Maybe Monad (3C)

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This document was produced by using LibreOffice.

Based on

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

https://www.schoolofhaskell.com/user/EFulmer/currying-and-partial-application

http://www.idryman.org/blog/2014/01/23/yet-another-monad-tutorial/

Maybe Monad

a **Monad** is just a special **Functor** with extra features

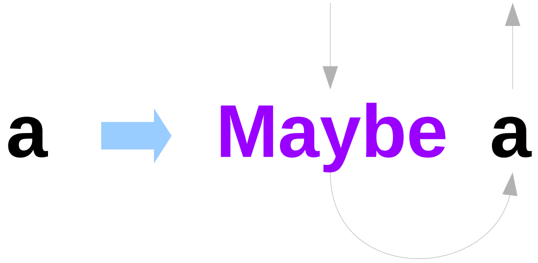
Monads like **Maybe**

map types a to a new type **Maybe** a
that represent "computations that result in values"

- Wrap meaningful values by **Just x**
- All meaningless values by **Nothing**

Monads like **Maybe**, the **bind** (**>>=**) operation

passes meaningful values through **Just**, while
Nothing will force the result to always be **Nothing**.



https://wiki.haskell.org/Maybe

An immediate abort

Maybe is also a **Monad**

represents "computations that could *fail* to return a value"

enables an immediate abort
by a valueless return in the middle of a computation.

enable a whole bunch of computations
without explicit checking for errors in each step

a computation on **Maybe** values *stops*
as soon as a **Nothing** is encountered

context

semantics

effects

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe type constructor

The type constructor is m = Maybe

general Monad type class

```
return :: a -> Maybe a
```

```
return :: a -> m a
```

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

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

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maybe Monad Implementation

The **type constructor** is **m = Maybe**

```
return :: a -> Maybe a

return x  = Just x
```

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

mx >>= g        = case mx of
                    Nothing -> Nothing
                    Just x  -> g x
```

mx :: Maybe a
g :: a -> Maybe b

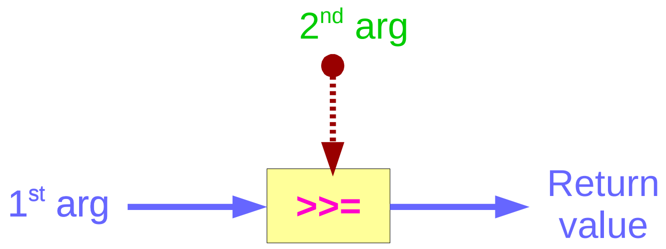
https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maybe Monad - >>=

Monad | Function | Monad

1st arg | 2nd arg | return

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



```
mx >>= g        = case mx of
                        Nothing  -> Nothing
                        Just x     -> g x
```

if there is an underlying value of type a in m,
we apply g to it, which brings the underlying value back into the Maybe monad.

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

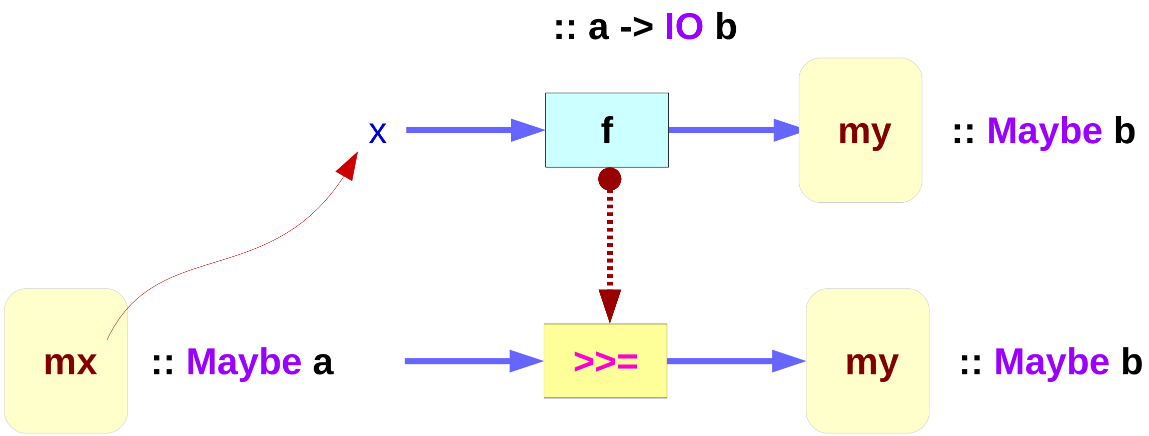
Maybe Monad

```
instance Monad Maybe where
  return x =  Just x


  mx >>= g        = case mx of
                        Nothing  -> Nothing
                        Just x     -> g x
```

```
ioX >>= f :: IO a -> (a -> IO b) -> IO b
```

```
type    IO t    =    World    ->    (t, World)
```

type synonym



https://www.cs.hmc.edu/~adavidso/monads.pdf

Maybe Monad

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

mx >>= g        = case mx of
                     Nothing  -> Nothing
                     Just x     -> g x
```

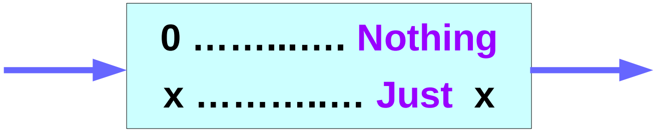
```
mx >>= g                          (a function with 2 args)

mx    :: Maybe a                  (Maybe monad)
g     :: (a -> Maybe b)           (function)

x     :: a
g x   :: Maybe b
```

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maybe as a Monad

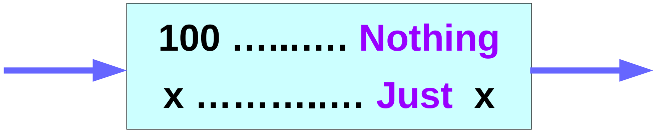
```
f::Int -> Maybe Int
f 0 = Nothing
f x = Just x
```

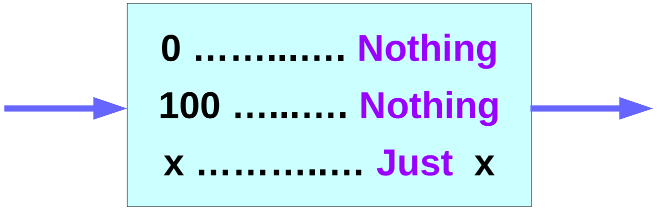
if **x**==0 then **Nothing**
else **Just x**



```
g :: Int -> Maybe Int
g 100 = Nothing
g x     = Just x
```

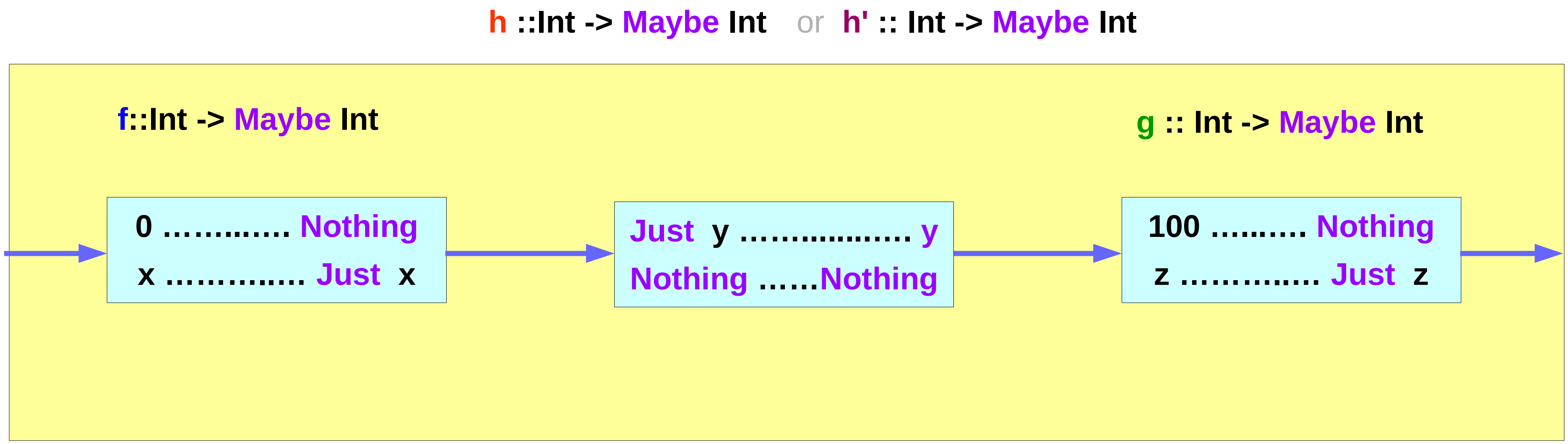
if **x**==100 then **Nothing**
else **Just x**





https://wiki.haskell.org/Maybe

Maybe as a Monad



h ::Int -> Maybe Int or h' :: Int -> Maybe Int

f::Int -> Maybe Int

0 ………..… Nothing

x ………….. Just x

Just y ………..……. y

Nothing ……Nothing

g :: Int -> Maybe Int

100 ……..…. Nothing

z ………….. Just z

$$\begin{tikzcd} \text{Int} \arrow[r, "f"] & \text{Maybe Int} \arrow[r, "\text{flattening}"] & \text{Int} \arrow[r, "g"] & \text{Maybe Int} \end{tikzcd}$$

https://wiki.haskell.org/Maybe

Maybe as a Monad

```
f::Int -> Maybe Int
f 0 = Nothing
f x = Just x
```

```
if x==0 then Nothing
else Just x
```

```
g :: Int -> Maybe Int
g 100 = Nothing
g x     = Just x
```

```
if x==100 then Nothing
else Just x
```

```
h ::Int -> Maybe Int
h x = case f x of
          Just n -> g n
          Nothing -> Nothing
```

```
if f x==Nothing then Nothing
else g n
```

```
h' :: Int -> Maybe Int
h' x = do n <- f x
           g n
```

```
g ( f x)
```

Compact Codes

h & h' give the same results
h 0 = h' 0 = h 100 = h' 100 = Nothing;
h x = h' x = Just x

https://wiki.haskell.org/Maybe

Maybe as a Monad

```
f 0 = Nothing
f x = Just x
```

```
g :: Int -> Maybe Int
g 100 = Nothing
g x     = Just x
```

```
h ::Int -> Maybe Int
h x = case f x of
            Just n -> g n
            Nothing -> Nothing
```

```
h' :: Int -> Maybe Int
h' x = do n <- f x
              g n
```

```
h'' ::Int -> Maybe Int
h'' x = f x >>= g
```

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

mx >>= g       = case mx of
                        Nothing -> Nothing
                        Just x  -> g x
```

```
f :: Int -> Maybe Int

g :: Int -> Maybe Int

f x :: Maybe Int
```

https://wiki.haskell.org/Maybe

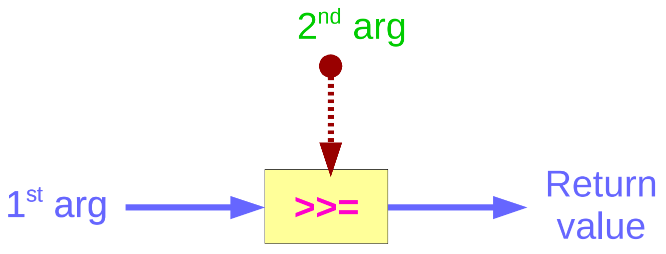
Monad Definition

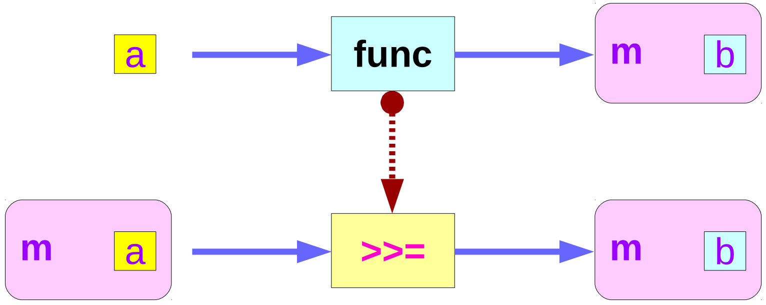
```
class Monad m where
    return :: a -> m a

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

    (>>) :: m a -> m b -> m b
    x >> y = x >>= \_ -> y

    fail :: String -> m a
    fail msg = error msg
```

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

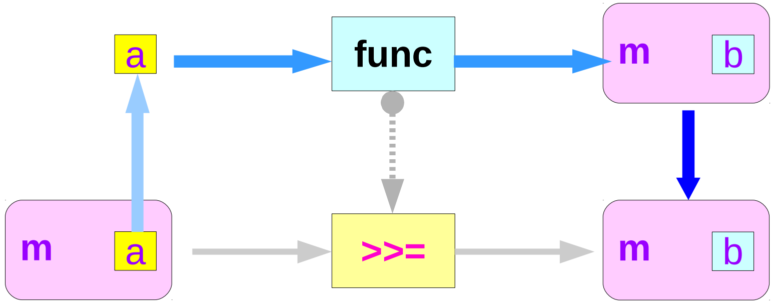
Monad – Bind Operation

```
class  Monad m  where
   (>>=) :: m a -> (a -> m b) -> m b
```





1st arg	Monad	**m a**
2nd arg	Function	**(a -> m b)**
return	Monad	**m b**

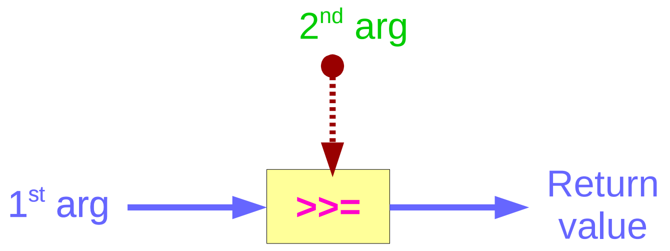


Maybe Monad

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

mx >>= g      = case mx of
                    Nothing  -> Nothing
                    Just x    -> g x
```

1st arg	Monad	**m a**
2nd arg	Function	**(a -> m b)**
return	Monad	**m b**

```
mx    :: Maybe a             (Maybe monad)
g     :: (a -> Maybe b)      (function)

mx >>= g                     (a function with 2 args)
```



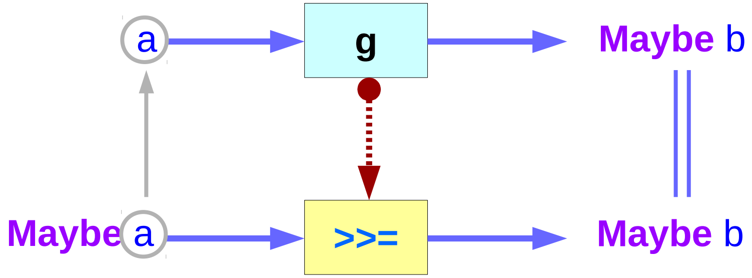
```
g     :: (a -> Maybe b)
x     :: a
g x   :: Maybe b
```

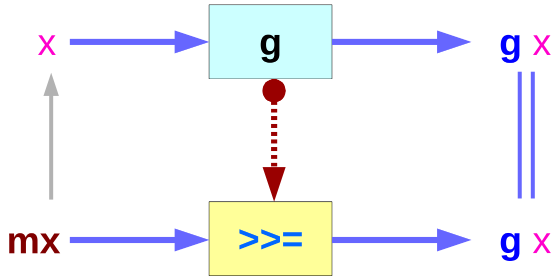
https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Monad Class Function **>>= & >>**

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

```
mx >>= g = case mx of
             Nothing  -> Nothing
             Just x      -> g x
```





Just x → g x

Nothing → Nothing

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Monad Class Function >>= & >>

Maybe is the monad

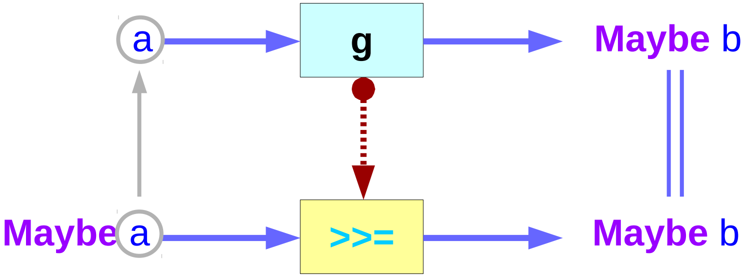
return brings a value into it
by wrapping it with **Just**

(>>=) takes
a value **m** :: **Maybe** a
a function **g** :: a -> **Maybe** b

if m is **Nothing**,
there is nothing to do and the result is **Nothing**.
Otherwise, in the **Just** x case,
the underlying value x is wrapped in **Just**
g is applied to x, to give a **Maybe** b result.

Note that this result *may* or *may not* be **Nothing**,
depending on what **g** does to x.

```
(>>=)  :: Maybe a -> (a -> Maybe b) -> Maybe b
m >>= g = case m of
           Nothing -> Nothing
           Just x  -> g x
```



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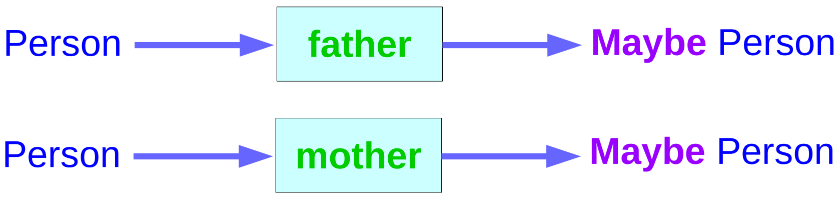
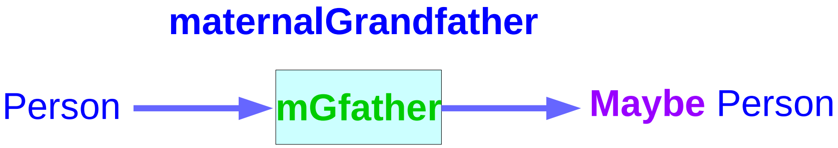
Maybe Person Examples

a family database that provides two functions:

father :: Person -> **Maybe** Person
mother :: Person -> **Maybe** Person



maternalGrandfather :: Person -> **Maybe** Person



Input the name of someone's father or mother.

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Nothing

Maybe Person

- Database
- Query information

when a query is failed
(no relevant information in the database)

➡ **Maybe** is useful

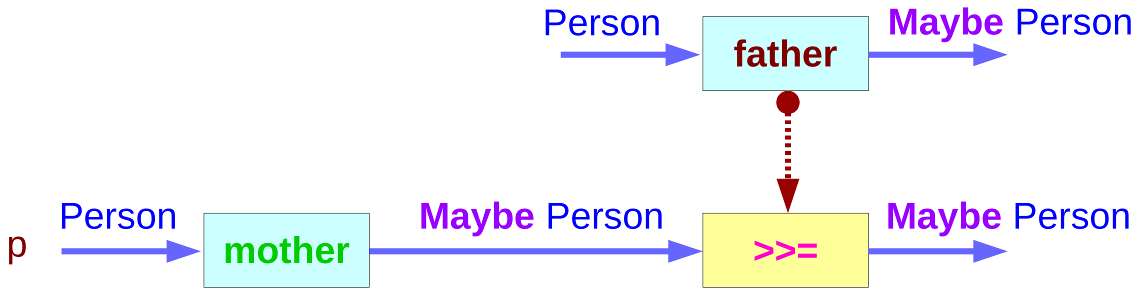
Maybe returns a **Nothing** value
to indicate that the lookup failed,
rather than crashing the program.

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maternal Grand Father

```
maternalGrandfather :: Person -> Maybe Person
maternalGrandfather p =
    case mother p of
        Nothing -> Nothing
        Just mom -> father mom
```

```
maternalGrandfather p = mother p >>= father
```



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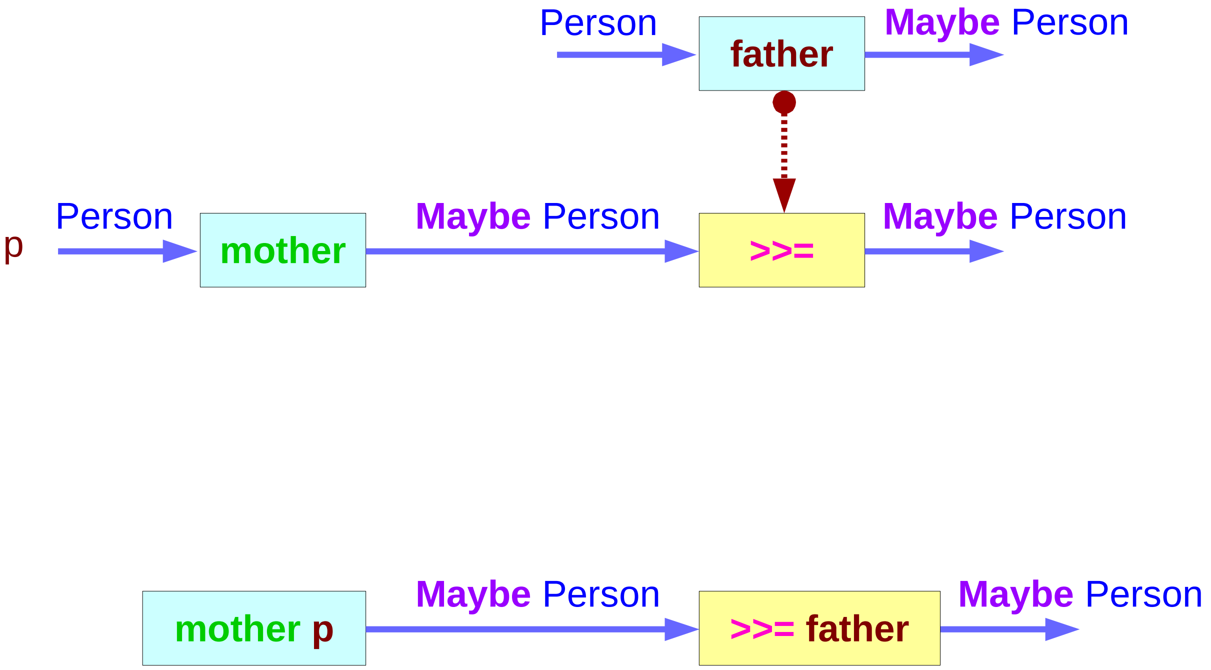
Maternal Grand Father

```
maternalGrandfather p = mother p >>= father
```



https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maternal and Paternal Grand Fathers

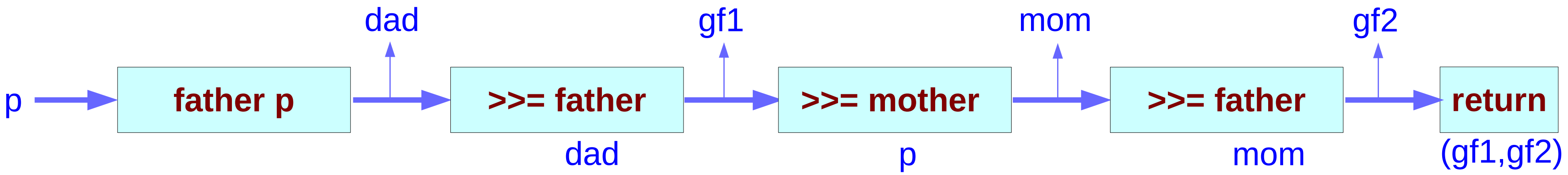
https://en.wikibooks.org/wiki/Haskell/Understanding_monads

```
bothGrandfathers :: Person -> Maybe (Person, Person)
bothGrandfathers p =
    case father p of
        Nothing -> Nothing
        Just dad ->
            case father dad of
                Nothing -> Nothing
                Just gf1 ->                        -- found first grandfather
                    case mother p of
                        Nothing -> Nothing
                        Just mom ->
                            case father mom of
                                Nothing -> Nothing
                                Just gf2 ->        -- found second grandfather
                                    Just (gf1, gf2)
```

Maybe Monad Examples

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

```
bothGrandfathers p =
  father p >>=
      (\dad -> father dad >>=
          (\gf1 -> mother p >>=   -- gf1 is only used in the final return
              (\mom -> father mom >>=
                  (\gf2 -> return (gf1,gf2) ))))
```



Data Type Definition Monad

```
data Maybe a     = Just a
                   | Nothing
```

a type definition: **Maybe** a

a parameter of a type variable a,

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Two Data Constructors

```
data Maybe a     = Just a
                   | Nothing
```

two constructors: **Just** a and **Nothing**

a value of **Maybe** a type must be constructed via either **Just** or **Nothing**
there are no other (non-error) possibilities.

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Just and Nothing Data Constructors

```
data Maybe a     = Just a
                  | Nothing
```

Nothing has no parameter type,
names a constant value
that is a member of type **Maybe** a for all types a.

Just constructor has a type parameter,
acts like a function from type a to **Maybe** a,
i.e. it has the type a -> **Maybe** a

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Pattern Matching in Data Constructors

the (data) constructors of a type *build a value* of that type;

when using that *value*,
pattern matching can be applied

- Unlike functions, *constructors* can be used in *pattern binding expressions*
- **case analysis** of values that belong to types with more than one constructor.
- need to provide **a pattern** for each constructor

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Pattern Matching in Maybe Monad

```
case maybeVal of
    Nothing    -> "There is nothing!"
    Just val   -> "There is a value, and it is " ++ (show val)
```

a pattern for each constructor

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe as a monad

the type signature **IO a** looks remarkably similar to **Maybe a**.

- IO doesn't expose its constructors
- only be "run" by the Haskell runtime system
- a Functor
- a Monad

a Monad is just a special kind of Functor with some extra features

value returning
Monads like **IO** *map* types to new types
that represent "computations that result in values"

lifting function
can *lift* **functions** into **Monad types**
via a very fmap-like function called **liftM**
that turns a regular function into a
"computation that results in the value obtained by evaluating the function."

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe as a monad

valueless return
Maybe is also a **Monad**
represents "computations that could *fail to return a value*"

no explicit check in each step
don’t have to check explicitly for errors after each step.

immediate abort
Because of the way the Monad instance is constructed,
a computation on Maybe values *stops as soon as* a **Nothing** is encountered,

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Monad – List Comprehension Examples

```
[x*2 | x<-[1..10], odd x]
```

```
do
   x <- [1..10]
   if odd x
       then [x*2]
       else []
```

```
[1..10] >>= (\x -> if odd x then [x*2] else [])
```

https://stackoverflow.com/questions/44965/what-is-a-monad

Monad – I/O Examples

```
do
  putStrLn "What is your name?"
  name <- getLine
  putStrLn ("Welcome, " ++ name ++ "!")
```

https://stackoverflow.com/questions/44965/what-is-a-monad

Monad – A Parser Example

```
parseExpr = parseString <|> parseNumber

parseString = do
        char '"'
        x <- many (noneOf "\"")
        char '"'
        return (StringValue x)

parseNumber = do
    num <- many1 digit
    return (NumberValue (read num))
```

https://stackoverflow.com/questions/44965/what-is-a-monad

Monad – Asynchronous Examples

```
let AsyncHttp(url:string) =
   async {  let req = WebRequest.Create(url)
            let! rsp = req.GetResponseAsync()
            use stream = rsp.GetResponseStream()
            use reader = new System.IO.StreamReader(stream)
            return reader.ReadToEnd() }
```

https://stackoverflow.com/questions/44965/what-is-a-monad

References

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