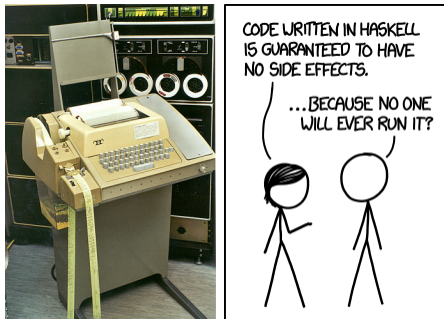


I/O

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Let Blocks: The Third Type of `do` Block Statement Syntax

```
-- let1.hs
```

```
import Data.Char(toUpper)
```

```
main = do      -- The three kinds of syntax for do block statements:
  putStr "First Name? "      -- 1/3: expr
  fname <- getLine           -- 2/3: name <- expr
  putStr "Last Name? "
  lname <- getLine
  let fshout = map toUpper fname  -- 3/3: let decls
      lshout = map toUpper lname  -- in not used in do blocks
  putStrLn $ "WELCOME " ++ fshout ++ " " ++ lshout
```

```
$ stack runhaskell let1
```

```
First Name? Stephen
```

```
Last Name? Edwards
```

```
WELCOME STEPHEN EDWARDS
```

Let is for pure Haskell; <- takes a result from an I/O action

I/O actions are just normal Haskell expressions until connected to *main*

```
-- let2.hs
```

```
printTwo = putStrLn "Two"
```

```
main = do
```

```
    putStrLn "One"
```

```
    let printFour = putStrLn "Four"
```

```
        getMyLine = getLine
```

```
        printThree = putStrLn "Three"
```

```
printTwo
```

```
printThree
```

```
putStrLn "Type something "
```

```
myLine <- getMyLine
```

```
printFour
```

```
putStrLn $ "You typed \"" ++
```

```
    myLine ++ "\""
```

```
$ stack runhaskell let2
```

```
One
```

```
Two
```

```
Three
```

```
Type something OK
```

```
Four
```

```
You typed "OK"
```

The I/O actions in the *let* block don't do anything until they're referenced in the *do* block

Return Encapsulates a Value in a *do* Block

```
readFromUser :: IO String
readFromUser = getLine

justReturn :: IO String
justReturn = do
  putStrLn "justReturn invoked"
  return "this string"

main :: IO ()
main = do
  line1 <- readFromUser
  putStrLn line1
  line2 <- justReturn
  putStrLn "after justReturn"
  putStrLn line2
```

A *do* block returns the value of the last expression, which must be of type `IO t` and cannot be a *let* or `<-`.

Return is a vacuous I/O action that puts a value in an `IO t`

Set the return value of a *do* block with a *return* at the end

```
$ stack runhaskell do1
I typed this
justReturn invoked
after justReturn
this string
```

Basic I/O Functions

```
putChar  :: Char    -> IO ()
putStr   :: String  -> IO ()
putStrLn :: String  -> IO ()      -- Adds a newline
print    :: Show a => a -> IO ()  -- putStrLn . show
```

```
getChar   :: IO Char      -- End-of-file throws an exception
getLine   :: IO String    -- Read up to newline
getContents :: IO String  -- Read entire input (lazily)
interact  :: (String -> String) -> IO () -- Read, apply f, print
readIO    :: Read a => String -> IO a    -- Parse a string in a do
readLn    :: Read a => IO a              -- Read a line and parse
```

```
import Data.Char(toUpper)
main :: IO ()
main = interact $
      map toUpper
```

```
$ stack runhaskell interact < interact.hs
IMPORT DATA.CHAR(TOUPPER)
MAIN :: IO ()
MAIN = INTERACT $
      MAP TOUPPER
```

Implementations of Output Functions

putChar is a primitive

```
putStr      :: String -> IO ()  -- Equivalent to the Prelude def.  
putStr []   = return ()        -- Produces an IO ()  
putStr (x:xs) = do putChar x  
                  putStr xs     -- Recurse
```

```
putStrLn    :: String -> IO ()  
putStrLn s = do putStr s  
                putStr "\n"    -- Print a newline after the string
```

```
print       :: Show a => a -> IO ()  
print x     = putStrLn (show x) -- Transform to string with show
```

Implementations of Input Functions

```
getLine    :: IO String
getLine    =  do c <- getChar
               if c == '\n' then return "" else
               do s <- getLine -- Recurse: get the rest
               return (c:s)
```

```
interact    :: (String -> String) -> IO ()
interact f  =  do hSetBuffering stdin  NoBuffering -- Disable
                  hSetBuffering stdout NoBuffering -- buffering
                  s <- getContents    -- Lazily read all the input
                  putStr (f s)        -- Starts before input is done
```

When is an *if* without an *else* for *do* blocks

```
when :: Bool -> IO () -> IO () -- Prelude definition is more general  
when p s = if p then s else return ()
```

```
-- when.hs  
import Control.Monad(when) -- "Monad" in Category Theory is "Action"  
  
main :: IO ()  
main = do c <- getChar  
         when (c /= ' ') $ do putChar c  
                             main
```

The default is line buffering: a whole line is read before it is examined

```
$ stack runhaskell when  
This-will-stop-at-the-first-space did it?  
This-will-stop-at-the-first-space$
```


sequence Applies a List of I/O Actions and Captures the Result

```
sequence :: [IO a] -> IO [a] -- Prelude definition is more general
```

```
main :: IO () -- Like Unix head: print the first 10 input lines
main = do
    inputLines <- sequence $ replicate 10 getLine
    sequence_ $ map putStrLn inputLines -- sequence_ discards result
```

`mapM` or `mapM_`, which discards the result, is better for the second *sequence*

```
mapM   :: (a -> IO b) -> [a] -> IO [b] -- Not the actual type;
mapM_ :: (a -> IO b) -> [a] -> IO ()   -- Prelude def. is more general
```

```
main :: IO ()
main = do
    inputLines <- sequence $ replicate 10 getLine
    mapM_ putStrLn inputLines -- Apply putStrLn to lines, return IO ()
```

forM and *forM_* are just *mapM* with arguments reversed

Why? Because it makes *forM* look like a traditional *for* loop (well, *foreach*)

```
import Control.Monad(forM, forM_)

main :: IO ()
main = do
  colors <- forM ([1..4] :: [Int]) $ \a -> do
    putStrLn $ "What color is #" ++ show a ++ "?"
    getLine                                     -- Result saved in colors
  putStrLn "You ranked the colors"
  forM_ colors putStrLn                       -- forM_ returns IO ()
```

The version in *Learn You a Haskell...* is redundant:

```
colors <- forM [1,2,3,4] (\a -> do -- Unnecessary parentheses
  putStrLn $ "Which .."
  color <- getLine
  return color)                  This is what getLine would return anyway
```

```
*Main> main
```

```
What color is #1?
```

```
Red
```

```
What color is #2?
```

```
Green
```

```
What color is #3?
```

```
Blue
```

```
What color is #4?
```

```
Black
```

```
You ranked the colors
```

```
Red
```

```
Green
```

```
Blue
```

```
Black
```

```
mapM f as = sequence (map f as)    -- Prelude definitions
```

```
forM = flip mapM
```

Forever Loops Forever

```
-- forever.hs
import Control.Monad(forever)
import Data.Char(toUpper)

main :: IO ()
main = forever $ do
  l <- getLine
  putStrLn $ map toUpper l
```

```
$ stack runhaskell forever < forever.hs
-- FOREVER.HS
IMPORT CONTROL.MONAD(FOREVER)
IMPORT DATA.CHAR(TOUPPER)

MAIN :: IO ()
MAIN = FOREVER $ DO
  L <- GETLINE
  PUTSTRNLN $ MAP TOUPPER L
forever: <stdin>: hGetLine: end of file
```

```

import System.IO(openFile, IOMode(ReadMode), hGetContents,
                  hClose, hPutStrLn, stderr)
import System.Exit(exitFailure); import Data.Char(isAlpha, toLower)
import System.Environment(getArgs, getProgName)

main :: IO () -- Report whether each line of a file is a palindrome
main = do args <- getArgs
      case args of
        [filename] -> do -- Expects one filename
          h <- openFile filename ReadMode
          contents <- hGetContents h -- Read the file
          mapM_ (putStrLn . isAPalindrome) $ lines contents
          hClose h
        _ -> do pn <- getProgName -- Usage message
          hPutStrLn stderr $ "Usage: " ++ pn ++ " <filename>"
          exitFailure -- Terminate the program

isAPalindrome :: String -> String -- Report whether the string is one
isAPalindrome s = s ++ ": " ++ show (ls == reverse ls)
      where ls = map toLower $ filter isAlpha s

```

palindromes.txt:

Able was I saw elba

Taco cat

Race car

Palindrome

A man, a plan, a canal, Panama!

```
$ stack runhaskell palindrome palindromes.txt
```

Able was I saw elba: True

Taco cat: True

Race car: True

Palindrome: False

A man, a plan, a canal, Panama!: True

```
-- System.Environment    Command-line args; environment variables
getArgs :: IO [String]   -- The list of command-line arguments
getProgName :: IO String -- Name of the invoked program (argv[0])

-- System.IO    File Handle; open; close; read; write; "h" I/O action variants
type FilePath = String
openFile :: FilePath -> IOMode -> IO Handle
data IOMode = ReadMode | WriteMode | AppendMode | ReadWriteMode
stderr :: Handle                -- Handle for standard error
hGetContents :: Handle -> IO String -- getContents from a Handle
hPutStrLn :: Handle -> String -> IO () -- putStrLn to a Handle
hClose :: Handle -> IO ()              -- Close the (file) handle
withFile :: FilePath -> IOMode -> (Handle -> IO r) -> IO r
readFile :: FilePath -> IO String

-- System.Exit    Like exit() in the C standard library
exitFailure :: IO a -- Terminate program with a failure code
```

```
import System.IO(withFile, IOMode(ReadMode), hGetContents,
                  hPutStrLn, stderr)
import System.Exit(exitFailure); import Data.Char(isAlpha, toLower)
import System.Environment(getArgs, getProgName)

main :: IO ()
main = do args <- getArgs
        case args of
            [filename] -> do
                withFile filename ReadMode (\h -> do  -- Simpler
                    contents <- hGetContents h
                    mapM_ (putStrLn . isAPalindrome) $ lines contents)
            _ -> do pn <- getProgName
                    hPutStrLn stderr $ "Usage: " ++ pn ++ " <filename>"
                    exitFailure

isAPalindrome :: String -> String
isAPalindrome s = s ++ ": " ++ show (ls == reverse ls)
                where ls = map toLower $ filter isAlpha s
```



```
import System.IO(readFile)
import System.Exit(die); import Data.Char(isAlpha, toLower)
import System.Environment(getArgs, getProgName)

main :: IO ()
main = do args <- getArgs
      case args of
        [filename] -> do
          contents <- readFile filename -- Even simpler
          mapM_ (putStrLn . isAPalindrome) $ lines contents
        _ -> do pn <- getProgName
                die $ "Usage: " ++ pn ++ " <filename>"

isAPalindrome :: String -> String
isAPalindrome s = s ++ ": " ++ show (ls == reverse ls)
                where ls = map toLower $ filter isAlpha s
```

-- More in System.IO

```
hGetChar      :: Handle -> IO Char
hGetLine      :: Handle -> IO String
hPutStr       :: Handle -> String -> IO ()
hFlush        :: Handle -> IO ()
data BufferMode
  = NoBuffering | LineBuffering | BlockBuffering (Maybe Int)
hSetBuffering :: Handle -> BufferMode -> IO ()
openTempFile  :: FilePath -> String -> IO (FilePath, Handle)
writeFile     :: FilePath -> String -> IO ()
appendFile    :: FilePath -> String -> IO ()
```

-- System.Directory

```
removeFile    :: FilePath -> IO ()
renameFile     :: FilePath -> FilePath -> IO ()
renamePath     :: FilePath -> FilePath -> IO ()
listDirectory  :: FilePath -> IO [FilePath]
```

ByteString: Faster strings

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

Data.ByteString implements strings as packed Word8 (byte) arrays:
compact and faster

Data.ByteString is strict (no laziness, infinite lists, etc.)

Data.ByteString.Lazy is “lazy” on 64K blocks

Data.ByteString.Char8 and Data.ByteString.Lazy.Char8 work with Char8
arrays instead of Word8

“grep” with String

```
import Data.List(isInfixOf)
import System.Environment(getArgs, getProgName)
import System.Exit(die)

main :: IO ()
main = do args <- getArgs
        (pat, filename) <- case args of
            [p, f] -> return (p, f)
            _ -> do pn <- getProgName
                    die $ "Usage: "++pn++" <pattern> <filename>"
        file <- readFile filename
        putStr $ grep pat file

grep :: String -> String -> String
grep pat input =
    unlines $ filter (isInfixOf pat) $ lines input
```

“grep” with Data.ByteString.Char8

```
import qualified Data.ByteString.Char8 as B
import System.Environment(getArgs, getProgName)
import System.Exit(die)

main :: IO ()
main = do args <- getArgs
        (pat, filename) <- case args of
            [p, f] -> return (p, f)
            _ -> do pn <- getProgName
                    die $ "Usage: "++pn++" <pattern> <filename>"
        file <- B.readFile filename
        B.putStr $ grep (B.pack pat) file
                -- pack :: String -> ByteString
grep :: B.ByteString -> B.ByteString -> B.ByteString
grep pat input =
    B.unlines $ filter (B.isInfixOf pat) $ B.lines input
```

“grep” with Data.ByteString.Lazy.Char8

```
import qualified Data.ByteString.Lazy.Char8 as B
import System.Environment(getArgs, getProgName)
import System.Exit(die)

main :: IO ()
main = do args <- getArgs
        (pat, filename) <- case args of
            [p, f] -> return (p, f)
            _ -> do pn <- getProgName
                    die $ "Usage: "++pn++" <pattern> <filename>"
        file <- B.readFile filename
        B.putStr $ grep (B.pack pat) file
                -- pack :: String -> ByteString
grep :: B.ByteString -> B.ByteString -> B.ByteString
grep pat input =
    B.unlines $ filter (isInfixOf pat) $ B.lines input where
    isInfixOf p s = any (B.isPrefixOf p) $ B.tails s
```

Quick Experiment

Selecting 3500 lines that contain “fe” from a 49M/218 kl log file:

```
$ stack ghc -- --make -O bgrep.hs  
$ /usr/bin/time -f "%E %M" ./bgrep fe /tmp/log > /dev/null
```

Version	Time	Memory	Note
String	2600 ms	6.2 MB	[Char]
ByteString.Lazy	1300 ms	6.2 MB	64K blocks
ByteString	110 ms	56 MB	Single byte array; naïve isInfixOf
grep	40 ms	2.5 MB	GNU implementation; >3000 LoC

Exceptions

TL;DR: Don't use 'em; use something like *Maybe* or *Either*

Work best in I/O contexts (sequential evaluation; lots to go wrong)

Only I/O code can catch exceptions, but they may be thrown anywhere

Some of the I/O exception handling functions in `System.IO.Error`:

```
catchIOError      :: IO a -> (IOError -> IO a) -> IO a
isUserError       :: IOError -> Bool
isDoesNotExistError :: IOError -> Bool
isPermissionError :: IOError -> Bool
ioeGetFileName     :: IOError -> Maybe FilePath
```

More extensive exception facilities in `Control.Exception`

Line Count with some error checking

```
import System.Environment(getArgs)
import System.IO.Error(catchIOError, isUserError,
                        isDoesNotExistError, ioeGetFileName, isPermissionError)
import System.Exit(die)
import qualified Data.ByteString.Char8 as B

main :: IO ()
main = do [filename] <- getArgs           -- Match may fail
          contents <- B.readFile filename -- Many possible failures
          print $ length $ B.lines contents

`catchIOError` \ e -> die $ case ioeGetFileName e of

    Just fn | isDoesNotExistError e -> fn ++ ": No such file"
            | isPermissionError e   -> fn ++ ": Permission denied"
    _       | isUserError e         -> "Usage: lc <filename>"
            | otherwise              -> show e
```

Line Count in Action

```
$ stack ghc -- --make -O -Wall lc.hs
[1 of 1] Compiling Main                ( lc.hs, lc.o )
Linking lc ...
$ ./lc
Usage: lc <filename>
$ ./lc foo bar
Usage: lc <filename>
$ ./lc foo
foo: No such file
$ ./lc /var/log/btmp
/var/log/btmp: Permission denied
$ ./lc /var/log/syslog
4705
```