Background – Constructors (1A)

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

This document was produced by using OpenOffice.

Based on

Haskell in 5 steps

https://wiki.haskell.org/Haskell_in_5_steps

Data Constructor

$$\underbrace{\textbf{data Color}}_{} = \underbrace{\textbf{Red} \mid \textbf{Green} \mid \textbf{Blue}}_{}$$

Type Constructor	Data Constructors
	values

Red is a *constructor* that contains a *value* of the type **Color**.

Green is a *constructor* that contains a *value* of the type **Color**.

Blue is a *constructor* that contains a *value* of the type **Color**.

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Variable binding examples

```
data Color = Red | Green | Blue
    deriving (Eq, Ord, Show)


pr :: Color -> String
pr x
  | x == Red   = "Red"
  | x == Green = "Green"
  | x == Blue  = "Blue"
  | otherwise  = "Not a Color"
```

```
Prelude> data Color = Red | Green | Blue
                 deriving(Eq, Ord, Show)

Prelude> let x = Red          x ← Red
Prelude> let y = Green        x ← Green
Prelude> let z = Blue         x ← Blue
```

```
*Main> pr Red               x ← Red
"Red"
*Main> pr Green             x ← Green
"Green"
*Main> pr Blue              x ← Blue
"Blue"
```

```
Prelude> show(x)
"Red"
Prelude> show (y)
"Green"
Prelude> show(z)
"Blue"
```

Data Constructor with Parameters

$$\underbrace{\text{data Color}}_{}\ =\ \underbrace{\text{RGB Int Int Int}}_{}$$

Type Constructor type	**Data Constructors** (a function returning a value)

RGB is not a value but a *function* taking three Int's and *returning a value*

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Data Constructor with Parameters – type declaration

data Color = **RGB** Int Int Int

RGB :: Int -> Int -> Int -> Color   a function type declaration

RGB is a **data constructor** that is a *function*
taking three Int values as its arguments,
and then uses them to construct a new value.

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Type Constructors and Data Constructors

A **type constructor**

- a "function" that takes 0 or more types
- returns a new **type**.

Type constructors with parameters

allows slight variations in types

type **SBTree** = **BTree** String

type **BBTree** = **BTree** Bool

BTree String returns a new type

BTree Bool returns a new type

A **data constructor**

- a "function" that takes 0 or more values
- returns a new **value**.

Data constructors with parameters

allows slight variations in values

RGB 12 92 27 → #0c5c1b

RGB 255 0 0

RGB 0 255 0

RGB 0 0 255

returns a value of Color type

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Type Constructor

Consider a binary tree to store Strings

$$\underbrace{\textbf{data}\ \textbf{SBTree}}_{}\ =\ \underbrace{\textbf{Leaf}\ \text{String}\ \mid\ \textbf{Branch}\ \text{String}\ \textbf{SBTree}\ \textbf{SBTree}}_{}$$

Type Constructor type	**Data Constructors** (functions returning a value)

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Data Constructors – type declarations

Consider a binary tree to store Strings

data SBTree = **Leaf** String | **Branch** String **SBTree SBTree**

SBTree Type Constructor	Leaf Data Constructor	Branch Data Constructor

```
Leaf    :: String -> SBTree
Branch  :: String -> SBTree -> SBTree -> SBTree
```

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Similar Type Constructors

Consider a binary tree to store Strings

```
data SBTree = Leaf String | Branch String SBTree SBTree
```

Consider a binary tree to store Bool

```
data BBTree = Leaf Bool | Branch Bool BBTree BBTree
```

Consider a binary tree to store a parameter type a

```
data BTree a = Leaf a | Branch a (BTree a) (BTree a)
```

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Type Constructor with a Parameter

```
data SBTree = Leaf String  |  Branch String SBTree SBTree
data BBTree = Leaf Bool    |  Branch Bool BBTree BBTree
```

```
data BTree a = Leaf a      |  Branch a (BTree a) (BTree a)
```

a **type variable** **a**

as a parameter to the type constructor.

BTree has become a function.

It takes a **type** as its argument

and it returns a **new type**.

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

( ) : the unit type

( ) is both a **type** and a **value**.

( ) is a special **type**, pronounced "**unit**",
has one **value** **( )**, sometimes pronounced "**void**"

the unit type **( )**
the **void value ( )**

the **unit type** has only one **value** which is called **unit**.

data ( ) = **( )**
( ) :: ( )

data Type :: Expression
Value :: Type

Immutable **Variable :: Type**

It is the same as the void type **void** in Java or C/C++.

https://stackoverflow.com/questions/20380465/what-do-parentheses-used-on-their-own-mean

Unit Type

a **unit type** is a type that allows *only one value* (and thus can hold *no information*).

It is the same as the void type **void** in Java or C/C++.

:t

Expression :: Type

data Unit = Unit

Prelude> :t **Unit**

Unit :: Unit

data ( ) = ( )

Prelude> :t **( )**

( ) :: ( )

Prelude> :t ()

() :: ()

https://stackoverflow.com/questions/20380465/what-do-parentheses-used-on-their-own-mean

Never ending expressions

expressions : the entities on which calculations are performed — **1+2**

values : the entities that result from a calculation – i.e., the answers — **3**

an **expression** has only a never-ending sequence of calculations

```
x = x + 1
```

```
x
 ⇒ x + 1
 ⇒ (x + 1) + 1
 ⇒ ((x + 1) + 1) + 1
 ⇒ (((x + 1) + 1) + 1) + 1
 …
```

this expression is said to not terminate, or diverge.

the symbol ⊥, pronounced **bottom**,

is used to denote the **value** of the **expression**.

each **type** has its own version of ⊥.

https://www.reddit.com/r/haskell/comments/5h4o3u/a_beginnerfriendly_explanation_of_bottom_taken/

Bottom definition

The term **bottom** refers to a computation

that never completes successfully.

that fails due to some kind of error

that just goes into an infinite loop

(without returning any data).

The mathematical symbol for **bottom** is '⊥'

In plain ASCII, '_|_

bottom is

a member **value** of any type Int, Float … ,

a member **value** of even the trivial type **( )**

a member **value** of the equivalent simple type:

```
data Unary = Unary
```

https://wiki.haskell.org/Bottom

Bottom Expressions

bottom can be expressed in Haskell thus:

```
bottom = bottom                                      -- bottom yielding expression (infinite)
bottom = error "Non-terminating computation!"        -- function
```

the **type** of **bottom** is arbitrary,

and defaults to the most general type:

```
f n | n < 3 = -1
f n | n < 5 = 1
f n         = 2
```

```
bottom :: a
```

```
undefined = error "Prelude.undefined"                -- the Prelude function
undefined | False = undefined                        -- the Gofer function
```

https://wiki.haskell.org/Bottom

The Value Undefined

undefined is an **example** of a **bottom value** (denoted ⊥)
that represents any undefined, stuck or partial state in the program.

Many different forms of **bottom** exist:
non-terminating loops, exceptions, pattern match failures
basically any state in the program that is undefined in some sense.

The value **undefined :: a** is a canonical example of
a value that puts the program in an undefined state.

https://stackoverflow.com/questions/3962939/whats-the-difference-between-undefined-in-haskell-and-null-in-java

Undefined examples

undefined itself isn't particularly special -- its not wired in --
and you can implement Haskell's **undefined**

using any **bottom**-yielding expression.
E.g. this is a valid implementation of undefined:

undefined = undefined

exiting immediately (the old Gofer compiler used this definition):

undefined | False = undefined

The primary property of **bottom** is
that if an expression evaluates to **bottom**,
your entire program will evaluate to **bottom**:
the program is in an undefined state.

https://stackoverflow.com/questions/3962939/whats-the-difference-between-undefined-in-haskell-and-null-in-java

Undefined usages

As bottom is an inhabitant of every type

bottoms can be used

wherever a value of every type would be.

useful in a number of circumstances:

-- for leaving a part in your program to come back to later:

foo = undefined

-- when dispatching to a type class instance:

print (sizeOf (undefined :: Int))

-- when using laziness:

print (head (1 : undefined))

```
:set +m --multiline
let foo=undefined
foo
        *** Exception: Prelude.undefined
```

```
import  Foreign.Storable
print(sizeOf(undefined::Int))
        8
let i = 10
let i = 10 :: Int
print(sizeOf(i))
        8
```

```
print (head (1 : undefined))
        1
print (head (1 : [1, 2, 3]))
        1
print (head (undefined : [1, 2, 3]))
        *** Exception: Prelude.undefined
```

https://wiki.haskell.org/Bottom

A new datatype declaration

data TypeC Tpar … Tpar = ValC type … type | … |
ValC type … type

A new **datatype** declaration

The keyword **data** introduces a new **datatype** declaration,

- the **new type** TypeC **T**par … **T**par
- its **values** **ValC** type … type | … | **ValC** type … type

datatype

data type

data type = data

https://stackoverflow.com/questions/16892570/what-is-in-haskell-exactly

Type Language and Expression Language

data TypeC **T**var … **T**var = **ValC**_1 type … type | … |
ValC_n type … type

A new **datatype** declaration

TypeC (**T**ype **Cons**tructor) is added to *the type language*

ValC (**V**alue **Cons**tructor) is added to *the expression language*

and *its pattern sub-language*

must not appear in types

expression language

***Value** equivalent*

***Variable** (immutable)*

https://stackoverflow.com/questions/16892570/what-is-in-haskell-exactly

Expression Language : always at the RHS

data TypeC Tvar … Tvar = ValC_1 type … type | … |

ValC_n type … type

argument types in (Tconst Tvar … Tvar)

can be used as argument types in Vconst type … type

https://stackoverflow.com/questions/16892570/what-is-in-haskell-exactly

Datatype Declaration Examples

```
data Tree a =   Leaf |  Node (Tree a) (Tree a)

Tree            (Type Constructor)
Leaf or Node    (Value Constructor)
```

data Type = Value

```
data ( ) =  ( )

( )    (Type Constructor)
( )    (Value Constructor)
```

the type (), often pronounced "Unit"

the value (), sometimes pronounced "void"

the type () containing only one value ()

https://stackoverflow.com/questions/16892570/what-is-in-haskell-exactly

Type Synonyms

A **type synonym** is a new name for an existing type.

Values of different synonyms of the same type
are entirely compatible.

```
type MyChar = Char
```

The same as **typedef** in C

https://wiki.haskell.org/Type_synonym

Type Synonym Examples

```
type String = [Char]                          no data constructor

phoneBook :: [(String,String)]
```

```
type PhoneBook = [(String,String)]            no data constructor

phoneBook :: PhoneBook
```

```
type PhoneNumber = String                     no data constructor
type Name = String
type PhoneBook = [(Name,PhoneNumber)]

phoneBook :: PhoneBook
```

```
phoneBook =
    [("betty","555-2938")
    ,("bonnie","452-2928")
    ,("patsy","493-2928")
    ,("lucille","205-2928")
    ,("wendy","939-8282")
    ,("penny","853-2492")
    ]
```

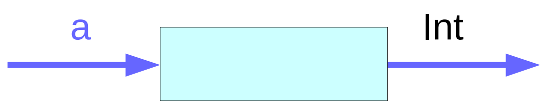
http://learnyouahaskell.com/making-our-own-types-and-typeclasses

Type Synonyms for Functions

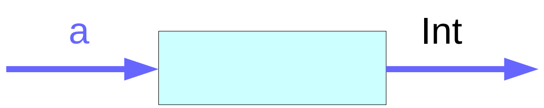
```
type Bag a = a -> Int                    no data constructor

data Gems = Sapphire | Emerald | Diamond deriving (Show)
```

a -> Int



Bag a




```
type Bag a = a -> Int
type Bag Int = Int -> Int
type Bag Char = Char -> Int
```

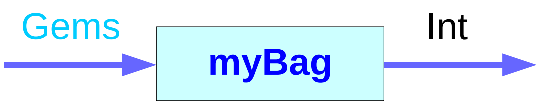
https://stackoverflow.com/questions/14166641/haskell-type-synonyms-for-functions

Type Synonyms for Functions

```
type Bag a = a -> Int                         no data constructor

data Gems = Sapphire | Emerald | Diamond deriving (Show)
```

myBag :: **Bag Gems**



emptyBag :: **Bag Gems**

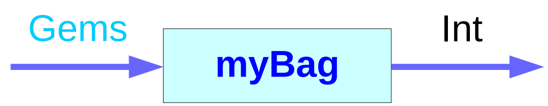
https://stackoverflow.com/questions/14166641/haskell-type-synonyms-for-functions

Type Synonyms for Functions

```
type Bag a = a -> Int                    no data constructor

data Gems = Sapphire | Emerald | Diamond deriving (Show)
```

```
myBag :: Bag Gems
myBag Sapphire = 3
myBag Diamond = 2
myBag Emerald = 0
```



Sapphire	3
Diamond	2
Emerald	0

```
emptyBag :: Bag Gems
emptyBag Sapphire = 0
emptyBag Diamond = 0
emptyBag Emerald = 0
```

Sapphire	0
Diamond	0
Emerald	0

https://stackoverflow.com/questions/14166641/haskell-type-synonyms-for-functions

Pattern matching function

```
data Person = Person String String Int Float String String deriving (Show)
```

Type Const — Data Const

```
let guy = Person "Buddy" "Finklestein" 43 184.2 "526-2928" "Chocolate"
```

```
firstName :: Person -> String
firstName  (Person firstname _ _ _ _ _) = firstname        -- return firstname
```

```
Person "Buddy" "Finklestein" 43 184.2 "526-2928" "Chocolate"
```

firstname = Buddy

http://learnyouahaskell.com/making-our-own-types-and-typeclasses

Toward the Record Syntax

```
data Person = Person String String Int Float String String deriving (Show)

let guy = Person "Buddy" "Finklestein" 43 184.2 "526-2928" "Chocolate"
```

pattern matching functions	
firstName :: Person -> String firstName (Person firstname _ _ _ _ _) = firstname	firstName guy ► "Buddy"
lastName :: Person -> String lastName (Person _ lastname _ _ _ _) = lastname	lastName guy ► "John"
age :: Person -> Int age (Person _ _ age _ _ _) = age	age guy ► 43
height :: Person -> Float height (Person _ _ _ height _ _) = height	height guy ► 184.2
phoneNumber :: Person -> String phoneNumber (Person _ _ _ _ number _) = number	phoneNumber guy ► "526-2928"
flavor :: Person -> String flavor (Person _ _ _ _ _ flavor) = flavor	flavor guy ► "Chocolate"

http://learnyouahaskell.com/making-our-own-types-and-typeclasses

The Record Syntax

```
data Person = Person {  fName        :: String
                      , lName        :: String
                      , age          :: Int
                      , ht           :: Float
                      , ph           :: String
                      , flavor       :: String
                      } deriving (Show)
```

```
let guy = Person{  fName="Buddy",
                   lName="John",
                   age=43,
                   ht=184.2,
                   ph=”526-2928”,
                   flavor=“Orange” }
```

http://learnyouahaskell.com/making-our-own-types-and-typeclasses

The Record Syntax Example

```
data Car = Car String String Int deriving (Show)
```

non-record

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

```
data Car = Car { company :: String, model :: String, year :: Int } deriving (Show)
```

record

```
Car { company = "Ford", model = "Mustang", year = 1967 }
```

★
```
Car   "Ford"   "Mustang"   1967              -- no commas
```

http://learnyouahaskell.com/making-our-own-types-and-typeclasses

Accessor Functions

```
data Person = Person {  fName         :: String
                     ,  lName         :: String
                     ,  age           :: Int
                     ,  ht            :: Float
                     ,  ph            :: String
                     ,  flavor        :: String
                     } deriving (Show)
```

```
let guy = Person { fName="Buddy", lName="John", age=43, ht=184.2, ph="526-2928", flavor="Orange" }
```

accessor functions

```
fName      :: Person -> String
lName      :: Person -> String
age        :: Person -> Int
ht         :: Person -> Float
ph         :: Person -> String
flavor     :: Person -> String
```

```
fName   guy  ► "Buddy"
lName   guy  ► "John"
age     guy  ► 43
ht      guy  ► 184.2
ph      guy  ► "526-2928"
flavor  guy  ► "Orange"
```

http://learnyouahaskell.com/making-our-own-types-and-typeclasses

Update Functions

```
data Configuration = Configuration
                          { username        :: String
                           , localHost       :: String
                           , currentDir      :: String
                           , homeDir         :: String
                           , timeConnected   :: Integer
                          }
```

```
username :: Configuration -> String                          -- accessor function  (automatic)
localHost :: Configuration -> String
-- etc.
changeDir :: Configuration -> String -> Configuration         -- update function
changeDir cfg newDir =
  if directoryExists newDir                 -- make sure the directory exists
    then cfg { currentDir = newDir }
    else error "Directory does not exist"
```

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

Typeclass and Instance Example

```
class Eq a where
    (==) :: a -> a -> Bool        - a type declaration
    (/=) :: a -> a -> Bool        - a type declaration
    x == y = not (x /= y)         - a function definition
    x /= y = not (x == y)         - a function definition
```

```
data TrafficLight = Red | Yellow | Green
```

```
instance Eq TrafficLight where
    Red    == Red    = True
    Green  == Green  = True
    Yellow == Yellow = True
    _ == _           = False
```

```
ghci> Red == Red
True
ghci> Red == Yellow
False
ghci> Red `elem` [Red, Yellow, Green]
True
```

http://learnyouahaskell.com/making-our-own-types-and-typeclasses#the-functor-typeclass

Instance of a typeclass (1)

```
data State a = State { runState :: Int -> (a, Int) }

instance Show (State a) where                    not working!

instance (Show a) => Show (State a) where
    show (State f) = show [show i ++ " => " ++ show (f i) | i <- [0..3]]

getState = State (\c -> (c, c))

putState count = State (\_ -> ((), count))
```

(State a) is an instance of Show

a should be an instance of Show

State { runState = (\c -> (c, c)) }

State { runState = (_ -> ((), c)) }

https://stackoverflow.com/questions/7966956/instance-show-state-where-doesnt-compile

Instance of a typeclass (2)

```
getState = State (\c -> (c, c))


show (State (\c -> (c, c)))                    (\c -> (c, c))

show (State        f       )                          f
```

```
instance (Show a) => Show (State a) where
    show (State f) = show [show i ++ " => " ++ show (f i) | i <- [0..3]]

       i=0                  i=1                  i=2                  i=3
show [0 => show (f 0),      1 => show (f, 1),    2 => show (f, 2),    3 => show (f, 3)]

      (\c -> (c, c)) 0      (\c -> (c, c)) 1     (\c -> (c, c)) 2     (\c -> (c, c)) 3

          (0,0)             (1, 1)               (2, 2)               (3, 3)
```

https://stackoverflow.com/questions/7966956/instance-show-state-where-doesnt-compile

Instance of a typeclass (3)

```
data State a = State { runState :: Int -> (a, Int) }

instance (Show a) => Show (State a) where
    show (State f) = show [show i ++ " => " ++ show (f i) | i <- [0..3]]

getState = State (\c -> (c, c))
putState count = State (\_ -> ((), count))
 f → (\c -> (c, c))
```

```
*Main> getState
["0 => (0,0)","1 => (1,1)","2 => (2,2)","3 => (3,3)"]

*Main> putState 1
["0 => ((),1)","1 => ((),1)","2 => ((),1)","3 => ((),1)"]
```

https://stackoverflow.com/questions/7966956/instance-show-state-where-doesnt-compile

newtype and **data**

data $\underset{\longleftarrow}{\not\longrightarrow}$ **newtype**

data can <u>only</u> be replaced with **newtype** $\longrightarrow$

if the type has exactly <u>*one value constructor*</u>

which can have exactly only <u>*one field*</u>

It ensures that the trivial **wrapping** and **unwrapping**

of the single field is eliminated by the **compiler**.

(using newtype is faster)

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

data, type, and newtype

```
data      State s a = State { runState :: s -> (s, a) }
type      State s a = ~~State { runState :: s -> (s, a) }~~        (X)
newtype   State s a = State { runState :: s -> (s, a) }
```

a new type, data constructor

an alias, no data constructor

a new type, data constructor

instance : **data**(O), **type**(X), **newtype**(O)

overhead : **data**(O), **type**(X), **newtype**(X)

```
data      State s a = State { runState :: s -> (s, a) }
type      MMM s a = State s a        -- existing type
                                     -- exactly same as typedef in C
```

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

Single value constructor with a single field

simple wrapper types such as State **Monad**

are usually defined with **newtype**.

type : type synonyms

```
newtype State s a = State { runState :: s -> (s, a) }
```

A single value **constructor** : State { runState :: s -> (s, a) }

A single **field** : { runState :: s -> (s, a) }

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

Single value constructor with a single field

one constructor with one field means that

the new type and **the type of the field**

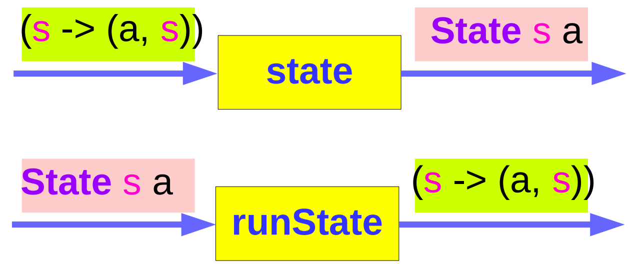
are in direct correspondence (**isomorphic**)

state :: (s -> (a, s)) -> **State** s a

runState :: **State** s a -> (s -> (a, s))

after the type is checked at compile time,

at run time the two types can be treated identically



(s -> (a, s)) **the type of the field**

State s a **the new type**

State { runState :: s -> (s, a) } **one constructor with one field**

https://stackoverflow.com/questions/2649305/why-is-there-data-and-newtype-in-haskell

Creating a new type class

to declare different new type class instances for a particular type,

or want to make a type abstract,

- wrap it in a **newtype**
- then the type checker treats it as a distinct new type
- but identical at runtime without incurring additional overheads.

Isomorphic relation means

that after the type is checked at compile time,

at run time the two types can be treated essentially the same,

without the overhead or indirection

normally associated with a data constructor.

https://stackoverflow.com/questions/2649305/why-is-there-data-and-newtype-in-haskell

data, newtype, type

	data	newtype	type
value constructors : number	many	only one	none
value constructors : evaluation	lazy	strict	N/A
value constructors : fields	many	only one	none
Compilation Time	affected	affected	affected
Run Time Overhead	runtime overhead	none	none
Created Type	a distinct new type	a distinct new type	a new name
Type Class Instances	type class instances	type class instances	no instance
Pattern Matching Evaluation	at least WHNF	no evaluation	same as the original
Usage	a new data type	higher level concept	higher level concept

https://stackoverflow.com/questions/2649305/why-is-there-data-and-newtype-in-haskell

data

data - creates new algebraic type with value constructors

- can have several value constructors
- value constructors are lazy
- values can have several fields
- affects both compilation and runtime, have runtime overhead
- created type is a distinct new type
- can have its own type class instances
- when pattern matching against value constructors,
  WILL be evaluated at least to weak head normal form (WHNF) *
- used to create new data type
  (example: Address { zip :: String, street :: String })

https://stackoverflow.com/questions/2649305/why-is-there-data-and-newtype-in-haskell

newtype

newtype - creates new "decorating" type with value constructor

- can have only one value constructor
- value constructor is strict
- value can have only one field
- affects only compilation, no runtime overhead
- created type is a distinct new type
- can have its own type class instances
- when pattern matching against value constructor,
  CAN not be evaluated at all *
- used to create higher level concept
  based on existing type with distinct set of
  supported operations or that is not
- interchangeable with original type
  (example: Meter, Cm, Feet is Double)

https://stackoverflow.com/questions/2649305/why-is-there-data-and-newtype-in-haskell

type

type - creates an alternative name (synonym)
for a type (like typedef in C)

- no value constructors
- no fields
- affects only compilation, no runtime overhead
- no new type is created (only a new name for existing type)
- can NOT have its own type class instances
- when pattern matching against data constructor,
  behaves the same as original type
- used to create higher level concept
  - based on existing type with the same set of
    supported operations (example: String is [Char])

https://stackoverflow.com/questions/2649305/why-is-there-data-and-newtype-in-haskell

newtype examples

```haskell
newtype Fd = Fd CInt
-- data Fd = Fd CInt would also be valid

-- newtypes can have deriving clauses just like normal types
newtype Identity a = Identity a
  deriving (Eq, Ord, Read, Show)

-- record syntax is still allowed, but only for one field
newtype State s a = State { runState :: s -> (s, a) }

-- this is *not* allowed:
-- newtype Pair a b = Pair { pairFst :: a, pairSnd :: b }
-- but this is allowed (no restriction in data):
data Pair a b = Pair { pairFst :: a, pairSnd :: b }          -- two fields
-- and so is this:
newtype NPair a b = NPair (a, b)              -- one value constructor
```

https://wiki.haskell.org/Newtype

newtype examples

Suppose you need to have a **type** which is very much like **Int**,

but with different **ordering :**

first by **even** numbers then by **odd** numbers

cannot **define** a **new instance** of **Ord** for **Int**

because then Haskell *will not know which one to use*.

defining a **type** which is **isomorphic** to **Int:**

One way to do this would be to define a new **datatype**:

```
data MyInt = MyInt Int
```

https://en.wikibooks.org/wiki/Yet_Another_Haskell_Tutorial/Type_advanced

Defining isomorphic types

Suppose you need to have a **type** which is very much like **Int**,

but with different **ordering :**

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Defining isomorphic types – bottom

data MyInt = MyInt Int

this type is not truly isomorphic to Int

it has one more value.

the type **Int –** all values of integers + one more value: ⊥

which is used to represent **erroneous** or **undefined computations**.

MyInt has not only values **MyInt 0**, **MyInt 1** and so on,

but also **MyInt ⊥**

since datatypes can themselves be undefined,

it has an additional value: **⊥**

which differs from **MyInt ⊥**

this makes the types non-isomorphic.

https://en.wikibooks.org/wiki/Yet_Another_Haskell_Tutorial/Type_advanced

Defining isomorphic types – efficiency

```
data MyInt = MyInt Int
```

efficiency issues with this representation:

instead of simply **storing** an **integer**,

we have to **store** a **pointer** to an **integer**

and have to **follow** that **pointer**

whenever we <u>need</u> the **value** of a **MyInt**.

https://en.wikibooks.org/wiki/Yet_Another_Haskell_Tutorial/Type_advanced

Defining isomorphic types – newtype

```
data MyInt = MyInt Int
```

To get around these problems of **datatype**

(not isomorphic and efficiency)

Haskell has a **newtype** construction.

it has a **constructor** like a **datatype**,

but it can have **only one constructor** and

this constructor can have **only one argument**.

```
newtype MyInt = MyInt Int
```

https://en.wikibooks.org/wiki/Yet_Another_Haskell_Tutorial/Type_advanced

Defining isomorphic types – one constructor one argument

But we cannot define any of:

newtype Bad1 = Bad1a Int | Bad1b Double **(2 constructors)**

newtype Bad2 = Bad2 Int Double **(2 arguments)**

the fact that we cannot define **Bad2** as above is not a big issue:

we simply use **type** instead:

type Good2 = Good2 Int Double

Or declare a **newtype alias** to the existing **tuple type**:

newtype Good2 = Good2 (Int,Double)

https://en.wikibooks.org/wiki/Yet_Another_Haskell_Tutorial/Type_advanced

Defining isomorphic types – MyInt example

```
instance Ord MyInt where
  compare (MyInt i) (MyInt j)
    | odd  i && odd  j    = compare i j
    | even i && even j   = compare i j
    | even i                   = LT
    | otherwise             = GT
```

Like **datatype**, we can still **derive classes** over **newtypes**

like **Show** and **Eq**

implicitly assuming we have derived **Eq** over **MyInt**

in recent versions of GHC, on **newtypes**, you are allowed

to derive any **class** of which the **base type** (**Int**) is an **instance**.

For example, we could derive **Num** on **MyInt**

to provide arithmetic functions over it.

Pattern matching over newtypes is exactly as in datatypes. We can write constructor and destructor functions for MyInt as follows:

https://en.wikibooks.org/wiki/Yet_Another_Haskell_Tutorial/Type_advanced

```
mkMyInt i = MyInt i
unMyInt (MyInt i) = i
```

Defining isomorphic types – Pattern Matching

Pattern matching over **newtypes**

is exactly as in **datatypes**.

We can write **constructor** and **destructor functions**

for **MyInt** as follows:

```
mkMyInt i = MyInt i
unMyInt (MyInt i) = i
```

https://en.wikibooks.org/wiki/Yet_Another_Haskell_Tutorial/Type_advanced

References

[1] ftp://ftp.geoinfo.tuwien.ac.at/navratil/HaskellTutorial.pdf

[2] https://www.umiacs.umd.edu/~hal/docs/daume02yaht.pdf