

Type Class: The Ultimate Ad Hoc

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Type classes are a language feature

- ▶ Haskell
- ▶ Purescript
- ▶ Eta
- ▶ Clean

or sometimes a design pattern

- ▶ Scala

Polymorphism

Something which is *polymorphic* has many shapes

Polymorphism is good

- ▶ less duplication
- ▶ more reuse
- ▶ fewer possible implementations

Broadly speaking there are two major forms of polymorphism in programming:

- ▶ *parametric* polymorphism
- ▶ *ad-hoc* polymorphism

A *parametrically polymorphic* type has at least one *type parameter* which can be instantiated to *any type*.

Example:

```
reverse :: [a] -> [a]
```

An *ad-hocly polymorphic* type can be instantiated to some different types, and may behave differently for each type

Example:

==

Interfaces

```
interface Equal<A> {  
    public boolean eq(A other);  
}
```

```
interface Equal<A> {  
    public boolean eq(A other);  
}
```

```
class Person implements Equal<Person> {  
    public int age;  
    public String name;  
  
    public boolean eq(Person other) {  
        return this.age == other.age && this.name.equals(other.name);  
    }  
}
```

```
static <A extends Equal<A>> boolean elementOf(A a, List<A> list) {  
    for (A element : list) {  
        if (a.eq(element)) return true;  
    }  
    return false;  
}
```

```
static <A extends Equal<A>> boolean elementOf(A a, List<A> list) {  
    for (A element : list) {  
        if (a.eq(element)) return true;  
    }  
    return false;  
}
```

```
elementOf(me, functionalProgrammers);  
// true
```

```
package java.lang;
```

```
class String {  
    private char[] value;  
    // other definitions  
}
```

```
package java.lang;
```

```
class String implements Equal<String> {  
    private char[] value;  
    // other definitions  
}
```

```
class List<A> {  
    // implementation details
```

```
}
```



```
class List<A> implements Equal<List<A>> {  
    // implementation details  
  
}
```

```
class List<A> implements Equal<List<A>> {  
    // implementation details  
  
    public boolean eq(List<A> other) {  
        // implementation...  
    }  
}
```

```
class List<A> implements Equal<List<A>> {  
    // implementation details  
  
    public boolean eq(List<A> other) {  
        // implementation...  
        // ... but how do we compare A for equality?  
    }  
}
```

- ▶ Interface implementation can't be conditional
- ▶ We can only implement interfaces for types we control

Type Classes

```
class Equal a where  
  eq :: a -> a -> Bool
```

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  eq :: a -> a -> Bool
```

```
data Person = Person {  
  age :: Int  
, name :: String  
}
```

```
class Equal a where  
    eq :: a -> a -> Bool
```

```
data Person = Person {  
    age :: Int  
, name :: String  
}
```

```
instance Equal Person where  
    eq p1 p2 = eq (age p1) (age p2) && eq (name p1) (name p2)
```



```
elementOf :: Equal a => a -> [a] -> Bool
elementOf a list =
  case list of
    []      -> False
    (h:t)   -> eq a h || elementOf a t
```

Instances can be constrained

```
instance (Equal a) => Equal [a] where
  eq [] [] = True
  eq (x:xs) [] = False
  eq [] (y:ys) = False
  eq (x:xs) (y:ys) = eq x y && eq xs ys
```

Instances can be constrained

```
instance (Equal a) => Equal [a] where
  eq [] [] = True
  eq (x:xs) [] = False
  eq [] (y:ys) = False
  eq (x:xs) (y:ys) = eq x y && eq xs ys
```

We can add type class instances for types we didn't write

- ▶ You can write instances for types you did not write
- ▶ Instances can depend on other instances

There are exactly two places a type class instance is allowed to exist

Person.hs

```
data Person = Person
  { age: Int
  , name: String }

instance Equal Person where
  eq p1 p2 = ...
```

Equal.hs

```
class Equal a where
  eq :: a -> a -> Bool
```

There are exactly two places a type class instance is allowed to exist

Person.hs

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data Person = Person
  { age: Int
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Equal.hs

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class Equal a where
  eq :: a -> a -> Bool

instance Equal Person where
  eq p1 p2 = ...
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Person.hs

```
data Person = Person  
  { age: Int  
  , name: String }
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Equal.hs

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class Equal a where  
  eq :: a -> a -> Bool
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EqualInstances.hs

```
instance Equal Person where  
  eq p1 p2 = ...
```

Person.hs

```
data Person = Person
  { age: Int
  , name: String }
```

Equal.hs

```
class Equal a where
  eq :: a -> a -> Bool
```

EqualInstances.hs

```
instance Equal Person where
  eq p1 p2 = ...
```

“Orphan instance”

Orphan instances break *type class coherence*

Type class coherence gives many sane benefits:

- ▶ There can only be zero or one instance
- ▶ Using an instance never depends on imports
- ▶ The semantics are what we expect

Type class coherence precludes:

- ▶ Custom local instances for quick things
- ▶ Multiple instances selectable by import

Implicits

More Flexible Than TypeclassesTM

```
case class Person(age: Int, name: String)
```

```
case class Person(age: Int, name: String)
```

```
trait Equal[A] {  
  def eq(a: A, b: A): Boolean  
}
```

```
case class Person(age: Int, name: String)
```

```
trait Equal[A] {  
  def eq(a: A, b: A): Boolean  
}
```

```
implicit def equalPerson: Equal[Person] = new Equal[Person] {  
  def eq(a: Person, b: Person): Boolean =  
    a.age == b.age && a.name == b.name  
}
```

```
def elementOf[A] (a: A, list: List[A])  
    (implicit equalA: Equal[A]): Boolean = {  
  list match {  
    case Nil => false  
    case (h::t) => equal.eq(a, h) || elementOf(a, t)  
  }  
}
```

```
implicit def equalList(implicit equalA: Equal[A]): Equal[List[A]] =  
  new Equal[List[A]] {  
    def eq(a: List[A], b: List[A]): Boolean = {  
      (a,b) match {  
        case (Nil, Nil)      => true  
        case (x::xs, Nil)   => false  
        case (Nil, y::ys)   => false  
        case (x::xs, y::ys) => equalA.eq(x,y) || eq(xs,ys)  
      }  
    }  
  }  
}
```


- ▶ We can define implicits for types we did not write
- ▶ We can write implicits that depend on implicits

- ▶ No restriction on orphan instances
- ▶ No restriction on number of instances

```
sealed trait Ordering  
case object LT extends Ordering  
case object EQ extends Ordering  
case object GT extends Ordering
```

```
sealed trait Ordering
case object LT extends Ordering
case object EQ extends Ordering
case object GT extends Ordering
```

```
trait Order[A] {
  def compare(a: A, b: A): Ordering
}
```

```
sealed trait Ordering
case object LT extends Ordering
case object EQ extends Ordering
case object GT extends Ordering
```

```
trait Order[A] {
  def compare(a: A, b: A): Ordering
}
```

```
implicit def orderPerson: Order[Person] = new Order[Person] {
  def compare(a: Person, b: Person): Ordering =
    intOrder.compare(a.age, b.age) match {
      case LT => LT
      case EQ => stringOrder.compare(a.name, b.name)
      case GT => GT
    }
}
```

```
def sort[A](list: List[A])(implicit orderA: Order[A]): List[A] = {  
  // quicksort goes here  
}
```

```
sort (  
  List (  
    Person (30, "Robert")  
  ,   Person (20, "John")  
  ,   Person (40, "Alfred")  
  )  
)
```

```
sort (  
  List (  
    Person (30, "Robert")  
  ,   Person (20, "John")  
  ,   Person (40, "Alfred")  
  )  
)
```

==>

```
List (  
  Person (20, "John")  
,   Person (30, "Robert")  
,   Person (40, "Alfred")  
)
```


Then the boss says “I want those sorted by name”.

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```
implicit def orderPersonByName: Order[Person] = new Order[Person] {  
  def compare(a: Person, b: Person): Ordering =  
    stringOrder.compare(a.name, b.name) match {  
      case LT => LT  
      case EQ => intOrder.compare(a.age, b.age)  
      case GT => GT  
    }  
}
```

```
sort (  
  List (  
    Person (30, "Robert")  
  ,   Person (20, "John")  
  ,   Person (40, "Alfred")  
  )  
)
```

```
sort (  
  List (  
    Person (30, "Robert")  
  ,   Person (20, "John")  
  ,   Person (40, "Alfred")  
  )  
)
```

==>

```
List (  
  Person (40, "Alfred")  
,   Person (20, "John")  
,   Person (30, "Robert")  
)
```

// both in scope

implicit def orderPerson: **Order**[**Person**] = ...

implicit def orderPersonByName: **Order**[**Person**] = ...

// what happens?

sort(persons)

// both in scope

implicit def orderPerson: **Order**[**Person**] = ...

implicit def orderPersonByName: **Order**[**Person**] = ...

// what happens?

sort(persons)

Hopefully a compiler error!

Set.scala

```
def emptySet[A]: Set[A]
```

```
def insert[A](a: A, set: Set[A])(implicit o: Order[A]): Set[A]
```

```
def union[A](s1: Set[A], s2: Set[A])(implicit o: Order[A]): Set[A]
```

```
def isElement[A](a: A, set: Set[A])(implicit o: Order[A]): Boolean
```

Persons.scala

```
implicit def orderPersonByAge: Order[Person] = ...
```

```
def persons: Set[Person] =  
  insert(p1, insert(p2, insert(p3, emptySet)))
```

Something.scala

```
import Persons.{p1, persons}
```

```
implicit def orderPersonByName: Order[Person] = ...
```

```
val x = isElement(p1, persons) // FALSE!
```


Recommendations when writing implicits:

- ▶ Only create instances in the file that defines the type or the “type class”
- ▶ Disallow creating more than one instance (regardless of which file you’re in)

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What about implicits in external libraries?

- ▶ Assess their usage of implicits. Do they use them as like type classes?
- ▶ If you distrust their implicits, pass everything of theirs explicitly

Type classes:

- ▶ Big wins in flexibility, expressiveness, and modularity
- ▶ Restrictions are straightforward and compiler checked
- ▶ Coherence keeps things sane

Thanks for listening!

Questions?