

abs takes an integer n and returns n if it is non-negative and -n otherwise.

### Conditional expressions can be nested:

```
signum :: Int \rightarrow Int signum n = if n < 0 then -1 else if n == 0 then 0 else 1
```

#### Note:

z In Haskell, conditional expressions must <u>always</u> have an else branch, which avoids any possible ambiguity problems with nested conditionals.

## **Guarded Equations**

As an alternative to conditionals, functions can also be defined using guarded equations.

abs 
$$n \mid n \ge 0 = n$$
  
  $\mid \text{otherwise} = -n$ 

As previously, but using guarded equations.

Guarded equations can be used to make definitions involving multiple conditions easier to read:

```
signum n | n < 0 = -1
| n == 0 = 0
| otherwise = 1
```

#### Note:

z The catch all condition <u>otherwise</u> is defined in the prelude by otherwise = True.

# **Pattern Matching**

Many functions have a particularly clear definition using <u>pattern matching</u> on their arguments.

```
not :: Bool → Bool
not False = True
not True = False
```

not maps False to True, and True to False.

Functions can often be defined in many different ways using pattern matching. For example

```
(&&) :: Bool → Bool → Bool
True && True = True
True && False = False
False && True = False
False && False = False
```

can be defined more compactly by

```
True && True = True
_ && _ = False
```

However, the following definition is more efficient, because it avoids evaluating the second argument if the first argument is False:

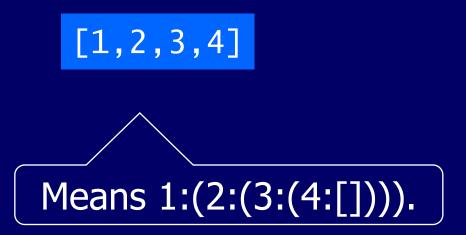
#### Note:

z The underscore symbol \_ is a wildcard pattern that matches any argument value. z Patterns are matched <u>in order</u>. For example, the following definition always returns False:

Z Patterns may not <u>repeat</u> variables. For example, the following definition gives an error:

## **List Patterns**

Internally, every non-empty list is constructed by repeated use of an operator (:) called "cons" that adds an element to the start of a list.



Functions on lists can be defined using x:xs patterns.

```
head :: [a] \rightarrow a
head (x:\_) = x

tail :: [a] \rightarrow [a]
tail (\_:xs) = xs
```

head and tail map any non-empty list to its first and remaining elements.

#### Note:

z x:xs patterns only match non-empty lists:

```
> head []
*** Exception: empty list
```

z x:xs patterns must be <u>parenthesised</u>, because application has priority over (:). For example, the following definition gives an error:

head 
$$x: = x$$

## Lambda Expressions

Functions can be constructed without naming the functions by using <u>lambda expressions</u>.



the nameless function that takes a number x and returns the result x + x.

#### Note:

- **z** The symbol  $\lambda$  is the Greek letter <u>lambda</u>, and is typed at the keyboard as a backslash \.
- **z** In mathematics, nameless functions are usually denoted using the  $\mapsto$  symbol, as in  $x \mapsto x + x$ .

**z** In Haskell, the use of the  $\lambda$  symbol for nameless functions comes from the <u>lambda calculus</u>, the theory of functions on which Haskell is based.

# Why Are Lambda's Useful?

Lambda expressions can be used to give a formal meaning to functions defined using <u>currying</u>.

For example:

```
add :: Int \rightarrow Int \rightarrow Int add x y = x + y
```

means

```
add :: Int \rightarrow (Int \rightarrow Int)
add = \lambda x \rightarrow (\lambda y \rightarrow x + y)
```

Lambda expressions can be used to avoid naming functions that are only <u>referenced once</u>.

## For example:

### can be simplified to

odds n = map 
$$(\lambda x \rightarrow x*2 + 1)$$
 [0..n-1]

## **Operator Sections**

An operator written <u>between</u> its two arguments can be converted into a curried function written <u>before</u> its two arguments by using parentheses.

### For example:

This convention also allows one of the arguments of the operator to be included in the parentheses.

### For example:

In general, if  $\oplus$  is an operator then functions of the form  $(\oplus)$ ,  $(x\oplus)$  and  $(\oplus y)$  are called <u>sections</u>.

# Why Are Sections Useful?

Useful functions can sometimes be constructed in a simple way using sections. For example:

- (1+) successor function
- (1/) reciprocation function
- (\*2) doubling function
- (/2) halving function

## **Exercises**

- (1) Consider a function <u>safetail</u> that behaves in the same way as tail, except that safetail maps the empty list to the empty list, whereas tail gives an error in this case. Define safetail using:
  - (a) a conditional expression;
  - (b) guarded equations;
  - (c) pattern matching.

Hint: the library function null ::  $[a] \rightarrow Bool$  can be used to test if a list is empty.

- (2) Give three possible definitions for the logical or operator (||) using pattern matching.
- (3) Redefine the following version of (&&) using conditionals rather than patterns:

```
True && True = True
_ && _ = False
```

(4) Do the same for the following version:

```
True && b = b
False && _ = False
```