Monády

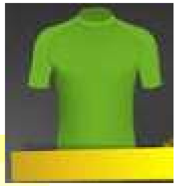
Monady sú použiteľný nástroj pre programátora poskytujúci:

- modularitu – skladať zložitejšie výpočty z jednoduchších (no side-effects),
- flexibilitu – výsledný kód je ľahšie adaptovateľný na zmeny,
- izoluje side-effect operácie (napr. IO) od čisto funkcionálneho zvyšku.

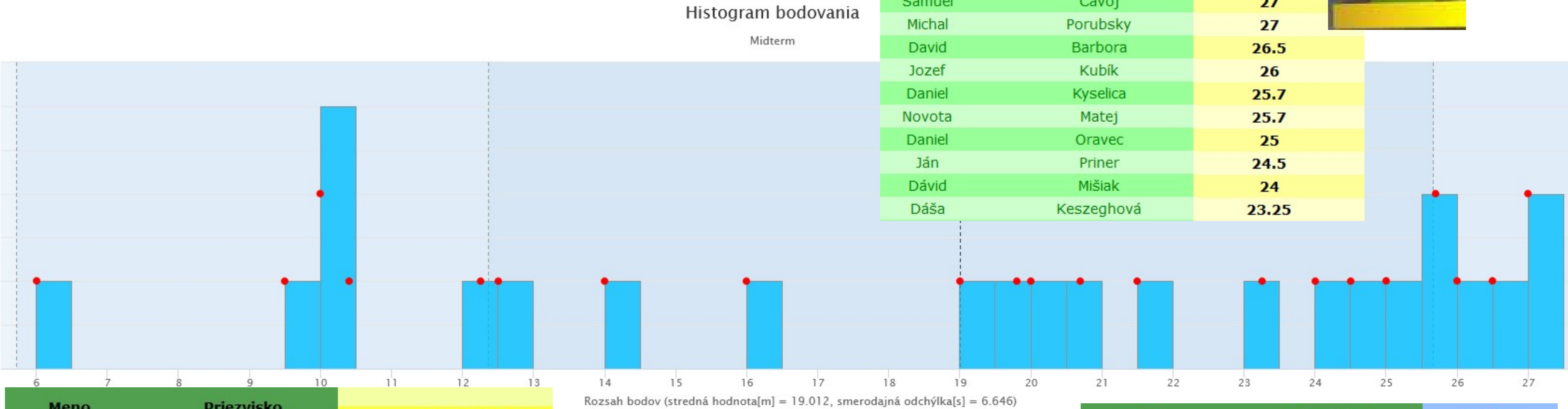
Štruktúra prednášok:

- Monády - prvý dotyk
  - Functor
  - Applicative
  - Monády – princípy a zákony
- Najbežnejšie monády
  - Maybe/Error monad
  - List monad
  - IO monad
  - State monad
  - Reader/Writer monad
  - Continuation monad
- Transformátory monád
- Monády v praxi

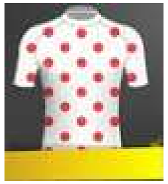
Midterm



Samuel	Čavoj	27
Michal	Porubsky	27
David	Barbora	26.5
Jozef	Kubík	26
Daniel	Kyselica	25.7
Novota	Matej	25.7
Daniel	Oravec	25
Ján	Priner	24.5
Dávid	Mišiak	24
Dáša	Keszeghová	23.25



Meno	Priezvisko	Domáca úloha ▼
Dávid	Mišiak	46
Dáša	Keszeghová	42.5
Daniel	Kyselica	42
Jozef	Kubík	40
Matúš	Gál	37.4
Novota	Matej	37.25
Jozef	Číž	37
Filip	Eliaš	36.5
Samuel	Čavoj	36
Ján	Priner	34.5



Meno	Priezvisko	Prémia ▼
Dávid	Mišiak	48.47
Dáša	Keszeghová	34.56
Jozef	Číž	33.9
Novota	Matej	33.47
David	Barbora	33.25
Daniel	Oravec	31.45
Jozef	Kubík	28.9
Bohdan	Jóža	27.88
Maroš	Malý	25.6
Samuel	Čavoj	25.5

Meno	Priezvisko	Spolu ▼
Dávid	Mišiak	134.67
Dáša	Keszeghová	117.11
Novota	Matej	114.22
Jozef	Kubík	111.5
Daniel	Oravec	107.8
Samuel	Čavoj	103.1
David	Barbora	99.05
Jozef	Číž	97
Daniel	Kyselica	96.09
Filip	Kerák	91.6

Monády – úvod

- Phil Wadler: https://homepages.inf.ed.ac.uk/wadler/papers/marktoberdorf/baastad.pdf Monads for Functional Programming In *Advanced Functional Programming*, Springer Verlag, LNCS 925, 1995,
- Noel Winstanley: What the hell are Monads?, 1999 http://www-users.mat.uni.torun.pl/~fly/materialy/fp/haskell-doc/Monads.html
- Jeff Newbern's: All About Monads https://www.cs.rit.edu/~swm/cs561/All_About_Monads.pdf
- A Gentle Introduction to Haskell, https://www.haskell.org/tutorial/monads.html https://wiki.haskell.org/All_About_Monads
- Sujit Kamthe: Understanding Functor and Monad With a Bag of Peanuts https://medium.com/beingprofessional/understanding-functor-and-monad-with-a-bag-of-peanuts-8fa702b3f69e
- Functors, Applicatives, And Monads In Pictures http://adit.io/posts/2013-04-17-functors,_applicatives,_and_monads_in_pictures.html
- Monads in Haskell and Category Theory https://www.diva-portal.org/smash/get/diva2:1369286/FULLTEXT01.pdf

Monads, Arrows, and Idioms

Philip Wadler, https://homepages.inf.ed.ac.uk/wadler/topics/monads.html

Články Phila Wadlera na stránke

- Monads for functional programming
- The essence of functional programming
- Comprehending monads
- The arrow calculus
- Monadic constraint programming
- Idioms are oblivious, arrows are meticulous, monads are promiscuous
- The marriage of effects and monads
- How to declare an imperative
- Imperative functional programming

What the hell are Monads?

Noel Winstanley,
https://www-users.mat.uni.torun.pl//~fly/materialy/fp/haskell-doc/Monads.html

Obsah:

- Maybe
- State
- The Monad Class
- Do notation
- Monadic IO
- Programming in the IO Monad

All About Monads

Jeff Newbern, https://www.cs.rit.edu/~swm/cs561/All_About_Monads.pdf

Obsah:

Part I - Understanding Monads

What is a monad? Meet the Monads. Doing it with class Monad support in Haskell

Part II - A Catalog of Standard Monads

Introduction. The Identity monad. The Maybe monad. The Error monad. The List monad. The IO monad. The State monad. The Reader monad. The Writer monad. The Continuation monad.

Part III - Monads in the Real

Combining monads the hard way. Monad transformers. Standard monad transformers. Anatomy of a monad transformer. More examples with monad transformers. Managing the transformer.

Roadmap

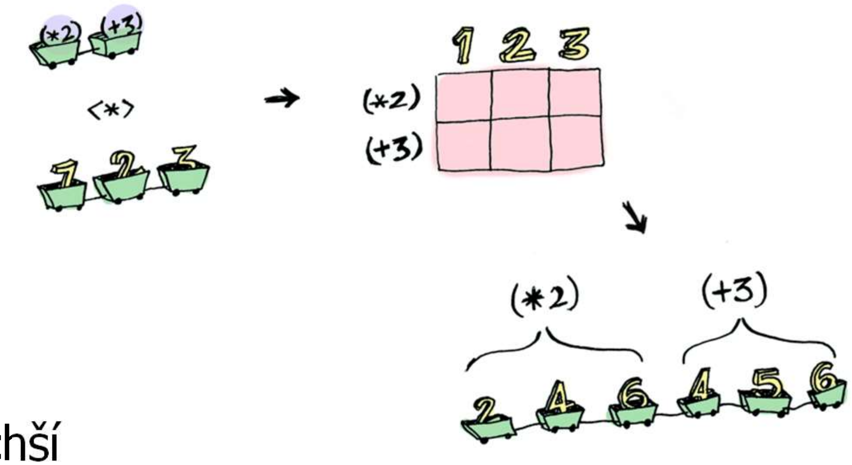
Když egyptský král Ptolemaios žádal slavného matematika Euklida o jednodušší cestu k pochopení matematiky (jako farao se nechtěl obtěžovat těžkou prací studenta), Euklides mu nekompromisně odpověděl:
"V matematice neexistuje žádná královská cesta."

- Haskell má triedy, ale sú to vlastne konceptuálne interface (Java)
- Haskell má podtriedy, čo je konceptuálne dedenie na interface (Java)
- dedenie na interface ste určite v Jave videli, napr. na kolekciách

Relevantné triedy v Haskelli:

- Functor
- Applicatives
- Monad
- MonadPlus
- ...

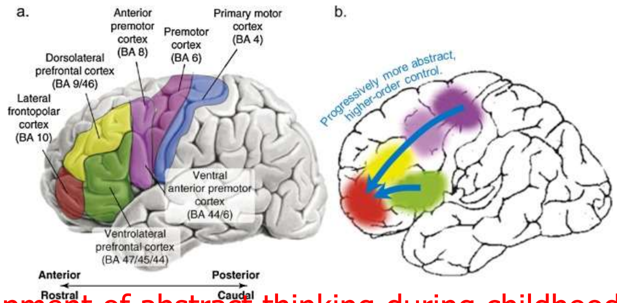
Takže monáda nie je najjednoduchší typ v tejto hierarchii



Alternatívny prístup:
Functors, Applicatives, And Monads In Pictures
http://adit.io/posts/2013-04-17-functors,_applicatives,_and_monads_in_pictures.html

Functor

prvotná idea



[Development of abstract thinking during childhood and adolescence: The role of rostrolateral prefrontal cortex]

```
double :: [Int] -> [Int]
double [] = []
double (x:xs) = (x+x):double xs
```

```
sqr :: [Int] -> [Int]
sqr [] = []
sqr (x:xs) = x*x: sqr xs
```

```
map :: (a->b) -> [a] -> [b]
map f [] = []
map f (x:xs) = f x : map f xs
```

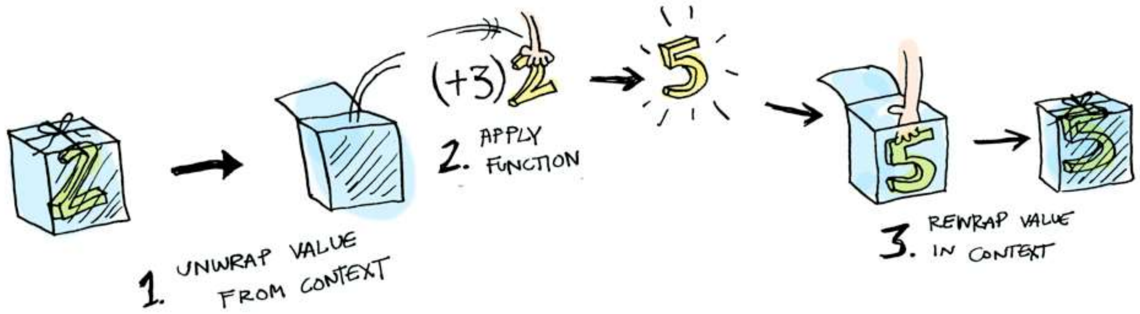
```
map (*2)
```

```
map (^2)
```

```
class Functor f where
  fmap :: (a->b) -> f a -> f b
```

fmap aplikuje funkciu f na hodnoty zabalené do typu, ktorý implementuje interface Functor

Functor



http://adit.io/posts/2013-04-17-functors,_applicatives,_and_monads_in_pictures.html

Zoberme jednoduchšiu triedu, z modulu Data.Functor je definovaná takto:

```
                                         -- každý typ t, ak implementuje Funtor t,
class Functor t where                    -- musí mať funkciu fmap s profilom
  fmap :: (a -> b) -> t a -> t b         -- haskell class je podobne java interface
```

a každá jej inštancia musí spĺňať <u>dve pravidlá</u> (to je <u>sémantika</u>, mimo syntaxe)

- fmap id = id -- identita
- fmap (p . q) = (fmap p) . (fmap q) -- kompozícia

Cvičenie1: Príklad inštancie pre **data $\mathbf{M_1}$ a = Raise String | Return a**, overte, že platia obe sémantické pravidlá:

instance Functor M1 where
    fmap **f** (Raise str) = Raise str
    fmap **f** (Return x) = Return (**f** x)

Cvičenie

```
class Functor t where
  fmap :: (a -> b) -> t a -> t b
```

Definícia:

fmap **f** (Raise str) = Raise str
fmap **f** (Return x) = Return (**f** x)

Dokázať:

fmap id = id
fmap (p . q) = (fmap p) . (fmap q)

Cvičenie1 (pokrač.):

- fmap id =? id
  - fmap id (Raise str) = Raise str
  - fmap id (Return x) = Return (id x) = Return x

- fmap (p.q) =? (fmap p) . (fmap q)
  - Prípad Raise error:
  - L.S. = fmap (p.q) (Raise str) = Raise str
  - P.S. = ((fmap p) . (fmap q)) (Raise str) = (fmap p) ((fmap q) (Raise str)) = Raise str

  - Prípad Return hodnota:
  - L.S. = fmap (p.q) (Return x) = Return ((p.q) x) = (Return (p (q x)))
  - P.S. = ((fmap p) . (fmap q)) (Return x)

    = (fmap p) ((fmap q) (Return x))

    = (fmap p) (Return (q x)) = (Return (p (q x)))…. q.e.d.

Functor

Maybe, List

```
class Functor t where
  fmap :: (a -> b) -> t a -> t b

fmap id        = id
fmap (p . q)  = (fmap p) . (fmap q)
```

Cvičenie2: Definujte inštanciu triedy Functor pre typy:

data MyMaybe a = MyJust a | MyNothing deriving (Show) -- alias Maybe a

data MyList a = Null | Cons a (MyList a) deriving (Show) -- alias [a]

… a pochopíte, ako je Functor definovaný pre štandardné typy Maybe a [].

```
> fmap (even) (Cons 1 (Cons 2 Null))                 -- f : Int->Bool
Cons False (Cons True Null)
> fmap (\s -> s+s) (Cons 1 (Cons 2 Null))            -- f : Int->Int
Cons 2 (Cons 4 Null)
> fmap (show) (Cons 1 (Cons 2 Null))                 -- f : Int->String
Cons "1" (Cons "2" Null)

> fmap ((\t -> t++t) . (show)) (Cons 1 (Cons 2 Null))    -- f : (String->String).(Int->String)
Cons "11" (Cons "22" Null)
> fmap (\t -> t++t)    (fmap (show) (Cons 1 (Cons 2 Null))) -- "overenie" vlastnosti kompozície
Cons "11" (Cons "22" Null)

> fmap id (Cons 1 (Cons 2 Null))                     --  overenie vlastnosti identity
Cons 1 (Cons 2 Null)
```

Functor

Maybe, List

```
class Functor t where
  fmap :: (a -> b) -> t a -> t b

fmap id        = id
fmap (p . q)  = (fmap p) . (fmap q)
```

Cvičenie2 (pokrač.): Definujte inštanciu triedy Functor pre typy:

```
data MyMaybe a = MyJust a | MyNothing deriving (Show)      -- alias Maybe a
data MyList a     = Null | Cons a (MyList a) deriving (Show)    -- alias [a]

instance Functor MyMaybe  where
      fmap f MyNothing     =  MyNothing
      fmap f (MyJust x)    =  MyJust (f x)

instance  Functor MyList  where
      fmap f Null = Null
      fmap f (Cons x xs) = Cons (f x) (fmap f xs)

instance  Functor []  where
      fmap = map
```

```
> fmap even [1,2,3]
[False,True,False]
> fmap (*2) [1,2,3]
[2,4,6]
> fmap (show) [1,2,3]
["1","2","3"]
> fmap (\x->x++x) $ fmap (show) [1,2,3]
["11","22","33"]
> fmap ((\x->x++x). show) [1,2,3]
["11","22","33"]
```

... stále ale chýba dôkaz platnosti dvoch vlastností ...

```
class Functor t where
  fmap :: (a -> b) -> t a -> t b
fmap id        = id
fmap (p . q)  = (fmap p) . (fmap q)
```

Functor – strom

Cvičenie3: Binárny strom (skoro ako tradičný LExp, ale parametrizovaný typ):

```
data LExp a = ID a | APP (LExp a) (LExp a) | ABS a (LExp a) deriving (Show)
instance Functor LExp where
    fmap f (ID x)                = ID (f x)
    fmap f (APP left right)      = APP (fmap f left) (fmap f right)
    fmap f (Abs x body)          = ABS (f x) (fmap f body)
```

```
omega = ABS "x" (APP (ID "x") (ID "x"))
> fmap (\t -> t++t) omega
ABS "xx" (APP (ID "xx") (ID "xx"))
> fmap (\t -> (length t)) omega
ABS 1 (APP (ID 1) (ID 1))
```

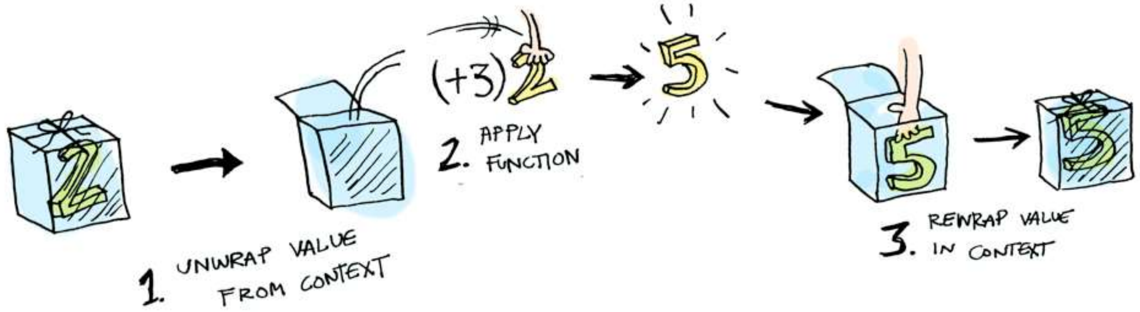
Cvičenie4: Ľubovoľne n-árny strom (prezývaný RoseTree alias Rhododendron):

```
data RoseTree a = Rose a [RoseTree a]
instance Functor RoseTree where
    fmap f (Rose a bs)      = Rose (f a) (map (fmap f) bs)
```

... opäť chýba dôkaz platnosti vlastností pre Cvičenie 3 aj 4 ...

Functor

zhrnutie



http://adit.io/posts/2013-04-17-functors,_applicatives,_and_monads_in_pictures.html

```
instance Functor [] where
  -- fmap :: (a->b) -> [a] -> [b]
   fmap = map
```

```
instance Functor Maybe where
   -- fmap :: (a->b) -> Maybe a -> Maybe b
   fmap _ Nothing = Nothing
   fmap g (Just x) = Just (g x)
```

```
instance Functor IO where
  -- fmap :: (a->b) -> IO a -> IO b
   fmap g mx = do { x<-mx; return (g x) }
```

```
infixl 4 <$>
<$>  = fmap
main :: IO ()
main = do  res <- words <$> getLine
           res <- fmap words getLine
           putStrLn $ show res
```

```
double :: Functor f => f Int -> f Int
double = fmap (*2)

sqr :: Functor f => f Int -> f Int
sqr = fmap (^2)
```

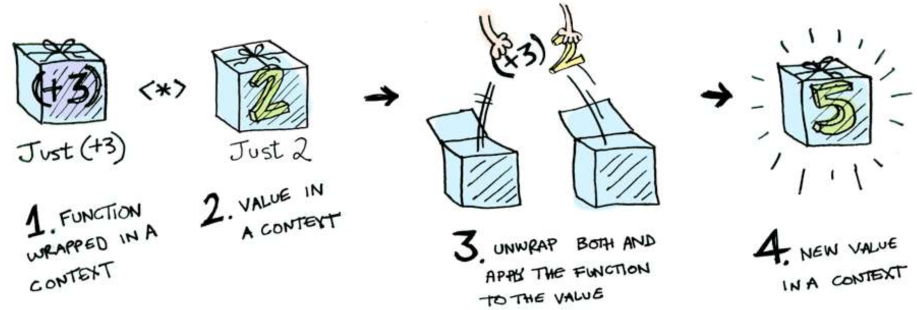
```
double (Just 7) = Just 14
double [1,2,3,4] = [2,4,6,8]

double (Branch (Leaf 7) (Leaf 9)) =
          Branch (Leaf 14) (Leaf 18)

double (Rose 3 [Rose 5 [], Rose 7 []]) =
          Rose 6 [Rose 10 [],Rose 14 []]
```

Applicative
prvotná idea

- Functor predstavuje abstrakciu aplikácie **unárnej funkcie** na každý prvok "Functor-like" dátovej štruktúry, nech je akákoľvek komplikovaná…
- Čo, ak by sme mali funkcie s veľa argumentami (nie len unárne):
  - fmap0 :: a -> f a
  - fmap1 :: (a->b) -> f a -> f b -- fmap
  - fmap2 :: (a->b->c) -> f a -> f b -> f c
  - fmap3 :: (a->b->c->d) -> f a -> f b -> f c -> f d -- ☹
- riešenie = **Currying** je transformácia funkcie s mnohými argumentami na unárnu, ktorá vráti inú funkciu,ktorá skonzumuje všetky ďalšie argumenty
  - **pure :: a -> f a**
  - **(<*>) :: f (a->b) -> f a -> f b** **infixl**

  Napr. nech g chce "tri argumenty"
  - pure g <*> x <*> y <*> z = ((pure g <*> x) <*> y) <*> z
- Hierarchia -- x :: f a, y :: f b, z :: f c
  - pmap0 g0 = pure g0 -- g0 je konštanta, lebo má 0-args.
  - fmap1 g1 x = pure g1 <*> x -- g1 :: a->b, pure g1 :: f (a->b)
  - fmap2 g2 x y = pure g2 <*> x <*> y -- g2 :: a->b->c, pure g2::f (a->b->c)
  - fmap3 g3 x y z = pure g3 <*> x <*> y <*> z -- …

Applicative



http://adit.io/posts/2013-04-17-functors,_applicatives,_and_monads_in_pictures.html

class **Functor f => Applicative f** where -- Applicative je podtrieda Functor
  pure :: a -> f a
  (<*>) :: f (a -> b) -> f a -> f b (infixl 4)

a každá jej inštancia musí spĺňať pravidlá (to je sémantika, mimo syntaxe)

- pure id <*> v = v -- identita
- pure (.) <*> u <*> v <*> w = u <*> (v <*> w) -- kompozícia
- pure f <*> pure x = pure (f x) -- homomorfizmus
- u <*> pure y = pure ($ y) <*> u = pure (\g->g y) <*> u -- výmena

Príklad (pre M1):
Return id <*> Return 4 = Return 4

Return (.) <*> Return (+1) <*> Return (+2) <*> Return 4 = Return 7
Return (+1) <*> (Return (+2) <*> Return 4) = Return 7

Return (+4) <*> Return 3 = Return 7 -- pure f <*> pure x = pure (f x)

data M1 a = Raise String | Return a deriving(Show, Read, Eq)

Applicative

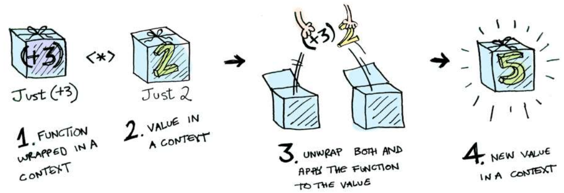
```
class Functor f => Applicative f where
  pure :: a -> f a
  (<*>) :: f (a -> b) -> f a -> f b

pure id <*> v = v                                 -- identita
pure (.) <*> u <*> v <*> w = u <*> (v <*> w)      -- kompozícia
pure f <*> pure x = pure (f x)                    -- homomorfizmus
u <*> pure y = pure ($ y) <*> u = pure (\g->g y) <*> u
```

Cvičenie5: definujte inštanciu M1 pre triedu Applicative a overte 4 pravidlá:

```
instance Applicative M1 where
    pure a              = Return a
    (Raise e)  <*> _    = Raise e       -- e:: String, Raise e::M1 a
    (Return f) <*> a    = fmap f a      -- f::a->b, Return f :: M1(a->b)
```

Príklad:

1) Return id <*> Return 4 = Return 4



2) L.S. = Return (.) <*> Return (+1) <*> Return (+2) <*> Return 4 = Return 7
   P.S. = Return (+1) <*> (Return (+2) <*> Return 4) = Return 7

3) Return (+4) <*> Return 3 = Return 7   -- pure f <*> pure x = pure (f x)

4) Return (+2) <*> Return 7 = Return 9 = Return ($ 7) <*> Return (+2)

```
data M1 a    =   Raise String | Return a  deriving(Show, Read, Eq)
```

Applicative

```haskell
class Functor f => Applicative f where
  pure :: a -> f a
  (<*>) :: f (a -> b) -> f a -> f b

pure id <*> v = v                              -- identita
pure (.) <*> u <*> v <*> w = u <*> (v <*> w) -- kompozícia
pure f <*> pure x = pure (f x)                 -- homomorfizmus
u <*> pure y = pure ($ y) <*> u = pure (\g->g y) <*> u
```

Cvičenie5 (pokrač.): definujte inštanciu M1 pre Applicative a overte pravidlá:

```haskell
instance Applicative M1 where
    pure a              = Return a
    (Raise e)  <*> _    = Raise e        -- e:: String, Raise e::M1 a
    (Return f) <*> a    = fmap f a        -- f::a->b, Return f :: M1(a->b)
```

Dôkaz:

1) (Return id) <*> v = fmap id v = v   pravidlo identity pre Functors

3) pure f <*> pure x = (Return f) <*> (Return x) = fmap f (Return x) = Return (f x) = pure (f x)

2) (Return (.)) <*> (Return fu) <*> (Return fv) <*> (Return fw) =
   (Return (.) fu) <*> (Return fv) <*> (Return fw) =
   (Return ((.) fu) fv) <*> (Return fw) = (Return (fu . fv)) <*> (Return fw) =
   (Return ((fu . fv) fw)) = Return (fu (fv (fw)))

4) L.S. = (Return f) <*> (Return y) = fmap f (Return y) = (Return (f y))
   P.S. = (Return ($ y)) <*> (Return f) = fmap ($ y) (Return f) = Return (($ y) f) =
   Return ((\g->g y) f) = Return (f y)

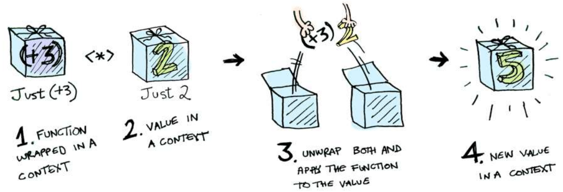
```haskell
data M1 a    =   Raise String | Return a  deriving(Show, Read, Eq)
```

```
class Functor f => Applicative f where
  pure :: a -> f a
  (<*>) :: f (a -> b) -> f a -> f b

pure id <*> v = v                                   -- identita
pure (.) <*> u <*> v <*> w = u <*> (v <*> w)        -- kompozícia
pure f <*> pure x = pure (f x)                      -- homomorfizmus
u <*> pure y = pure ($ y) <*> u = pure (\g->g y) <*> u
```

Applicative

Cvičenie5": definujte inštanciu Maybe pre triedu Applicative a overte pravidlá:

```
instance Applicative Maybe where
      pure              :: a -> Maybe a
      pure              = Just
      pure x            = Just x
      (<*>)             :: Maybe (a->b) -> Maybe a -> Maybe b
      Nothing  <*> _    = Nothing
      (Just g) <*> a    = fmap g a
```



Príklad:

```
pure (*2) <*> Just 7                                  = Just 14
pure (+) <*> Just 7 <*> Just 9                        = Just 16
pure (+) <*> Nothing <*> Just 9                       = Nothing
pure (\x y z->(x,y,z)) <*> Just 1 <*> Just 2 <*> Just 3  = Just (1,2,3)
```

```
data Maybe a    =    Just a | Nothing  deriving(Show, Read, Eq)
```

Applicative

```
class Functor f => Applicative f where
  pure :: a -> f a
  (<*>) :: f (a -> b) -> f a -> f b

pure id <*> v = v                                  -- identita
pure (.) <*> u <*> v <*> w = u <*> (v <*> w) -- kompozícia
pure f <*> pure x = pure (f x)                -- homomorfizmus
u <*> pure y = pure ($ y) <*> u = pure (\g->g y) <*> u
```

Cvičenie6: definujte inštanciu [] pre triedu Applicative a overte pravidlá:

```
instance Applicative [] where
    pure a          = [a]
    fs  <*> xs      = [ f x | f <- fs, x <- xs]
```

Príklad:

```
1)  pure (+1) <*> [1..5]                                   = [2,3,4,5,6]
    pure (+) <*> [1,2] <*> [11,12]                         = [12,13,13,14]
    pure (,) <*> [1,2] <*> [11,12]              = [(1,11),(1,12),(2,11),(2,12)]
2)  pure (.) <*> pure (+1) <*> pure (+3) <*> pure 9       = 13
    pure (.) <*> pure (+1) <*> pure (+3) <*> [9]          = [13]
    pure (.) <*> pure (+1) <*> pure (+3) <*> Just 9       = Just 13
3)  pure (+1) <*> pure 7                                   = 8
4)  pure ($ 7) <*> pure (+1)                               = 8
```

type [a]   =   [] | a:[a]

Applicative

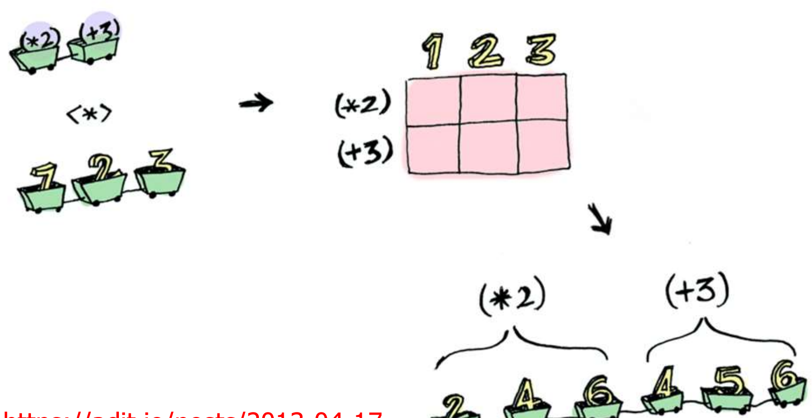
```
class Functor f => Applicative f where
  pure :: a -> f a
  (<*>) :: f (a -> b) -> f a -> f b

pure id <*> v = v                              -- identita
pure (.) <*> u <*> v <*> w = u <*> (v <*> w) -- kompozícia
pure f <*> pure x = pure (f x)                 -- homomorfizmusu
<*> pure y = pure ($ y) <*> u = pure (\g->g y) <*> u
```

Cvičenie6: definujte inštanciu [] pre Applicative, a overte pravidlá:

```
instance Applicative [] where
    pure a          = [a]
    fs  <*> xs      = [ f x | f <- fs, x <- xs]
```

Dôkaz:

1) (Return id) <*> v = [id] <*> v = v
2) [(.)] <*> [ui] <*> [vj] <*> [wk] =
   [(.)ui] <*> [vj] <*> [wk] =
   [ui . vj] <*> [wk] = [(ui . vj) wk] =
   [(ui (vj wk)]
3) pure f <*> pure x = [f] <*> [x] = [f x]
4) [f1,… fn] <*> [y] = [f1 y, … fn y]



https://adit.io/posts/2013-04-17-functors,_applicatives,_and_monads_in_pictures.html

Príklady:

```
[(*2), (+3)] <*> [1,2,3] = [2,4,6,4,5,6]
(,) <$> [1,2,3] <*> [4,5,6] = [(1,4),(1,5),(1,6),(2,4),(2,5),(2,6),(3,4),(3,5),(3,6)]
(\x y z -> (x,y,z)) <$> [1,2] <*> [3,4] <*> [5,6] = [(1,3,5),(1,3,6),(1,4,5),(1,4,6),(2,3,5),(2,3,6),(2,4,5),(2,4,6)]
pure (,,) <*> [1,2] <*> [3,4] <*> [5,6]          = [(1,3,5),(1,3,6),(1,4,5),(1,4,6),(2,3,5),(2,3,6),(2,4,5),(2,4,6)]
```

Kartézsky súčin

domáca úloha

```
module KSucin where
cart  :: [[t]] -> [[t]]
```

Príklad:

cart [[1,2], [3,4], [5]] = [[1,3,5],[1,4,5],[2,3,5],[2,4,5]]

cart [[1,2], [3,4], [5,6,7]] = [[1,3,5],[1,3,6],[1,3,7],[1,4,5],[1,4,6],[1,4,7],[2,3,5],[2,3,6],
[2,3,7],[2,4,5],[2,4,6],[2,4,7]]

cart [[1,2], [3,4], [5,6]] = [[1,3,5],[1,3,6],[1,4,5],[1,4,6],[2,3,5],[2,3,6],[2,4,5],[2,4,6]]

cart [[1,2], [3,4], []] = []

cart [["janka", "danka"], ["misko", "palko"]] = [["janka","misko"],["janka","palko"],["danka","misko"],
["danka","palko"]]

GHC.Base

- https://hackage.haskell.org/package/base-4.15.0.0/docs/GHC-Base.html

```
▹ Applicative []                                   #
```
Since: base-2.1

```
▿ Applicative Maybe                                #
```
Since: base-2.1

Defined in GHC.Base

Methods

```
pure :: a -> Maybe a

(<*>) :: Maybe (a -> b) -> Maybe a -> Maybe b

liftA2 :: (a -> b -> c) -> Maybe a -> Maybe b -> Maybe c

(*>) :: Maybe a -> Maybe b -> Maybe b

(<*) :: Maybe a -> Maybe b -> Maybe a
```

```
▹ Applicative IO                                   #
```
Since: base-2.1

Monáda

(class Monad)

monáda **m** je typ implementujúci dve funkcie:

class Applicative m => Monad **m** where -- interface predpisuje tieto funkcie
  return :: a -> m a -- to bude pure z Applicatives
  >>= :: m a -> (a -> m b) -> m b -- náš `bind`

ktoré spĺňajú isté (sémantické) zákony:

neutrálnosť return:

- return c >>= (\x->g) **=** g[x/c]
- m >>= \x->return x **=** m

neutrálnosť asociativita:

- m1 >>= (****x->m2 >>= (****y->m3)) **=** (m1 >>= (****x->m2)) >>= (****y->m3)

inak zapísané:

  return c >>= f = f c -- ľavo neutrálny prvok
  m >>= return = m -- pravo neutrálny prvok
  (m >>= f) >>= g = m >>= (\x-> f x >>= g)
  -- asocitativita >>=