Haskell4Life: Introduction

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Slides and code examples available online:

http://lacl.fr/~sivanov/doku.php?id=en:haskell_for_life

Overlaps Between Programming and Cooking

https://wiki.haskell.org/wikiupload/8/86/HaskellBCurry.jpg

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1. Cooking receipt = program

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Haskell B. Curry

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(joke)

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Outline

1. The Basics
2. The Types
3. The Functions
4. The Real Functional Programming
5. The Fun

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1. The Basics
2. The Types
3. The Functions
4. The Real Functional Programming
5. The Fun

Getting Started

- Install Haskell: `https://www.haskell.org/platform/`
- Run interactively: `ghci`
- Compile: `ghc source.hs -o executable`
- Get all kinds of help: `https://www.haskell.org/`

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There are Haskell syntax highlighting modules in all major IDEs and Haskell modes in Emacs and Vim.

Saying Hello

```
λ> putStrLn "Hello World!"
Hello World
```

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- call the function `putStrLn` with with one argument

Saying Hello

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Hello World
```

- call the function `putStrLn` with with one argument
- no parentheses
- no commas
- no semicolons

Haskell Calculator

```
λ> 1 + 2
```

Haskell Calculator

```
λ> 1 + 2
3
```

Haskell Calculator

```
λ> 1 + 2
3
```

```
λ> 2 * 3
```

Haskell Calculator

```
λ> 1 + 2
3
```

```
λ> 2 * 3
6
```

Haskell Calculator

```
λ> 1 + 2
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```

```
λ> 2 * 3
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```

```
λ> (+) 1 2
```

Haskell Calculator

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3
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Haskell Calculator

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λ> (+) 1 2
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```

(+) is a function of two arguments.

Haskell Calculator

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λ> 1 + 2
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λ> 2 * 3
6
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```
λ> (+) 1 2
3
```

`(+)` is a function of two arguments.

Normal functions are usually written in prefix form.

- `putStrLn "Hello"`

Haskell Calculator

```
λ> 1 + 2
3
```

```
λ> 2 * 3
6
```

```
λ> (+) 1 2
3
```

`(+)` is a function of two arguments.

Normal functions are usually written in prefix form.

- `putStrLn "Hello"`

Operators are usually written in infix form.

- `1 + 2`

Haskell Calculator

```
λ> 1 + 2
3
```

```
λ> 2 * 3
6
```

```
λ> (+) 1 2
3
```

`(+)` is a function of two arguments.

Normal functions are usually written in prefix form.

- `putStrLn "Hello"`

Operators are usually written in infix form.

- `1 + 2`

Parentheses are used to write operators in prefix form.

- `(+) 1 2`

Negative Numbers

```
λ> 2 + -3
```

Negative Numbers

```
λ> 2 + -3
<interactive>:12:1-6:
    Precedence parsing error
        cannot mix '+' [infixl 6] and prefix '-' [infixl 6]
        in the same infix expression
```

Negative Numbers

```
λ> 2 + -3
<interactive>:12:1-6:
    Precedence parsing error
        cannot mix '+' [infixl 6] and prefix '-' [infixl 6]
        in the same infix expression
```

Parsing ambiguity!

How does one parse `function - 3`:

- apply `function` to -3?
- subtract 3 from `function`?

Negative Numbers

```
λ> 2 + -3
<interactive>:12:1-6:
    Precedence parsing error
        cannot mix '+' [infixl 6] and prefix '-' [infixl 6]
        in the same infix expression
```

Parsing ambiguity!

How does one parse `function - 3`:

- apply `function` to -3?
- subtract `3` from `function`?

```
λ> 2 + (-3)
-1
```

Boolean Values and Operators

```
λ> True && False
False
```

```
λ> True || False
True
```

Boolean Values and Operators

```
λ> True && False
False
```

```
λ> True || False
True
```

No direct coercion to/from numbers:

```
λ> True && 1
```

... won't work :-)

Comparison Operators

Typical comparison operators:

```
λ> 1 == 2
False
```

```
λ> 1 <= 2
True
```

Comparison Operators

Typical comparison operators:

```
λ> 1 == 2
False
```

```
λ> 1 <= 2
True
```

Unusual "not equals":

```
λ> 1 /= 2
True
```

Variables

```
λ> let a = 1
```

Variables

```
λ> let a = 1
λ> a
1
```

Variables

```
λ> let a = 1
λ> a
1
λ> a + 1
2
```

Variables

```
λ> let a = 1
λ> a
1
λ> a + 1
2
λ> let e = exp 1
λ> e
2.718281828459045
```

Lists

```
λ> [1,2,3]
[1,2,3]
```

Lists

```
λ> [1,2,3]
[1,2,3]

λ> [1..5]
[1,2,3,4,5]
```

Lists

```
λ> [1,2,3]
[1,2,3]

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[1,2,3,4,5]

λ> [True,"three"]
```

... type error

Lists

```
λ> [1,2,3]
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λ> [1..5]
[1,2,3,4,5]

λ> [True,"three"]
```

... type error

All elements of a list must be of the same type.

Lists

```
λ> [1,2,3]
[1,2,3]
```

```
λ> 1:[2,3]
[1,2,3]
```

```
λ> [1..5]
[1,2,3,4,5]
```

```
λ> [True,"three"]
```

... type error

All elements of a list must be of the same type.

Lists

```
λ> [1,2,3]
[1,2,3]
```

```
λ> 1:[2,3]
[1,2,3]
```

```
λ> [1..5]
[1,2,3,4,5]
```

```
λ> [1,2,3]++[4,5]
[1,2,3,4,5]
```

```
λ> [True,"three"]
```

... type error

All elements of a list must be of the same type.

Lists

```
λ> [1,2,3]
[1,2,3]
```

```
λ> 1:[2,3]
[1,2,3]
```

```
λ> [1..5]
[1,2,3,4,5]
```

```
λ> [1,2,3]++[4,5]
[1,2,3,4,5]
```

```
λ> [True,"three"]
```

... type error

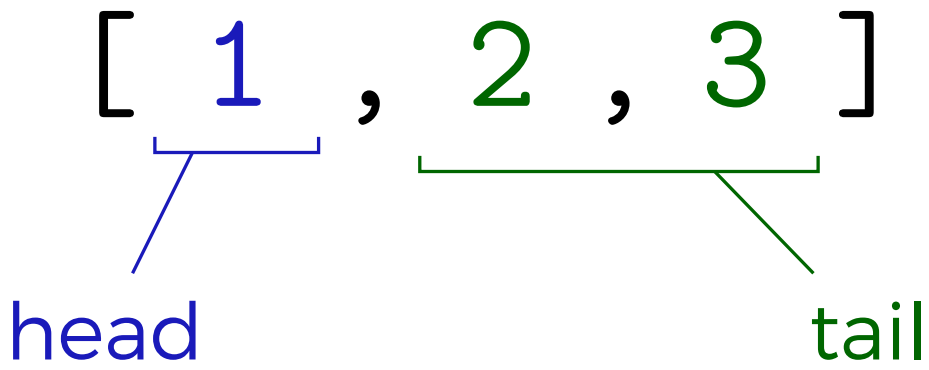
```
λ> length [4,5]
2
```

All elements of a list must be of the same type.

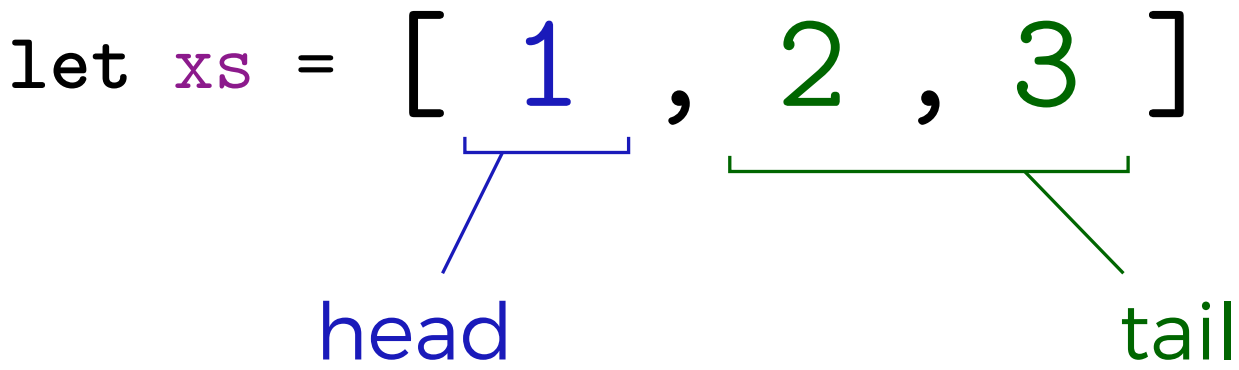
Lists: Heads and Tails

```
[ 1 , 2 , 3 ]
```

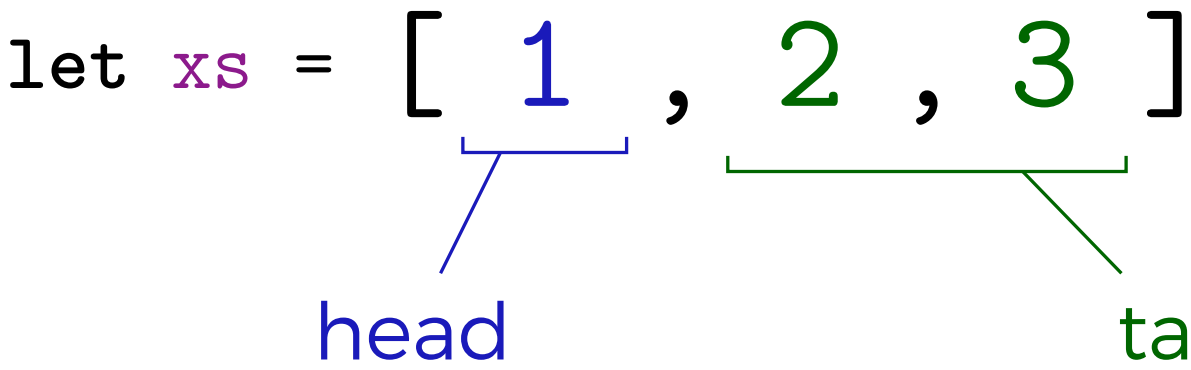
Lists: Heads and Tails



Lists: Heads and Tails



Lists: Heads and Tails




```
λ> head xs
1
```

```
λ> tail xs
[2,3]
```

Lists: Heads and Tails

```
let xs = [ 1 , 2 , 3 ]
```

head

tail

```
λ> head xs
1
```

```
λ> tail xs
[2,3]
```

```
∀ list. list == (head list) : (tail list)
```

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

Strings as Lists

```
λ> putStrLn "String"
String
```

Strings as Lists

```
λ> putStrLn "String"
String

λ> "String" == ['S','t','r','i','n','g']
True
```

Strings as Lists

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True

λ> "" == []
True
```

Strings as Lists

```
λ> putStrLn "String"
String

λ> "String" == ['S','t','r','i','n','g']
True

λ> "" == []
True

λ> 'a':"bc"
abc
```

Tuples

```
λ> (1,2,3)
(1,2,3)
```

```
λ> (True,"three")
(True,"three")
```

Tuples can contain values of different types.

Tuples

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Tuples can contain values of different types.

Tuples are very "strict": no concatenation, no indexing.

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λ> (1,2,3)
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(True,"three")
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Tuples are very "strict": no concatenation, no indexing.

```
λ> fst (1,2)
1
```

```
λ> fst (1,2,3)
... type error
```

Tuples

```
λ> (1,2,3)
(1,2,3)
```

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λ> (True,"three")
(True,"three")
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Tuples can contain values of different types.

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```
λ> fst (1,2)
1
```

```
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... type error
```

Attention: `fst` is a function applied to one argument: the (two-element) tuple `(1,2)`.

A Simple Program (a reading exercise)

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`input`

`input` : : string

A Simple Program (a reading exercise)

```
                                                    lines input
```

```
input          :: string
lines input    :: list of strings (lines)
```

A Simple Program (a reading exercise)

```
                                        length (lines input)
input                   :: string
lines input             :: list of strings (lines)
length (lines input)    :: number of lines
```

A Simple Program (a reading exercise)

```
lineCount input = length (lines input)
```

`input`	:: string
`lines input`	:: list of strings (lines)
`length (lines input)`	:: number of lines
`lineCount input`	:: function of one argument (input)

A Simple Program (a reading exercise)

```
      interact lineCount
where lineCount input =       length (lines input)
```

```
input                 :: string
lines input           :: list of strings (lines)
length (lines input)  :: number of lines
lineCount input       :: function of one argument (input)
```

`interact` is function that "makes `lineCount` interact with the input".

A Simple Program (a reading exercise)

```
      interact lineCount
where lineCount input = show (length (lines input))
```

```
input                  :: string
lines input            :: list of strings (lines)
length (lines input)   :: number of lines
lineCount input        :: function of one argument (input)
```

`interact` is function that "makes `lineCount` interact with the input".

`show` is function that converts "anything" to a string.

A Simple Program (a reading exercise)

```
main = interact lineCount
  where lineCount input = show (length (lines input))
```

`input` :: string

`lines input` :: list of strings (lines)

`length (lines input)` :: number of lines

`lineCount input` :: function of one argument (input)

`interact` is function that "makes `lineCount` interact with the input".

`show` is function that converts "anything" to a string.

`main` is the entry point of the program.

Outline

Types

In Haskell, every expression has a type.

The type of an expression is specified using `::`

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2 + 3 :: Num a => a
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True :: Bool

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2 + 3 :: Num a => a
```

typeclass

Haskell's Types

Strong

- granular types (lots of details)
- no automatic coercion

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Static

- the type of anything is known at compile time

Haskell's Types

Strong

- granular types (lots of details)
- no automatic coercion

Static

- the type of anything is known at compile time

Inferred

- the type of anything is deduced automatically
  - almost anything

The Basic Types

`Char`	a Unicode character
`Bool`	`True` or `False`
`Int`	signed, 32- or 64-bit integer values, depending on the architecture
`Integer`	signed integers of unbounded size (more expensive that `Int`)
`Double`	floating-point numbers, typically 64 bits long, uses native floating-point representation
`Float`	narrower than `Double`, but much slower that `Double`, so its use is discouraged

Basic Composite Types: Lists and Tuples

```
λ> [1,2,3] :: [Int]
[1,2,3]
λ> (1,2,3) :: (Int,Int,Int)
(1,2,3)
```

Basic Composite Types: Lists and Tuples

```
λ> [1,2,3] :: [Int]
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λ> (1,2,3) :: (Int,Int,Int)
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λ> (True,"three") :: (Bool,String)
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```

A tuple type describes the type of each component.

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```

A tuple type describes the type of each component.

`[1,2]` and `[1,2,3]` are of the same type

- `[1,2] :: [Int]` and `[1,2,3] :: [Int]`

`(1,2)` and `(1,2,3)` are of different types

- `(1,2) :: (Int, Int)` and `(1,2,3) :: (Int, Int, Int)`

No Functions Working on All Tuples

`(1,2)` and `(1,2,3)` are of different types

- `(1,2) :: (Int, Int)` and `(1,2,3) :: (Int, Int, Int)`

No Functions Working on All Tuples

`(1,2)` and `(1,2,3)` are of different types

- `(1,2) :: (Int, Int)` and `(1,2,3) :: (Int, Int, Int)`

Conclusion: it is not (directly) possible to define a function accepting tuples of any length.

Outline

Function Types

```
λ> head [1,2,3]
1

λ> tail [1,2,3]
[2,3]
```

Function Types

```
λ> head [1,2,3]
1

λ> tail [1,2,3]
[2,3]

λ> :type head
```

Function Types

```
λ> head [1,2,3]
1

λ> tail [1,2,3]
[2,3]

λ> :type head
head :: [a] -> a
```

Function Types

```
λ> head [1,2,3]
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λ> tail [1,2,3]
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λ> :type tail
```

Function Types

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[2,3]

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head :: [a] -> a

λ> :type tail
tail :: [a] -> [a]
```

Function Types: Polymorphism

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head :: [a] -> a
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`a` is a type variable : `a` can be of any type.

Function Types: Polymorphism

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head :: [a] -> a
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`head` is a function taking a list of any type and returning an element of that type.

Function Types: Polymorphism

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head :: [a] -> a
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`a` is a type variable : `a` can be of any type.

`head` is a function taking a list of any type and returning an element of that type.

`head` is a polymorphic function.

Function Types: Polymorphism

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

`a` is a type variable : `a` can be of any type.

`head` is a function taking a list of any type and returning an element of that type.

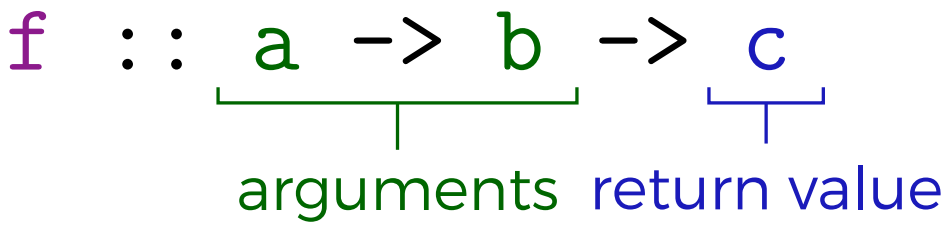
`head` is a polymorphic function.

Types give a rather detailed description of what a function may do.

Function Types: Multiple Arguments

```
f :: a -> b -> c
```

Function Types: Multiple Arguments



Function Types: Multiple Arguments

```
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```

arguments return value

```
f x y :: c
```

Function Types: Multiple Arguments

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f x y :: c

f x :: b -> c
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`f x` is a function of one argument.

Function Types: Multiple Arguments

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f :: a -> b -> c
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f x y :: c

f x :: b -> c
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`f x` is a function of one argument.

```
f :: a -> (b -> c)
```

`f` is a function of one argument returning a function of one argument.

Function Types: Multiple Arguments

```
f :: a -> b -> c
```

arguments return value

```
f x y :: c

f x :: b -> c
```

`f x` is a function of one argument.

```
f :: a -> (b -> c)
```

`f` is a function of one argument returning a function of one argument.

`f x` is called partially applying `f`.

Lists: `take` and `drop`

```
λ> :t take
take :: Int -> [a] -> [a]
```

Lists: take and drop

```
λ> :t take
take :: Int -> [a] -> [a]

λ> take 3 [1..5]
```

Lists: take and drop

```
λ> :t take
take :: Int -> [a] -> [a]
λ> take 3 [1..5]
[1,2,3]

λ> :t drop
drop :: Int -> [a] -> [a]
λ> drop 3 [1..5]
```

Lists: take and drop

```
λ> :t take
take :: Int -> [a] -> [a]
λ> take 3 [1..5]
[1,2,3]

λ> :t drop
drop :: Int -> [a] -> [a]
λ> drop 3 [1..5]
[4,5]
```

Higher-order Functions

Higher-order functions take other functions as arguments.

```
dup :: a -> (a -> a -> b) -> b
```

that's one argument

```
dup x f = f x x
```

Outline

if statement

```
if condition
  then expression
  else expression
```

The newlines are not required.

```
λ> if True then putStrLn "yes" else putStrLn "no"
True
```

Recursion: the Factorial

Recursion: the Factorial

```
factorial :: Int -> Int
```

Recursion: the Factorial

```
factorial :: Int -> Int
factorial x = if x == 0
              then 1
              else x * factorial (x-1)
```

Recursion: the Fibonacci Series

Recursion: the Fibonacci Series

```
fibonacci :: Int -> Int
```

Recursion: the Fibonacci Series

```
fibonacci :: Int -> Int
fibonacci n = if n == 1
              then 1
              else if n == 2
                   then 1
                   else fibonacci (n-1)
                        + fibonacci (n-2)
```

Pattern Matching

How do I write `not` ? (for Booleans)

Pattern Matching

How do I write `not` ? (for Booleans)

```
not :: Bool -> Bool
not True = False
not False = True
```

Better Factorial

Better Factorial

```
factorial :: Int -> Int
factorial 0 = 1
factorial n = n * factorial (n-1)
```

Better Fibonacci Series

Better Fibonacci Series

```
fibonacci :: Int -> Int
fibonacci 1 = 1
fibonacci 2 = 1
fibonacci n = fibonacci (n-1)
            + fibonacci (n-2)
```

Pattern Guards

Pattern Guards

```
fibonacci :: Int -> Int
fibonacci n | n <= 2 = 1
fibonacci n | n > 2 = fibonacci (n-1)
                    + fibonacci (n-2)
```

The first equation will only be picked if `n <= 2`.

The Catch-all Pattern

How to define `isZero`?

The Catch-all Pattern

How to define `isZero`?

```
isZero :: Int -> Bool
isZero 0 = True
isZero _ = False
```

The Catch-all Pattern

How to define `isZero`?

```
isZero :: Int -> Bool
isZero 0 = True
isZero _ = False
```

`_` matches anything, without giving it a name.

Pattern Matching on Lists and Tuples

```
λ> let list = [1,2,3]
λ> let [a,b,c] = list
λ> [c,a,b]
[3,1,2]
```

Pattern Matching on Lists and Tuples

```
λ> let list = [1,2,3]
λ> let [a,b,c] = list
λ> [c,a,b]
[3,1,2]

λ> let (one,_) = (1,2)
λ> one
1
```

Deconstructing Lists

```
λ> let (x:xs) = [1,2,3]
λ> (x,xs)
(1,[2,3])
```

Deconstructing Lists

```
λ> let (x:xs) = [1,2,3]
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```
head :: [a] -> a
```

```
tail :: [a] -> [a]
```

Deconstructing Lists

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λ> let (x:xs) = [1,2,3]
λ> (x,xs)
(1,[2,3])
```

```
head :: [a] -> a
head (x:_) = x

tail :: [a] -> [a]
```

Deconstructing Lists

```
λ> let (x:xs) = [1,2,3]
λ> (x,xs)
(1,[2,3])
```

```
head :: [a] -> a
head (x:_) = x

tail :: [a] -> [a]
tail (_:xs) = xs
```

Outline

Anonymous Functions (Lambda Abstraction)

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(\ arguments -> expression)
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Same thing as `f x y = x + y`

Sections

Partial application of operators.

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(- 2) == (\ x -> x - 2)
(2 -) == (\ x -> 2 - x)
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Fold $=$ apply a function to every element of the list, accumulating a result on the way.

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```
[ 1 , 2 , 3 ]
```

```
1 +
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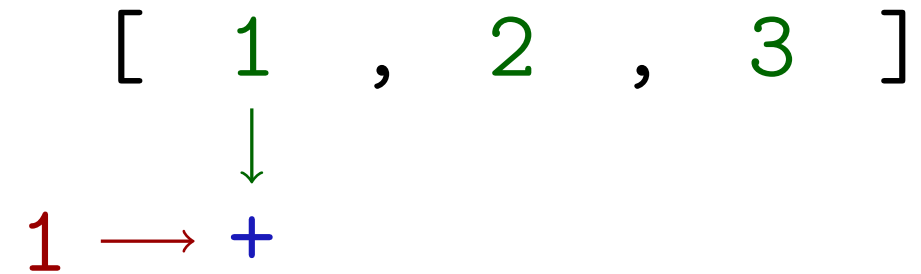

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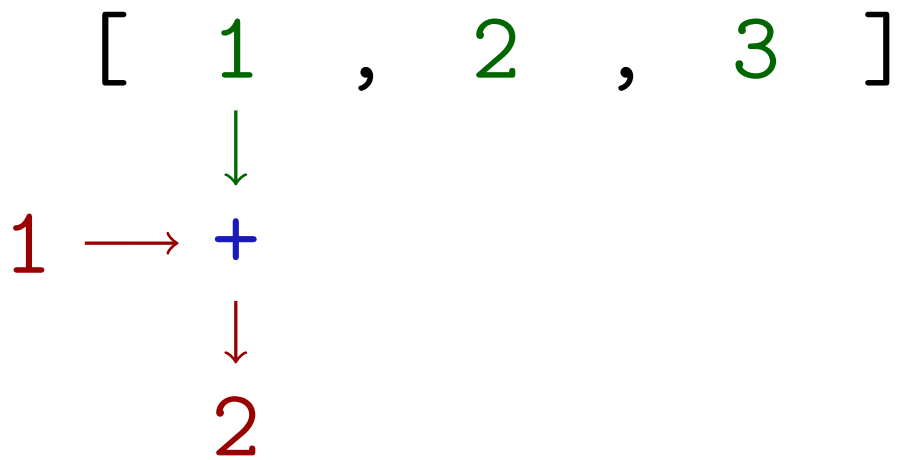

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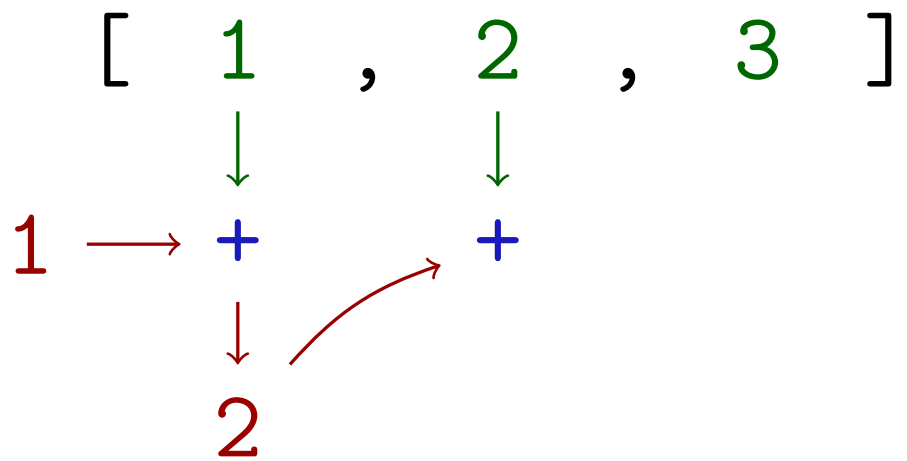

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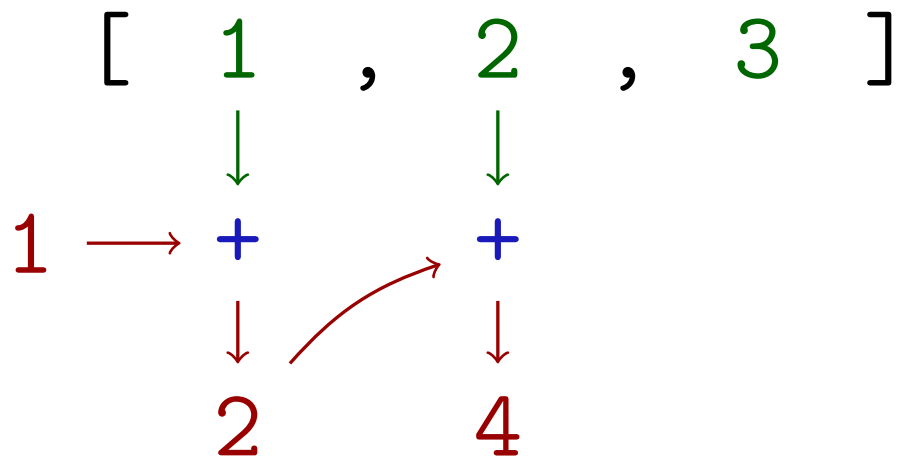

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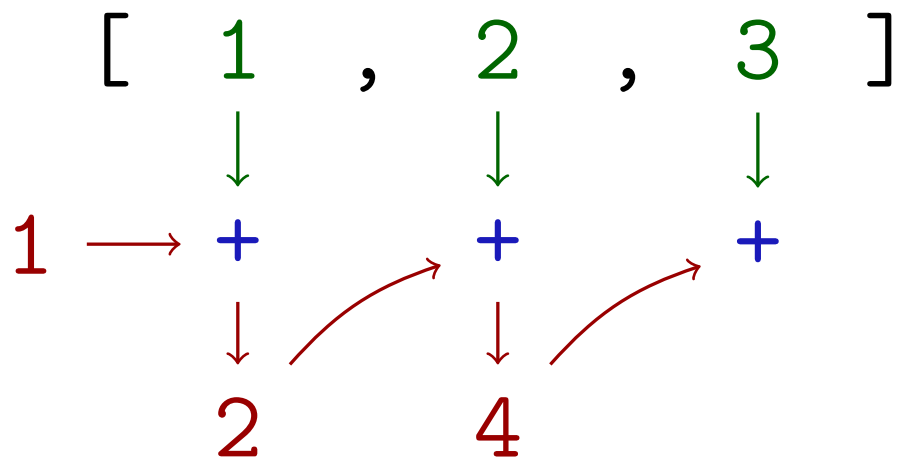

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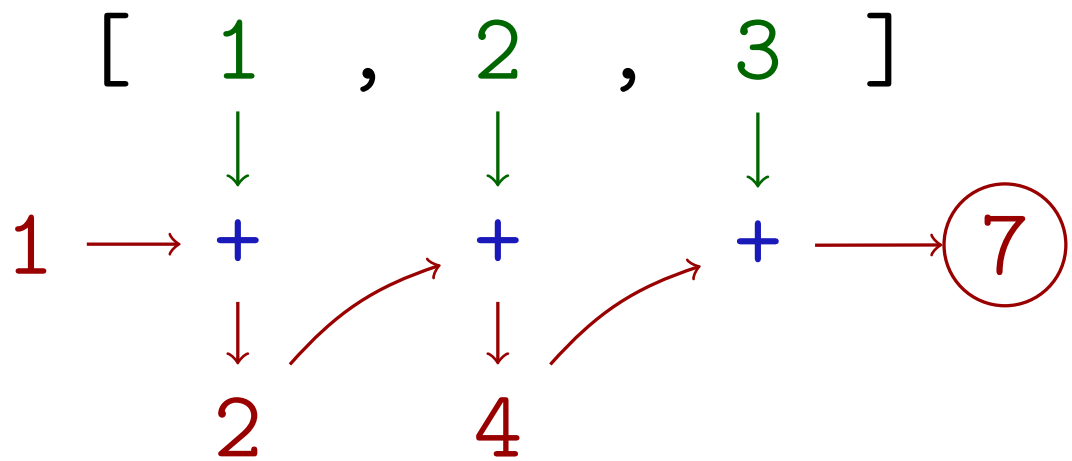

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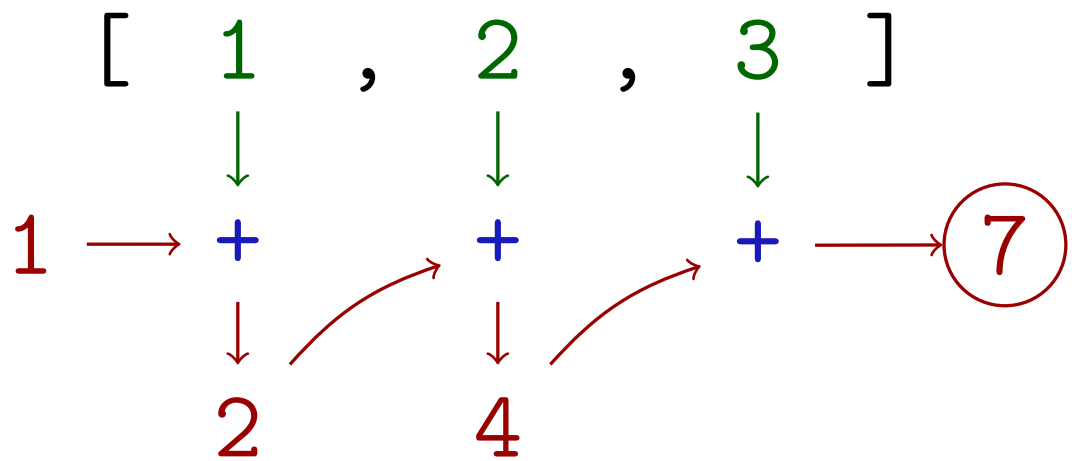

`foldr` does the same thing from the right to the left.

The Rest of the Fun is Online

The code shown during The Fun Session is online!