Reader & ReaderT Monad (11A)

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8/21/18

Please send corrections (or suggestions) to youngwlim@hotmail.com.

This document was produced by using LibreOffice.

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8/21/18

Based on

Haskell in 5 steps
https://wiki.haskell.org/Haskell_in_5_steps

Reader, ReaderT, MonadReader

MonadReader is not a **monad**.

MonadReader is is the **class** of all monads

that can read from some **environment**.

Reader is an **instance** of **MonadReader**,

but doesn't do anything else, except that it only acts as a **reader**,

ReaderT is the **reader monad transformer**,

which adds a read-only **environment** (**r**) to the given **monad** (**m**).

Generally, **instance monads** are defined

as a **monad transformer stack** with a **ReaderT** in somewhere

MonadReader	– class
Reader	– an **instance**
ReaderT	– another **instance**

https://stackoverflow.com/questions/39366069/reader-and-monadreader

Reader v.s. ReaderT

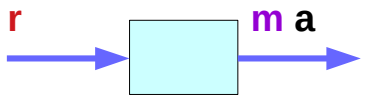
Reader has **ReaderT** only applied to the trivial **identity monad**:

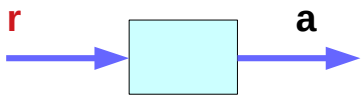
```
type Reader r = ReaderT r Identity
```

MonadReader includes **Reader** itself,
but also **MaybeT (ReaderT Int (ListT IO)).**

```
newtype   ReaderT r m a   = ReaderT { runReaderT :: r -> m a }

type      Reader r a      = ReaderT r Identity a                  (1)
                          = Reader { runReader :: r -> Identity a }
newtype   Reader r a      = Reader { runReader :: r -> a }        (2)
```





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Reader Monad

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

Reader Monad

```
newtype Reader e a = Reader { runReader :: (e -> a) }

instance Functor (Reader r) where
  fmap f (Reader f') = Reader $ f . f'

instance Applicative (Reader r) where
  pure a = Reader (const a)
  (Reader f) <*> (Reader f') = Reader $ \r -> f r (f' r)

instance Monad (Reader r) where
  return a = Reader $ \_ -> a
  m >>= k  = Reader $ \r -> runReader (k (runReader m r)) r  -- (1)

  (Reader e) >>= f  = Reader $ \r -> runReader (f (e r)) r        -- (2)
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
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Implementing ReaderT

Reader Monad type definition

A **Reader** is a data type that encapsulates an **environment**.

The **runReader** function

takes an **environment** (a **reader** of type **r**)

and runs it (**r -> a**),

producing the **result** of type **a**.

```
newtype Reader r a = Reader { runReader :: r -> a }
```

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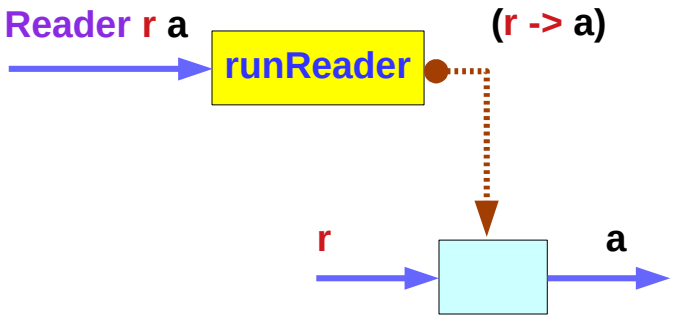
Implementing ReaderT

Reader Monad runReader Function

```
newtype Reader r a = Reader { runReader :: r -> a }
```

With the **record** syntax, the type of **runReader** is actually

```
runReader :: Reader r a -> (r -> a)
```



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Implementing ReaderT

Reader Monad Record Syntax

```
newtype Reader r a = Reader { runReader :: r -> a }
```

```
Reader function     r -> a

Reader $ r -> r + 1

Reader $ r -> "reader2: " ++ (show r)
```

initializing a record

```
Car "Ford" "Mustang" 1967
```

```
data Car = Car { company :: String, model :: String, year :: Int }

(1)   Car { company = "Ford", model = "Mustang", year = 1967 }

(2)   Car   "Ford"   "Mustang"   1967          -- no commas
```

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Implementing ReaderT

Reader Monad Example

Consider a **Reader** that increments its **environment value**,
returning the same type:

```
reader1 :: Num r => Reader r r
reader1 = Reader $ r -> r + 1
runReader reader1 100
> 101
```

Another **Reader** that converts its environment value into a **string**:

```
reader2 :: Show r => Reader r String
reader2 = Reader $ r -> "reader2: " ++ (show r)
runReader reader2 100
> "reader2: 100"
```

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Implementing ReaderT

Reader Monad – a runReader implementation

runReader is just taking the **function (r -> a)**

out of the data type **Reader r a**

a possible implementation

```
runReader' :: Reader r a -> (r -> a)
runReader' (Reader f) = f

reader1 :: Reader r r
reader1 = Reader $ r -> r + 1

runReader' reader1 100
> 101
```

```
f :: (r -> a)  -- function type
```

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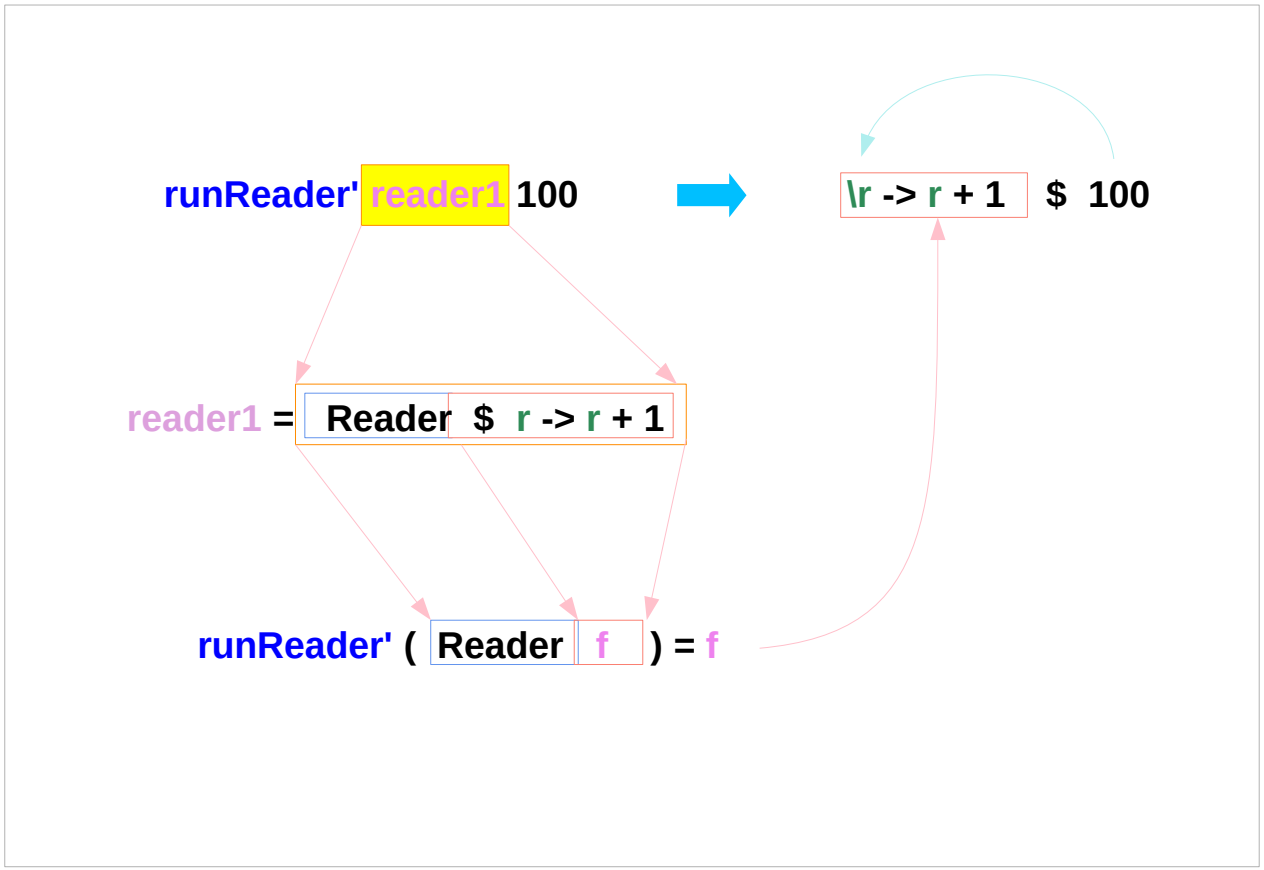
Implementing ReaderT

Reader Monad – pattern matching in runReader




```
runReader' :: Reader r a -> (r -> a)
runReader' (Reader f) = f

reader1 :: Reader r r
reader1 = Reader $ r -> r + 1

runReader' reader1 100
> 101
```

Reader ≠ Reader
Type Data

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
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Implementing ReaderT

Reader Monad – implementation (I)

make **Reader** an **instance** of **Monad**:

```
newtype Reader r a = Reader { runReader :: r -> a }

instance Monad (Reader r) where
  -- return :: a -> Reader r a
  return a = Reader $ \_ -> a
  -- (>>=) :: forall a b . Reader r a -> (a -> Reader r b) -> Reader r b
  m >>= k  =  Reader $ \r -> runReader (k (runReader m r)) r
    -- Reader $ \r -> runReader (k (runReader m r :: a) :: Reader r b) r
```

comparison with (->) r monad

(m >>= k) r = k (m r) r

m : a function (a monadic value)
r : a value
m r : a value (the result)
k (m r) : a function (a monadic value)
k (m r) r : a value (the result)

```
m :: Reader r
runReader m r :: a
runReader (k (runReader m r)) r :: b
```

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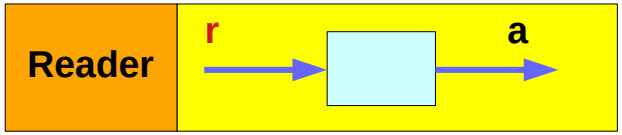
Implementing ReaderT

Reader Monad – implementation (I) – runReader m

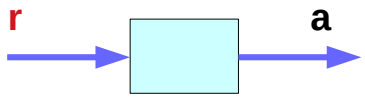
```
newtype Reader r a = Reader { runReader :: r -> a }

m >>= k  =  Reader $ \r -> runReader (k (runReader m r)) r
```

m :: Reader r



runReader m :: r->a
runReader m r :: a



comparison with (->) r monad

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m :: Reader r
runReader m r :: a
runReader (k (runReader m r)) r :: b

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Implementing ReaderT

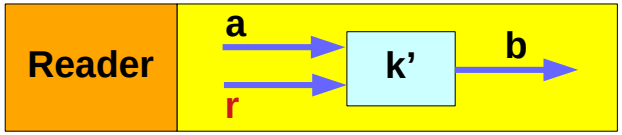
Reader Monad – implementation (I) – runReader k

```
newtype Reader r a = Reader { runReader :: r -> a }

m >>= k  =  Reader $ \r -> runReader (k (runReader m r)) r
```

m >>= k, k :: Reader r

k' :: a->r->b



runReader m :: r->a

runReader m r :: a

runReader k :: a->r->b k' :: a->r->b

runReader (k (runReader m r)) :: r->b

runReader (k (runReader m r)) r :: b

comparison with (->) r monad

(m >>= k) r = k (m r) r

m : a function (a monadic value)
r : a value
m r : a value (the result)
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k (m r) r : a value (the result)

m :: Reader r

runReader m r :: a

runReader (k (runReader m r)) r :: b

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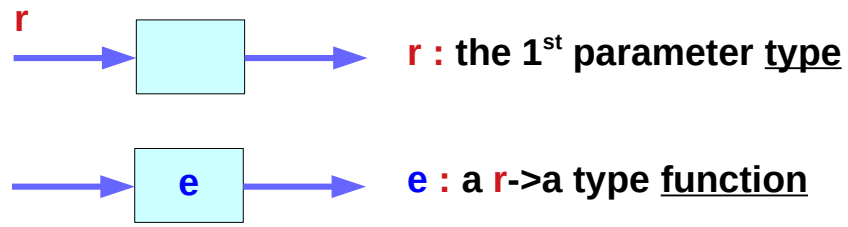
Implementing ReaderT

Reader Monad – implementation (II)

```
newtype Reader r a = Reader { runReader :: r -> a }

instance Monad (Reader r) where
   return a        = Reader $ \r -> a
   (Reader e) >>= f = Reader $ \r -> runReader (f (e r)) r
```



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(m >>= f) r = f (m r) r

m : a function (a monadic value)
r : a value
m r : a value
f (m r) : a function (a monadic value)
f (m r) r : a value

Reader ≠ Reader
Type Data

https://wiki.haskell.org/All_About_Monads
https://www.reddit.com/r/haskellquestions/comments/6r46zp/applicative_instance_for_reader/

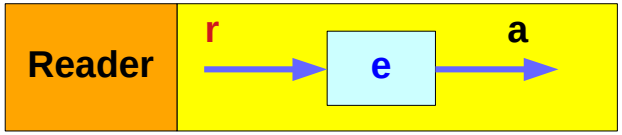
Implementing ReaderT

Reader Monad – implementation (II) – Reader e

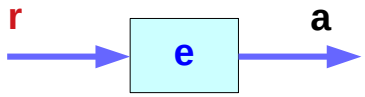
```
newtype Reader r a = Reader { runReader :: r -> a }

(Reader e) >>= f = Reader $ \r -> runReader (f (e r)) r
```

m = Reader e :: Reader r



runReader m :: r->a
runReader m r :: a



e = runReader m :: r->a
e r = runReader m r :: a

comparison with (->) r monad

(m >>= f) r = f (m r) r

m : a function (a monadic value)
r : a value
m r : a value
f (m r) : a function (a monadic value)
f (m r) r : a value

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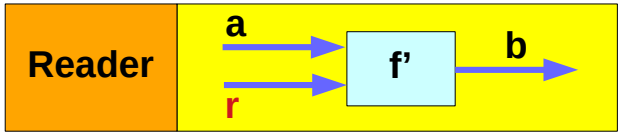
Implementing ReaderT

Reader Monad – implementation (II) – runReader k

```
newtype Reader r a = Reader { runReader :: r -> a }

(Reader e) >>= f = Reader $ \r -> runReader (f (e r)) r
```

```
m >>= f, f :: Reader r
 f' :: a->r->b
```




```
runReader m :: r->a
runReader m    r :: a
runReader f :: a->r->b
```

f' :: a->r->b

```
runReader (f (e r)) :: r->b
runReader (f (e r))    r :: b
```

comparison with (->) r monad

(m >>= f) r = f (m r) r

m : a function (a monadic value)
r : a value
m r : a value (the result)
f (m r) : a function (a monadic value)
f (m r) r : a value (the result)

```
m :: Reader r
runReader m r :: a
runReader (f (runReader m r)) r :: b
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
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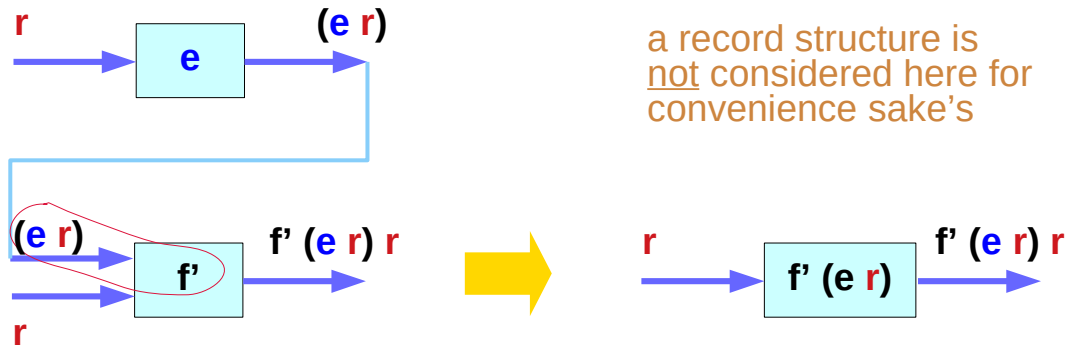
Implementing ReaderT

Reader Monad – implementation (II) – >>=

```
newtype Reader r a = Reader { runReader :: r -> a }

(Reader e) >>= f = Reader $ \r -> runReader (f (e r)) r
```



comparison with (->) r monad

(m >>= f) r = f (m r) r

m : a function (a monadic value)
r : a value
m r : a value
f (m r) : a function (a monadic value)
f (m r) r : a value

```
(>>=) :: (r->a) -> (a->r->b) -> (r->b)

    m :: r->a
    f :: a->r->b
    m>>=f :: r->b
```

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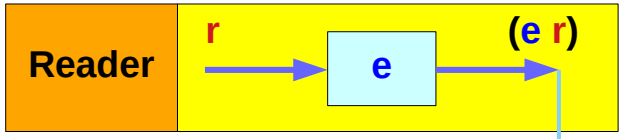
Implementing ReaderT

Reader Monad – implementation (II) – f' and f

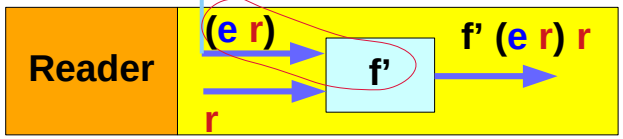
```
instance Monad (Reader r) where
   return a        = Reader $ \r -> a
   (Reader e) >>= f = Reader $ \r -> runReader (f (e r)) r

newtype Reader r a = Reader { runReader :: r -> a }
```

e ➡ (Reader e)



f' ➡ (Reader f') = f



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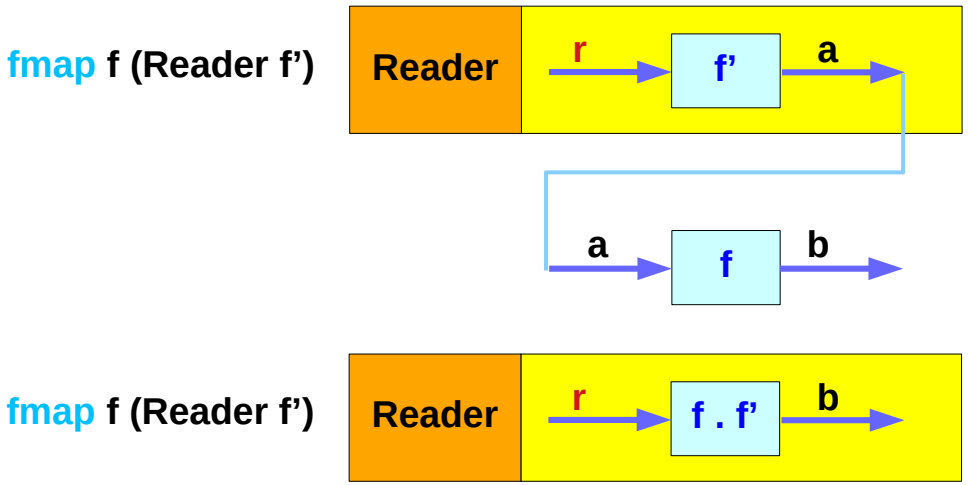
Implementing ReaderT

Reader Functor Implementation – fmap

```
instance Functor (Reader r) where
 -- fmap :: (a -> b) -> Reader r a -> Reader r b
   fmap f (Reader f') = Reader $ f . f'
```



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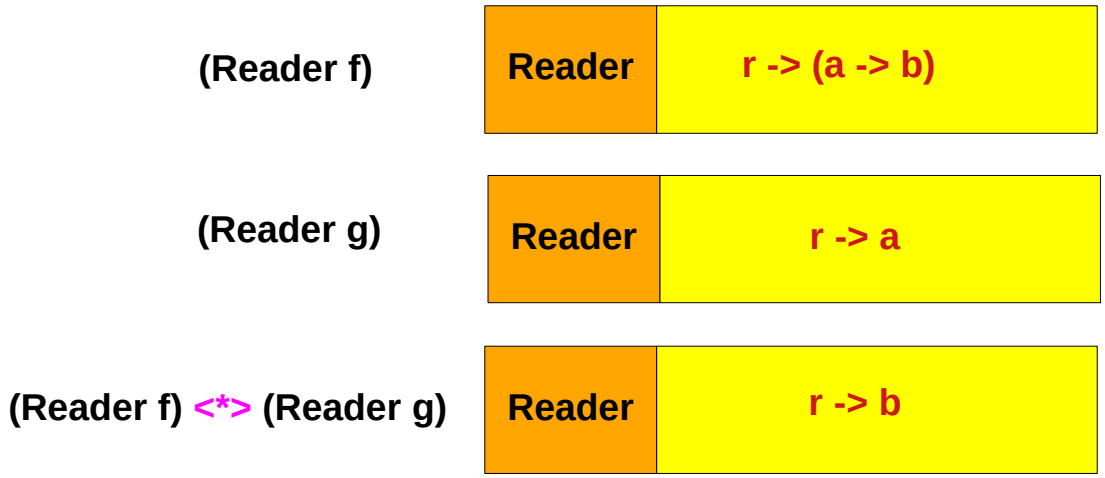
Implementing ReaderT

Reader Applicative Implementation – <*> type signature

```
instance Applicative (Reader r) where
 -- pure :: a -> Reader r a
    pure a = Reader (const a)
 -- (<*>) :: Reader r (a -> b) -> Reader r a -> Reader r b
    (Reader f) <*> (Reader g) = Reader $ \r -> f r (g r)
```



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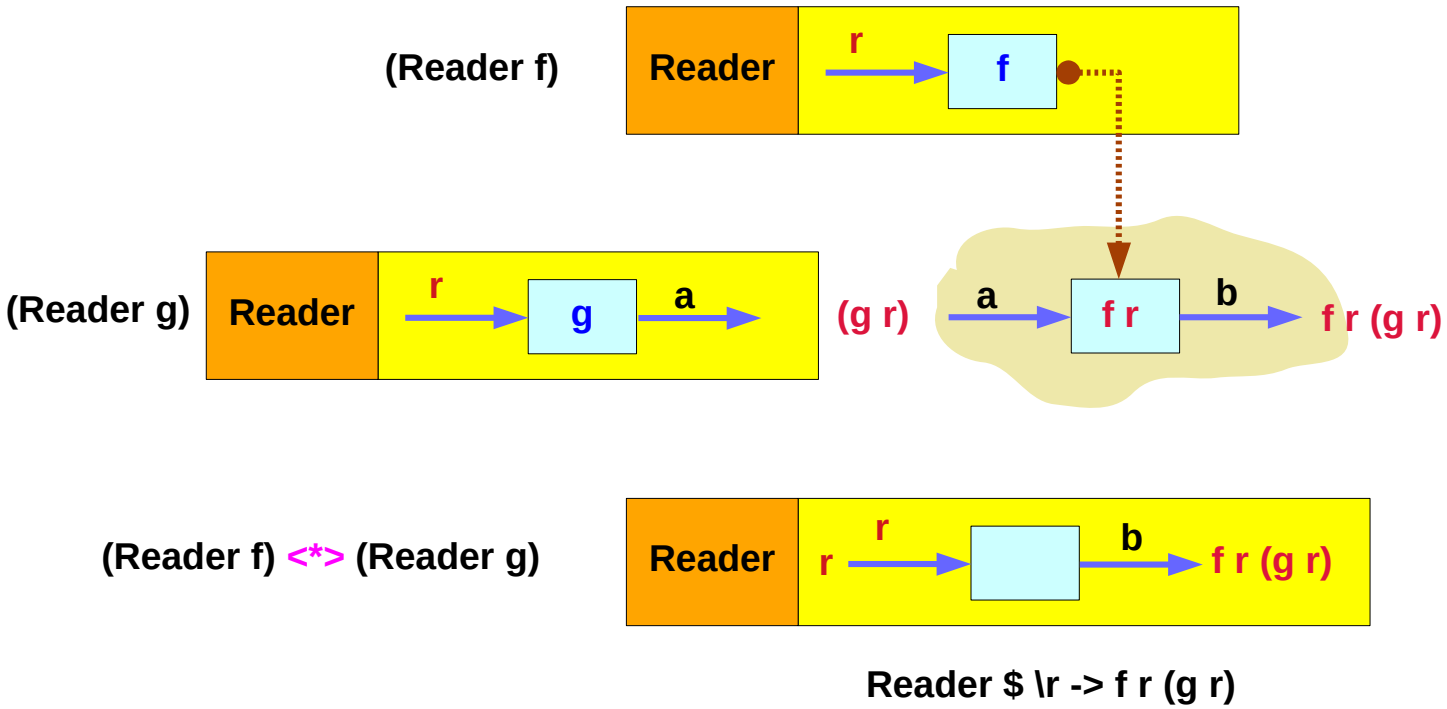
Implementing ReaderT

Reader Applicative Implementation – <*>

```
-- (<*>) :: Reader r (a -> b) -> Reader r a -> Reader r b
  (Reader f) <*> (Reader g) = Reader $ \r -> f r (g r)
```



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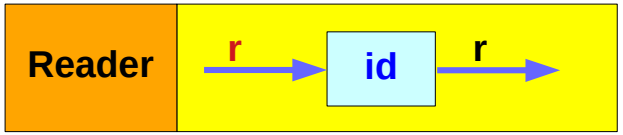
Implementing ReaderT

Reader Monad – examples eg1

```
eg1 :: Reader Int String
eg1 = Reader id >>= \e -> return $ "hey, " ++ show e
```

```
ghci> runReader eg1 100
"hey, 100"
```

Note that we use **id** to produce a **Reader**
that just passes its **environment** argument along as the **output**.
See **readerAsk** later for the equivalent situation
which uses return for **MonadReader**.



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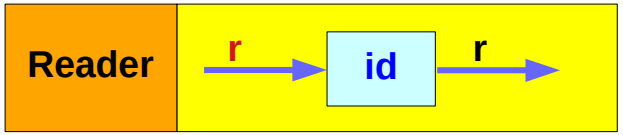
Implementing ReaderT

Reader Monad – examples eg1'

```
eg1' :: Reader Int String
eg1' = do e <- Reader id
          return $ "hey, " ++ show e

ghci> runReader eg1' 100
"hey, 100"
```

Note that we use **id** to produce a **Reader**
that just passes its **environment** argument along as the **output**.
See **readerAsk** later for the equivalent situation
which uses return for **MonadReader**.



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Implementing ReaderT

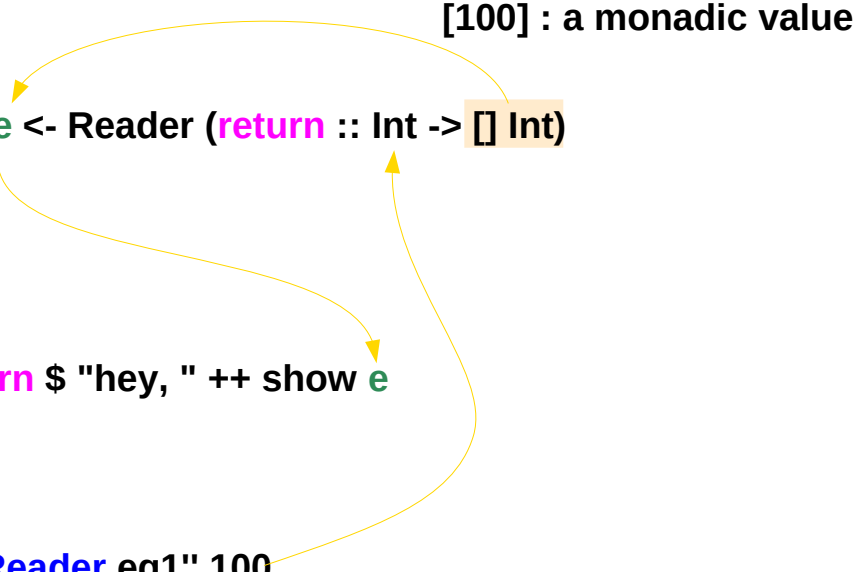
Reader Monad – examples eg1''

```
eg1" :: Reader Int String
```

[100] : a monadic value

```
eg1" = do e <- Reader (return :: Int -> [] Int)
          return $ "hey, " ++ show e

ghci> runReader eg1" 100
"hey, [100]"
```



ambiguous type variable 'm0' arising from a use of 'return'

Need to specify the type signature

use a **type annotation**

return of Monad m
return :: a -> m a
return :: Int -> [] Int

[] is an **instance** of **Monad**
[100] : a monadic value

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Implementing ReaderT

Reader Monad – src (1)

```
newtype Reader e a = Reader { runReader :: (e -> a) }

instance Functor (Reader r) where
  fmap f (Reader f') = Reader $ f . f'

instance Applicative (Reader r) where
  pure a = Reader (const a)
  (Reader f) <*> (Reader f') = Reader $ \r -> f r (f' r)

instance Monad (Reader r) where
  return a = Reader $ \_ -> a
-- m >>= k  = Reader $ \r -> runReader (k (runReader m r)) r  -- (1)
-- (Reader e) >>= f  = Reader $ \r -> runReader (f (e r)) r        -- (2)
  (Reader e) >>= f  = Reader $ \r -> runReader (f (e r)) r        -- (2)
```

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Implementing ReaderT

Reader Monad – src2

```
eg1 :: Reader Int String
eg1 = Reader id >>= \e -> return $ "hey, " ++ show e

eg1' :: Reader Int String
eg1' = do e <- Reader id
          return $ "hey, " ++ show e

eg1'' = do e <- Reader (return:: Int -> [] Int)
           return $ "hey, " ++ show e



----
*Main> runReader eg1 100
"hey, 100"
*Main> runReader eg1' 101
"hey, 101"
*Main> runReader eg1'' 102
"hey, [102]"
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Monad Transformer

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer

```
newtype ReaderT r m a = ReaderT { runReaderT :: r -> m a }

instance (Functor m) => Functor (ReaderT r m) where
   fmap f  = mapReaderT (fmap f)

instance (Applicative m) => Applicative (ReaderT r m) where
   pure    = liftReaderT . pure
   f <*> v = ReaderT $ \r -> runReaderT f r <*> runReaderT v r

instance (Monad m) => Monad (ReaderT r m) where
  return a = ReaderT $ \_ -> return a  -- (1)
  return = liftReaderT . return        -- (2)
  return = liftReaderT . pure          -- (3)

  h >>= k = ReaderT $ \r -> do
     a <- runReaderT h r
     runReaderT (k a) r
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer

ReaderT is the **transformer** version of **Reader**.
can add the **first argument threading** capabilities of **Reader**
with another **Monad**.

ReaderT e IO.

One advantage of using **ReaderT** directly is
that there is a more expressive version of **local**

Unlike **local**, **withReaderT** can change
the type of the **environment** from **r** to **r'**.

1st argument - reader e
monad IO.

https://hackernoon.com/the-reader-monad-part-1-1e4d947983a8

Implementing ReaderT

ReaderT Transformer – typeclass definition

to use the **Reader** in conjunction with other **monads**,
create a **transformer ReaderT**:

for example, running **IO actions** and also
having access to the **reader's environment**.

```
newtype ReaderT r m a = ReaderT { runReaderT :: r -> m a }
```

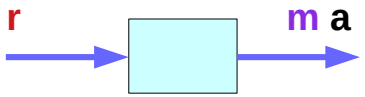
- **r** : the **reader environment**
- **m** : the **monad** (eg. **IO**)
- **a** : the **result** type of the **monad**

The type signature of the accessor function **runReaderT**:

```
runReaderT :: ReaderT r m a -> (r -> m a)
```

ReaderT r m a

r -> m a



https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – runReaderT

```
newtype ReaderT r m a = ReaderT { runReaderT :: r -> m a }

runReaderT :: ReaderT r m a -> (r -> m a)
runReaderT (ReaderT f) = f
```

runReaderT

runReaderT takes a ReaderT type — ReaderT

and returns a function — (r -> m a)

that takes a reader environment of type r

and produces a monadic value m a

```
runReader' :: Reader r a -> (r -> a)
runReader' (Reader f) = f
```

runReader

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – ReaderT instance

```
instance (Monad m) => Monad (ReaderT r m) where
   return a = ReaderT $ \_ -> return a
   h >>= k  = ReaderT $ \r -> do
      a <- runReaderT h r
      runReaderT (k a) r
   fail msg = ReaderT $ \_ -> fail msg

runReaderT :: ReaderT r m a -> (r -> m a)
runReaderT (ReaderT f) = f
```

```
instance Monad (Reader r) where
  return a = Reader $ \_ -> a
  m >>= k  =  Reader $ \r -> runReader (k (runReader m r)) r
```

ReaderT r m

ReaderT r m a

r -> m a

h :: ReaderT r m

Reader r

m :: Reader r

https://downloads.haskell.org/~ghc/6.8.3/docs/html/libraries/mtl/src/Control-Monad-Reader.html

Implementing ReaderT

ReaderT Transformer – ReaderT summary

```
newtype ReaderT r m a = ReaderT { runReaderT :: r -> m a }

runReaderT :: ReaderT r m a -> (r -> m a)
runReaderT (ReaderT f) = f



instance (Monad m) => Monad (ReaderT r m) where
   return a = ReaderT $ \_ -> return a
   h >>= k  = ReaderT $ \r -> do
      a <- runReaderT h r
      runReaderT (k a) r
   fail msg = ReaderT $ \_ -> fail msg
```

ReaderT r m

f :: (r -> m a)

https://downloads.haskell.org/~ghc/6.8.3/docs/html/libraries/mtl/src/Control-Monad-Reader.html

Implementing ReaderT

ReaderT Transformer – >>= bind operator

```
h >>= k  = ReaderT $ \r -> do
   a <- runReaderT h r
   runReaderT (k a) r


(>>=) :: ReaderT r m a -> (a -> ReaderT r m b) -> ReaderT r m b

    h           :: ReaderT r m a
    k           :: a -> ReaderT r m b
    h >>= k     :: ReaderT r m b
```

ReaderT r m

https://downloads.haskell.org/~ghc/6.8.3/docs/html/libraries/mtl/src/Control-Monad-Reader.html

Implementing ReaderT

ReaderT Transformer – liftReaderT

```
liftReaderT :: m a -> ReaderT r m a
liftReaderT m = ReaderT (\_ -> m)
```

with a **ReaderT** as the **outer monad**,
it is desired to impart the **reader capability** **lift**
to a **monadic computation**

when a **monadic action m** has nothing to do
with the **reader environment r**

In order to **lift** such a **monadic value m**,
liftReaderT does not take the **environment**:
but return a **ReaderT** monad value

Outer ReaderT monad
lift all monads to ReaderT

LiftReaderT does not use
environment r but return
ReaderT monad value

```
m a -> ReaderT r m a
```

supplying **r**

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – liftReaderT example

```
egLift :: ReaderT Int IO ()                                    side effect
egLift = do e  <- ReaderT return ------------------------------ e :: Int <-  ReaderT r m Int
            liftReaderT $ print "boo" ------------------------- ReaderT r m ()
            liftReaderT $ print $ "value of e: " ++ show e ---- ReaderT r m ()

liftReaderT :: m a -> ReaderT r m a
liftReaderT m = ReaderT (\_ -> m)       -- (1)
liftReaderT m = ReaderT (const m)       -- (2)

print :: Show a => a -> IO ()

liftReaderT print “boo”
IO () -> ReaderT r IO ()
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

print

print takes a value of any type that's an **instance** of **Show**
(meaning that we know how to represent it as a **string**),
calls **show** with that value to stringify it and then
outputs that **string** to the terminal.

It first runs **show** on a **value** and then **feeds** that to **putStrLn**,
which **returns** an **I/O action** that will print out our value.

```
main = do
        print True
        print 2
        print "haha"
        print 3.2
        print [3,4,3]
```

```
$ runhaskell print_test.hs
True
2
"haha"
3.2
[3,4,3]
```

putStrLn . show.

http://learnyouahaskell.com/input-and-output

print vs. **putStrLn**

When we **type** out a value (like 3 or [1,2,3])

and press the **return** key, GHCI actually uses

print on that value to display it on our terminal!

```
ghci> 3
3
ghci> print 3
3
ghci> map (++"!") ["hey","ho","woo"]
["hey!","ho!","woo!"]
ghci> print (map (++"!") ["hey","ho","woo"])
["hey!","ho!","woo!"]
```

to print out **strings**, use **putStrLn**
no **quotes**

to print out values of other types
use **print**

http://learnyouahaskell.com/input-and-output

show

- **Show a => a** : just run show and print it
- **Show a => IO a** : execute the action, run show and print
- **IO ()** : print nothing

```
ghci>15
15
ghci>'a' : 'b' : 'c' : []
"abc"
ghci>putStrLn "Hello, world!"
Hello, world!
ghci>putStrLn "Hello, world!" >> return 42
Hello, world!
42
ghci>
```

ghci has **three cases** for return values:

if you type an IO action,
it get's executed and
the result gets printed
if it's not ().

https://stackoverflow.com/questions/8332307/show-for-io-types

ReaderT Transformer – examples

```
egLift :: ReaderT Int IO ()
egLift = do e  <- ReaderT return
            liftReaderT $ print "boo"
            liftReaderT $ print $ "value of e: " ++ show e
```

```
return :: a -> m a
return :: Int -> IO Int

ghci> runReaderT egLift 100
"boo"
"value of e: 100"
```

```
eg1 :: Reader Int String
eg1 = Reader id >>= \e -> return $ "hey, " ++ show e

eg1' :: Reader Int String
eg1' = do e <- Reader id
          return $ "hey, " ++ show e
```

```
return :: a -> a

id :: a -> a

ghci> runReader eg1' 100
"hey, 100"
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

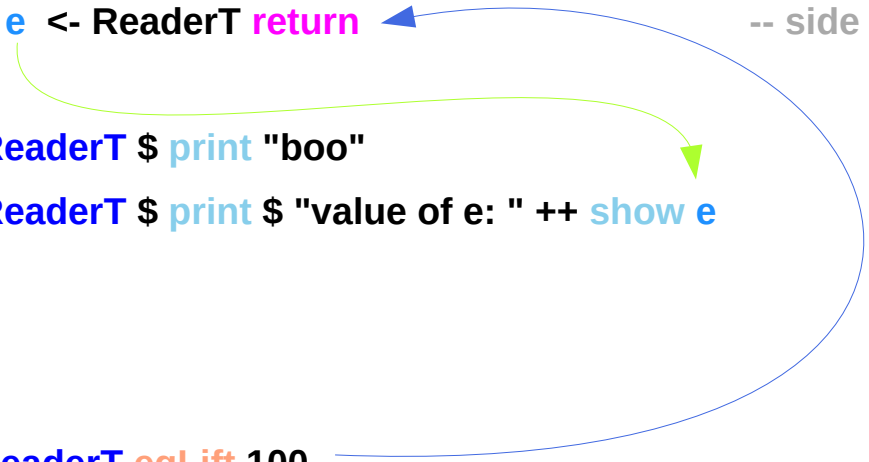
Implementing ReaderT

ReaderT Transformer – reading the environment

```
egLift :: ReaderT Int IO ()
egLift = do e  <- ReaderT return                    -- side effect

        liftReaderT $ print "boo"
        liftReaderT $ print $ "value of e: " ++ show e


ghci> runReaderT egLift 100
"boo"
"value of e: 100"
```



```
ReaderT r     m a
ReaderT Int IO ()

ReaderT return
ReaderT $ r -> m r
ReaderT $ Int -> IO Int

runReaderT egLift 100
runReaderT ReaderT $ Int -> IO Int  100
(Int -> IO Int) 100
IO 100

e <- IO 100        side effect
e <- 100           only the result
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

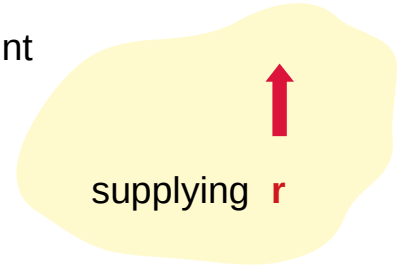
Implementing ReaderT

ReaderT Transformer – return

```
instance (Monad m) => Monad (ReaderT r m) where
  return a = ReaderT $ \_ -> return a          -- (1)
  return   = liftReaderT . return              -- (2)
  return   = liftReaderT . pure                -- (3)
```

The return function ignores the environment

Inject a value into the monadic type.



ReaderT r m

ReaderT r m a

r -> m a

```
instance Monad (Reader r) where
  return a = Reader $ \_ -> a
  m >>= k  =  Reader $ \r -> runReader (k (runReader m r)) r
```

Reader r

m :: Reader r

https://downloads.haskell.org/~ghc/6.8.3/docs/html/libraries/mtl/src/Control-Monad-Reader.html

Implementing ReaderT

Class Constraints and Overloading

```
class Eq a where
  (==)              :: a -> a -> Bool

data Tree a  = Leaf a | Branch (Tree a) (Tree a)


instance (Eq a) => Eq (Tree a) where
          Leaf a  == Leaf b              =  a == b
  (Branch l1 r1)  == (Branch l2 r2)      =  (l1==l2) && (r1==r2)
                  _  ==  _               =  False

          == in  (Tree a)                       == in  a
```

https://www.haskell.org/tutorial/classes.html

Implementing ReaderT

ReaderT Transformer – return

```
instance (Monad m) => Monad (ReaderT r m) where
  return a = ReaderT $ \_ -> return a
  return   =  liftReaderT . return
  return   =  liftReaderT . pure
```

return in ReaderT r m

return, pure in m

```
return ::
        a -> m a

return ::
liftReaderT . return  ::
        a -> ReaderT r m a
```

supplying r

```
readerT $ \_ -> return a
```

supplying r

https://downloads.haskell.org/~ghc/6.8.3/docs/html/libraries/mtl/src/Control-Monad-Reader.html

Implementing ReaderT

ReaderT Functor

```
mapReaderT :: (m a -> n b) -> ReaderT r m a -> ReaderT r n b
mapReaderT f m = ReaderT $ f . runReaderT m

instance (Functor m) => Functor (ReaderT r m) where
   fmap f  = mapReaderT (fmap f)
```

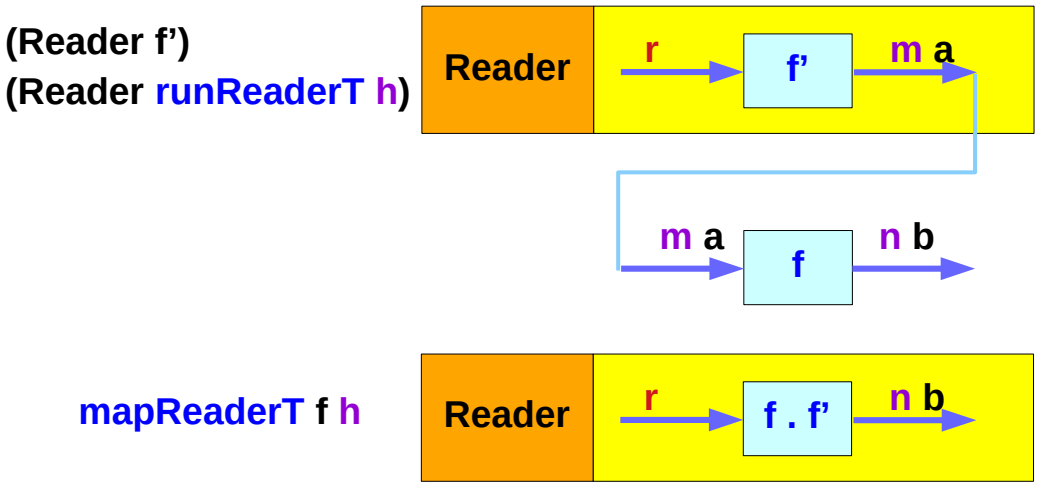
```
instance Functor (Reader r) where
 -- fmap :: (a -> b) -> Reader r a -> Reader r b
   fmap f (Reader f') = Reader $ f . f'
```

https://downloads.haskell.org/~ghc/6.8.3/docs/html/libraries/mtl/src/Control-Monad-Reader.html

Implementing ReaderT

ReaderT Functor – mapReaderT

```
mapReaderT :: (m a -> n b) -> ReaderT r m a -> ReaderT r n b
mapReaderT f m = ReaderT $ f . runReaderT m
mapReaderT f h = ReaderT $ f . runReaderT h
```




```
newtype ReaderT r m a
  = ReaderT { runReaderT :: r -> m a }

runReaderT ::
   ReaderT r m a -> (r -> m a)

runReaderT (ReaderT f') = f'

m' :: ReaderT r m a
h :: ReaderT r m a


runReaderT m :: (r -> m a)
runReaderT h :: (r -> m a)
```

https://downloads.haskell.org/~ghc/6.8.3/docs/html/libraries/mtl/src/Control-Monad-Reader.html

Implementing ReaderT

ReaderT Applicative

```
instance (Applicative m) => Applicative (ReaderT r m) where
   pure    = liftReaderT . pure
   f <*> v = ReaderT $ \r -> runReaderT f r <*> runReaderT v r
```

```
instance Applicative (Reader r) where
 -- pure :: a -> Reader r a
   pure a = Reader (const a)
 -- (<*>) :: Reader r (a -> b) -> Reader r a -> Reader r b
   (Reader f) <*> (Reader f') = Reader $ \r -> f r (f' r)
```

http://hackage.haskell.org/package/transformers-0.5.5.0/docs/src/Control.Monad.Trans.Reader.html#line-143

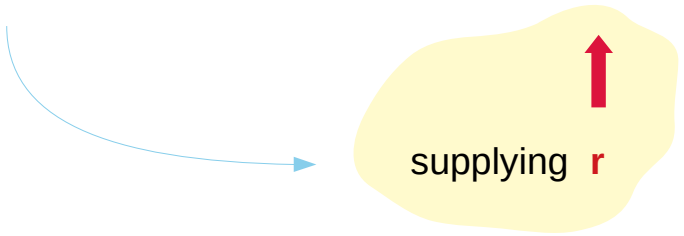
Implementing ReaderT

ReaderT Applicative – pure

```
pure :: a -> ReaderT r m a
pure = liftReaderT . pure

pure ::      a -> m a
pure ::      a -> ReaderT r m a

liftReaderT . return  ::      a -> ReaderT r m a
```



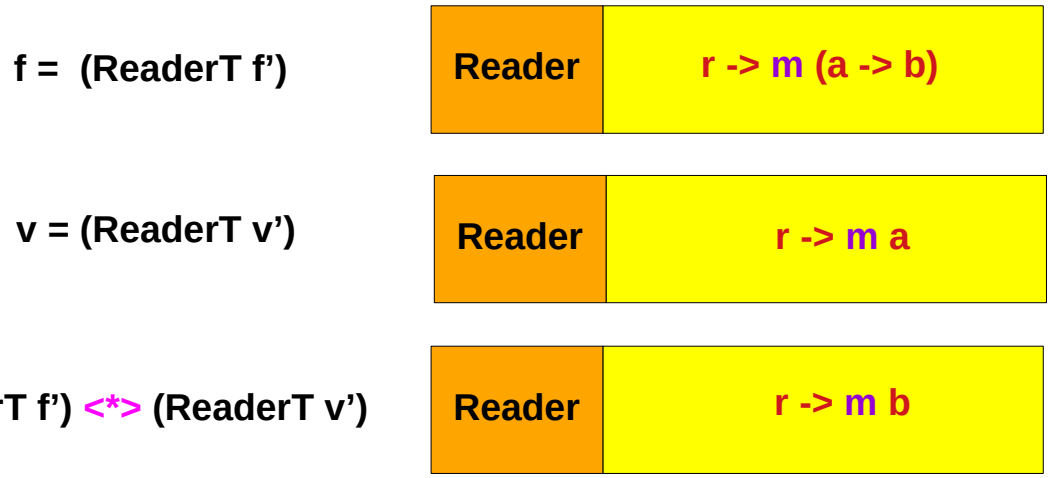

```
liftReaderT :: m a -> ReaderT r m a
liftReaderT m = ReaderT (\_ -> m)
```

http://hackage.haskell.org/package/transformers-0.5.5.0/docs/src/Control.Monad.Trans.Reader.html#line-143

Implementing ReaderT

ReaderT Applicative – <*>

```
(<*>) :: ReaderT r m (a -> b) -> ReaderT r m a -> ReaderT r m b
f <*> v = ReaderT $ \r -> runReaderT f r <*> runReaderT v r
```

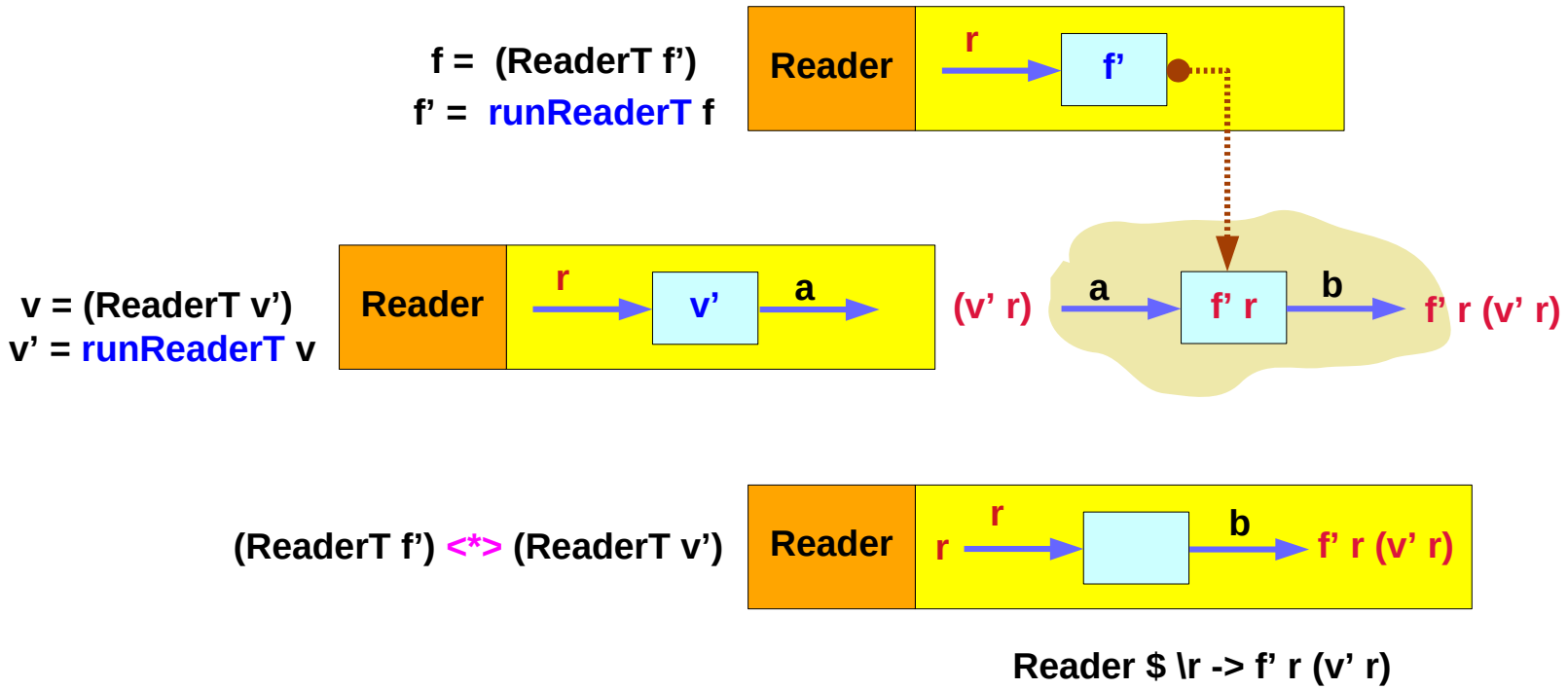


http://hackage.haskell.org/package/transformers-0.5.5.0/docs/src/Control.Monad.Trans.Reader.html#line-143

Implementing ReaderT

Reader Applicative Implementation – <*>

```
(<*>) :: ReaderT r m (a -> b) -> ReaderT r m a -> ReaderT r m b
f <*> v = ReaderT $ \r -> runReaderT f r <*> runReaderT v r
```



https://www.reddit.com/r/haskellquestions/comments/6r46zp/applicative_instance_for_reader/

Implementing ReaderT

ReaderT Transformer – readerAsk

```
readerAsk :: (Monad m) => ReaderT r m r
readerAsk = ReaderT return
```

ask function:

```
ReaderT r m r

return :: r -> m r
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – withReaderT

```
withReaderT :: (r' -> r) -> ReaderT r m a -> ReaderT r' m a
withReaderT   f     rt = ReaderT $ (runReaderT rt) . f
```

to modify the **environment**, use **withReaderT**

which takes a **function** as its first **parameter** **(r' -> r)**

to modify the **environment**. **(r into r')**

The type of the supplied **reader** **ReaderT r m a** **(*original*)**

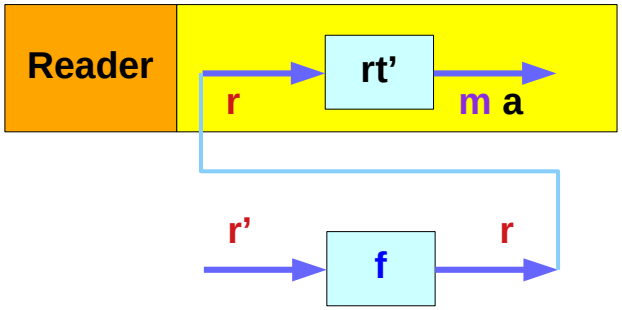
The type of the modified **reader** is **ReaderT r' m a** **(*modified*)**

so the **function** is of type **r' -> r** which modifies

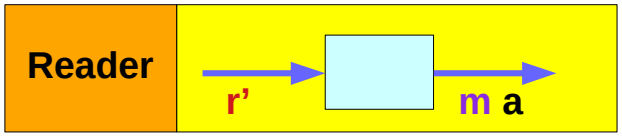
f :: r' -> r *modifying function*

rt : ReaderT r m a *supplied reader*

withReaderT



withReaderT



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https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – readerReader, readerAsk

```
readerReader :: Monad m => (r -> a) -> ReaderT r m a
readerReader f = ReaderT $ \r -> return (f r)
```

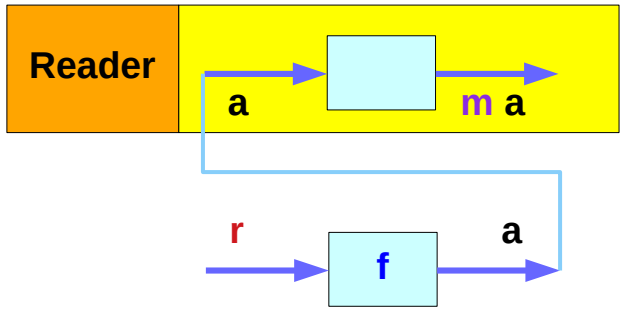
to apply a **function f** to the current **environment**. **(f r)**

This is almost the same as **readerAsk**

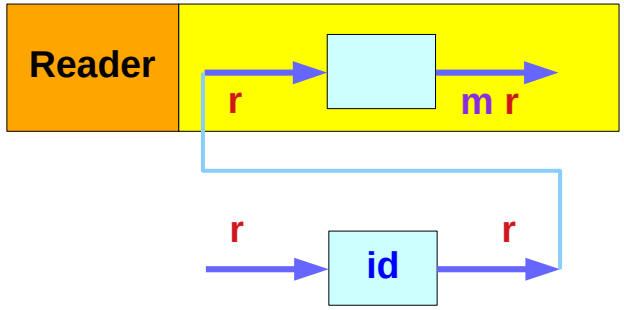
except that we create a **reader** that returns **f r** instead of **f**.

```
readerAsk' :: (Monad m) => ReaderT r m r
readerAsk' = readerReader id
```

readerReader



readerAsk'



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https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

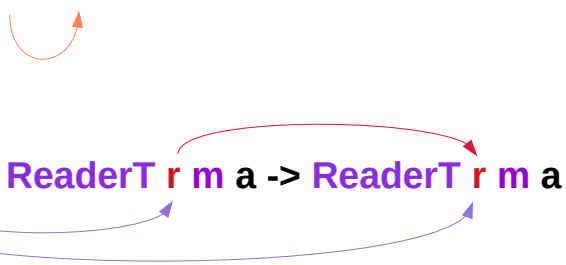
Implementing ReaderT

MonadReader Class

ReaderT instance of MonadReader class

An instance declaration for our **ReaderT** type:

```
instance Monad m => MonadReader r (ReaderT r m) where
  ask    = readerAsk    :: ReaderT r m r
  local  = withReaderT  :: (r -> r) -> ReaderT r m a -> ReaderT r m a
  reader = readerReader :: (r -> a) -> ReaderT r m a
```



https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Monad Example (1)

```
eg2 :: ReaderT Int IO String
eg2 = do

   e <- ask :: ReaderT Int IO Int


   liftReaderT $ print $ "in eg2 the environment is: "   ++ (show e)

   return $ "returned value: " ++ show e
```

use the **IO** monad as the inner monad in a **ReaderT**, with an **Int environment** (**r**) and **String result** (**a**) type.

Get the reader environment.

Run an **IO** action; we have to use **liftReaderT** since we are currently

in the **ReaderT** monad, not the **IO** monad.

Final return value, a string.

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Monad Example (2)

```
eg2 :: ReaderT Int IO String
eg2 = do
   e <- ask :: ReaderT Int IO Int
   liftReaderT $ print $ "in eg2 the environment is: "   ++ (show e)
   return $ "returned value: " ++ show e


ghci> result  "in eg2 the environment is: 100"
ghci> result
"returned value: 100"
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

Auto-lifting in **mtl MonadReader**

Each **monad** in the **mtl** is defined in terms of a type class.

Reader is an instance of **MonadReader**,
ReaderT is also an instance of **MonadReader**

anything that wraps a **MonadReader** is
also set up to be a **MonadReader**

asks and **local** functions will work without any (manual) lifting.
Other **mtl monads** behave in a similar way.

https://wiki.haskell.org/Monad_Transformers_Explained

MonadReader Class Definition

class Monad m => **MonadReader r m | m -> r where**

See examples in **Control.Monad.Reader**.

Note, the partially applied function type **(->) r** is a simple **reader** monad.

(ask | reader), local

ask :: m r

local :: (r -> r) -> m a -> m a

reader :: (r -> a) -> m a

http://hackage.haskell.org/package/mtl-2.2.2/docs/Control-Monad-Reader.html

MonadReader Class Methods

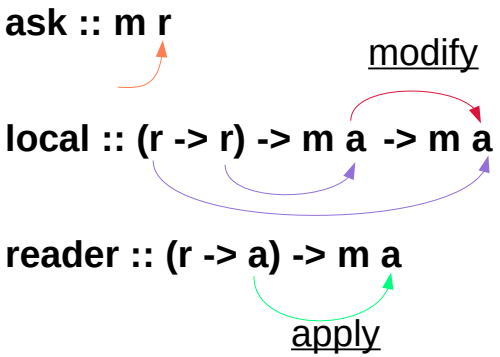
```
class Monad m => MonadReader r m | m -> r where


(ask | reader), local

ask :: m r          -- retrieves the monad environment.

local :: (r -> r)   -- the select function to modify the environment.
      -> m a        -- reader to run in the modified environment.
      -> m a        -- executes a computation in a modified environment.

reader :: (r -> a)  -- the selector function to apply to the environment.
       -> m a       -- retrieves a function of the current environment.
```



http://hackage.haskell.org/package/mtl-2.2.2/docs/Control-Monad-Reader.html

ReaderT Transformer – src (1)

```
{-# LANGUAGE FlexibleInstances #-}
{-# LANGUAGE FunctionalDependencies #-}
{-# LANGUAGE MultiParamTypeClasses #-}

newtype ReaderT r m a = ReaderT { runReaderT :: r -> m a }

instance (Functor m) => Functor (ReaderT r m) where
   fmap f  = mapReaderT (fmap f)

instance (Applicative m) => Applicative (ReaderT r m) where
   pure    = liftReaderT . pure
   f <*> v = ReaderT $ \ r -> runReaderT f r <*> runReaderT v r

instance (Monad m) => Monad (ReaderT r m) where
-- return a = ReaderT $ \_ -> return a  -- (1)
-- return = liftReaderT . return        -- (2)
-- return = liftReaderT . pure          -- (3)
  return a = ReaderT $ \_ -> return a  -- (1)

-- h >>= k  = ReaderT $ \r -> runReaderT (k (runReaderT h  r) )  r  -- (X)
  h >>= k = ReaderT $ \r -> do
     a <- runReaderT h r
     runReaderT (k a) r
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – src (2)

```
-- runReaderT :: ReaderT r m a -> (r -> m a)
-- runReaderT (ReaderT f a) = f a

mapReaderT :: (m a -> n b) -> ReaderT r m a -> ReaderT r n b
mapReaderT f m = ReaderT $ f . runReaderT m

liftReaderT :: m a -> ReaderT r m a
liftReaderT m = ReaderT (\_ -> m)



egLift :: ReaderT Int IO ()
egLift = do e  <- ReaderT return
            liftReaderT $ print "boo"
            liftReaderT $ print $ "value of e: " ++ show e


----
*Main> runReaderT egLift 100
"boo"
"value of e: 100"
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – src (3)

```
class Monad m => MonadReader r m | m -> r where
   ask :: m r
   ask = reader id
   local :: (r -> r) -> m a    -> m a
   reader :: (r -> a) -> m a
   reader f = do
        r <- ask
        return (f r)
   asks :: MonadReader r m => (r -> a)  -> m a
   asks = reader


instance Monad m => MonadReader r (ReaderT r m) where
   ask        = readerAsk
   local      = withReaderT
   reader     = readerReader
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – src (4)

```
readerAsk :: (Monad m) => ReaderT r m r
readerAsk = ReaderT return

withReaderT :: (r' -> r) -> ReaderT r m a -> ReaderT r' m a
withReaderT f rt = ReaderT $ (runReaderT rt) . f

readerReader :: Monad m => (r -> a) -> ReaderT r m a
readerReader f = ReaderT $ \r -> return (f r)

readerAsk' :: (Monad m) => ReaderT r m r
readerAsk' = readerReader id


eg2 :: ReaderT Int IO String
eg2 = do e <- ask :: ReaderT Int IO Int
       liftReaderT $ print $ "in eg2 the env is: " ++ (show e)
       return $ "returned value: " ++ show e



----
*Main> runReaderT eg2 100
"in eg2 the env is: 100"
"returned value: 100"
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

ReaderT Transformer – src using mtl package

```
import Control.Monad.Reader

liftReaderT :: m a -> ReaderT r m a
liftReaderT m = ReaderT (const m)

eg2 :: ReaderT Int IO String
eg2 = do e <- ask :: ReaderT Int IO Int
         liftReaderT $ print $ "in eg2 the env is: " ++ (show e)
         return $ "returned value: " ++ show e
```

```
----
*Main> runReaderT eg2 100
"in eg2 the env is: 100"
"returned value: 100"
```

https://carlo-hamalainen.net/2014/03/05/note-to-self-reader-monad-transformer/
https://github.com/carlohamalainen/playground/blob/master/haskell/transformers/MyOwnReaderT.lhs

Implementing ReaderT

Pragmas for MonadReader Class

```
{-# LANGUAGE FlexibleInstances #-}
{-# LANGUAGE FunctionalDependencies #-}
{-# LANGUAGE MultiParamTypeClasses #-}
```

Multi-parameter type class

Basically, type classes which can take multiple arguments, such as:

```
class Monad m => VarMonad m v where
  new :: a -> m (v a)
  get :: v a -> m a
  put :: v a -> a -> m ()

instance VarMonad IO IORef where ...
instance VarMonad (ST s) (STRef s) where ...
```

To enable them, use the {-# LANGUAGE MultiParamTypeClasses #-} pragma.

https://wiki.haskell.org/Multi-parameter_type_class

Functional dependencies

```
-- Read as: "container" type determines "elem" type.
class Extract container elem | container -> elem where
  extract :: container -> elem

instance Extract (a,b) a where
  extract (x,_) = x

-- instance Extract (a,b) b where ...

v = extract ('x', 3)

v :: Char
```

FlexibleInstances +
MultiParamTypeClasses +
FunctionalDependencies

we won't declare multiple instances
with the same "container" type.

we can't have the previous instance
and this one:

figure it out without
the functional dependency.

https://wiki.haskell.org/Multi-parameter_type_class

Flexible Instances

The FlexibleInstances extension allows
the head of the instance declaration
to mention arbitrary nested types.

For example, this becomes a legal instance declaration

instance C (Maybe Int) where ...

clss C where ...

Int
Maybe Int – a netsted type

https://downloads.haskell.org/~ghc/latest/docs/html/users_guide/glasgow_exts.html

References

[1] ftp://ftp.geoinfo.tuwien.ac.at/navratil/HaskellTutorial.pdf
[2] https://www.umiacs.umd.edu/~hal/docs/daume02yaht.pdf