Scala on the spotlight (part 2)

Mount Everest North Face as seen from the path to the base camp, Tibet. Wikimedia Commons. GNU 1.2.

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Scala as a composition language

- Component = class or trait
- Composition via mixins
- Abstraction:
  - Parameters
  - Abstract members
  - Self types

Class composition with traits

- A unit of code reusable through inheritance
- Traits mix traits of Bracha's *mixins* and Schärli *et al.*' *traits*!

A simple trait

```
scala> trait AbsIterator[T] {
  def hasNext: Boolean
  def next: T
}
defined trait AbsIterator
```

- Similar to a class but:
- No parameters
- Can be used for “mixin” composition

Example from An Overview of the Scala Programming Language
Tech. Report LAMP-REPORT-2006-001

Traits are not mere interfaces

```
trait AbsIterator[T] {
  def hasNext: Boolean
  def next: T
}

trait RichIterator[T] extends AbsIterator[T] {
  def foreach(f: T => Unit): Unit =
    while (hasNext) f(next)
}
```

- Traits may contain concrete methods and fields (and maintain state)

Traits composition

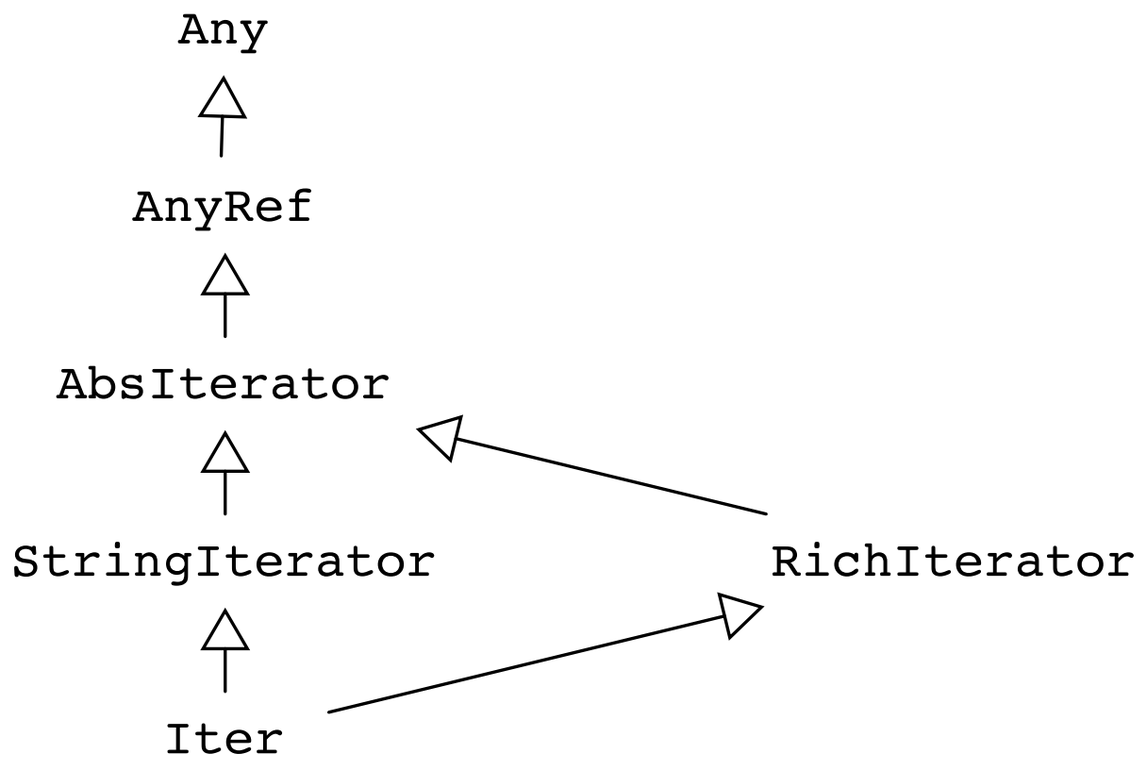
```
scala> class StringIterator(s: String) extends AbsIterator[char] {
  private var i = 0
  def hasNext = i < s.length
  def next = { val x = s charAt i; i = i + 1; x }
}
defined class StringIterator
scala> class Iter(s: String) extends StringIterator(s) with
RichIterator[Char]
defined class Iter
scala> new Iter("foo") foreach println
f
o
o
```

- `Iter` has two parents: a *superclass* `StringIterator` and a *mixin* `RichIterator`

Questions

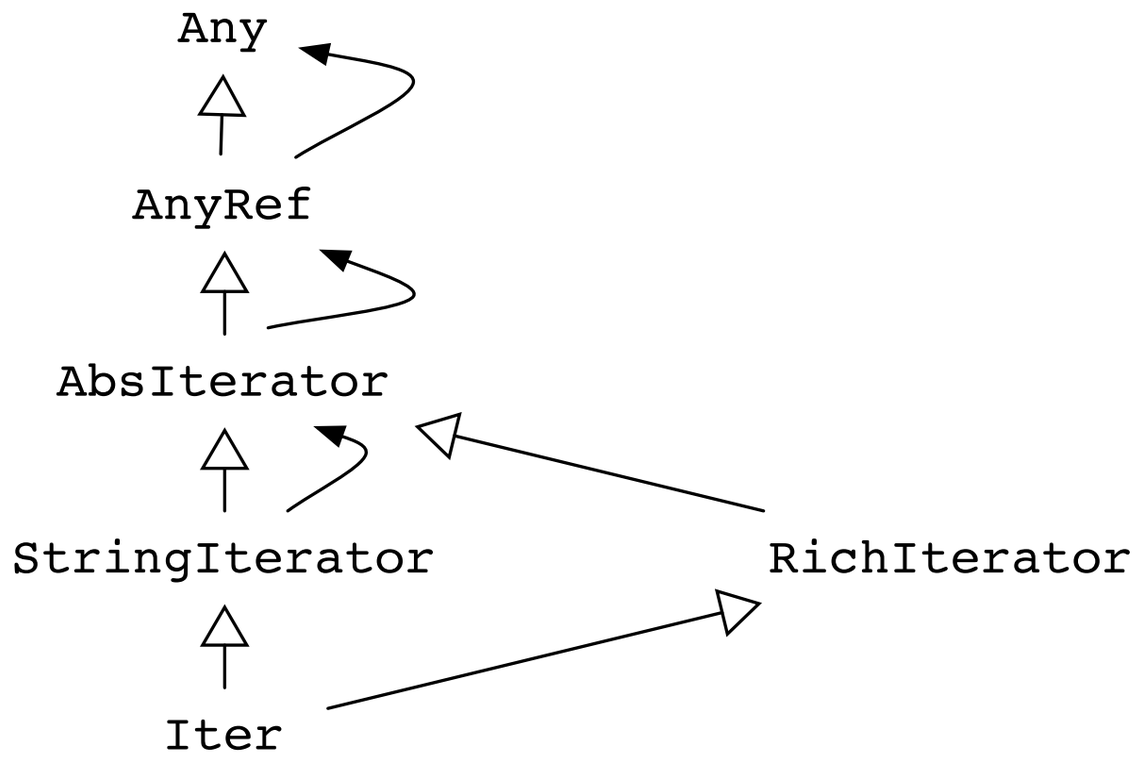
- What happens if the same parent is inherited via different paths?
- What happens if several parents define the same member?
- How to resolve supercalls?

Linearization



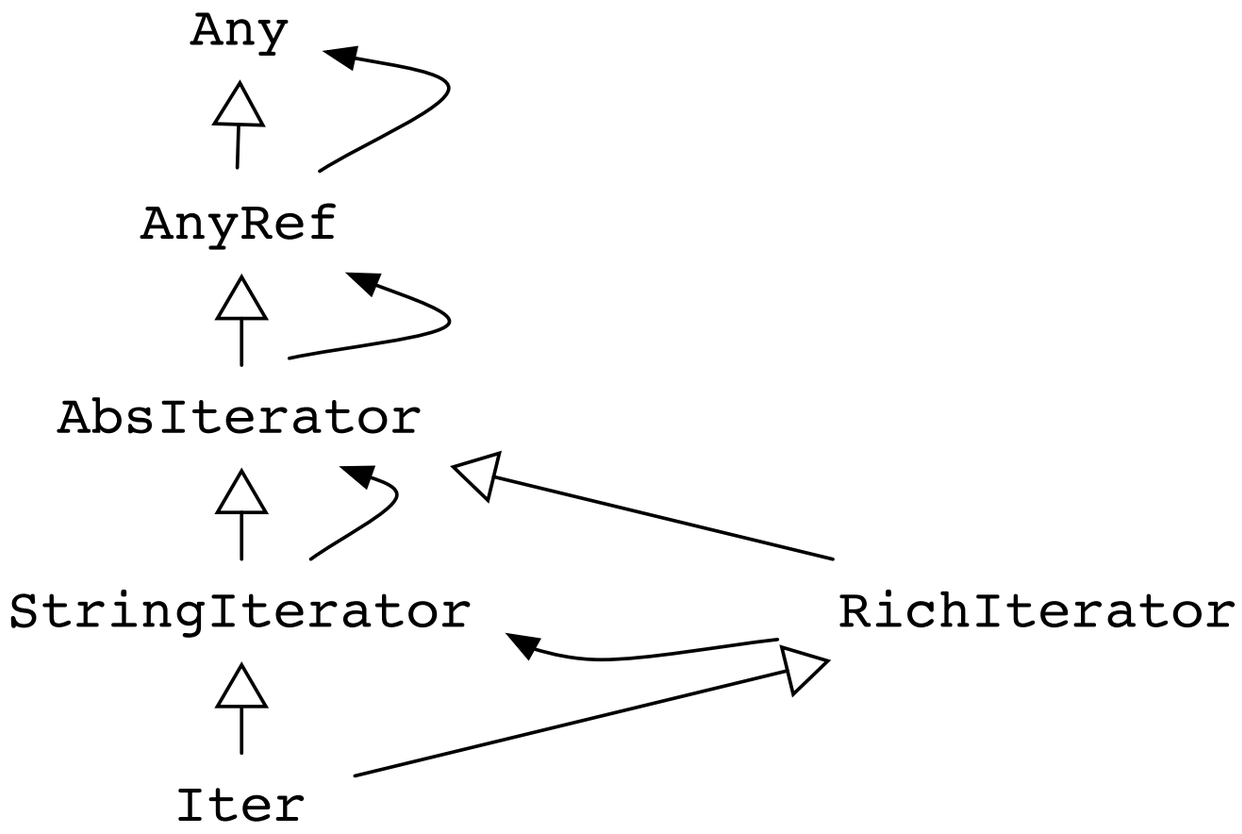
- The inheritance relationship forms a DAG
- *Linearization* rebuilds a total order

Linearization - I



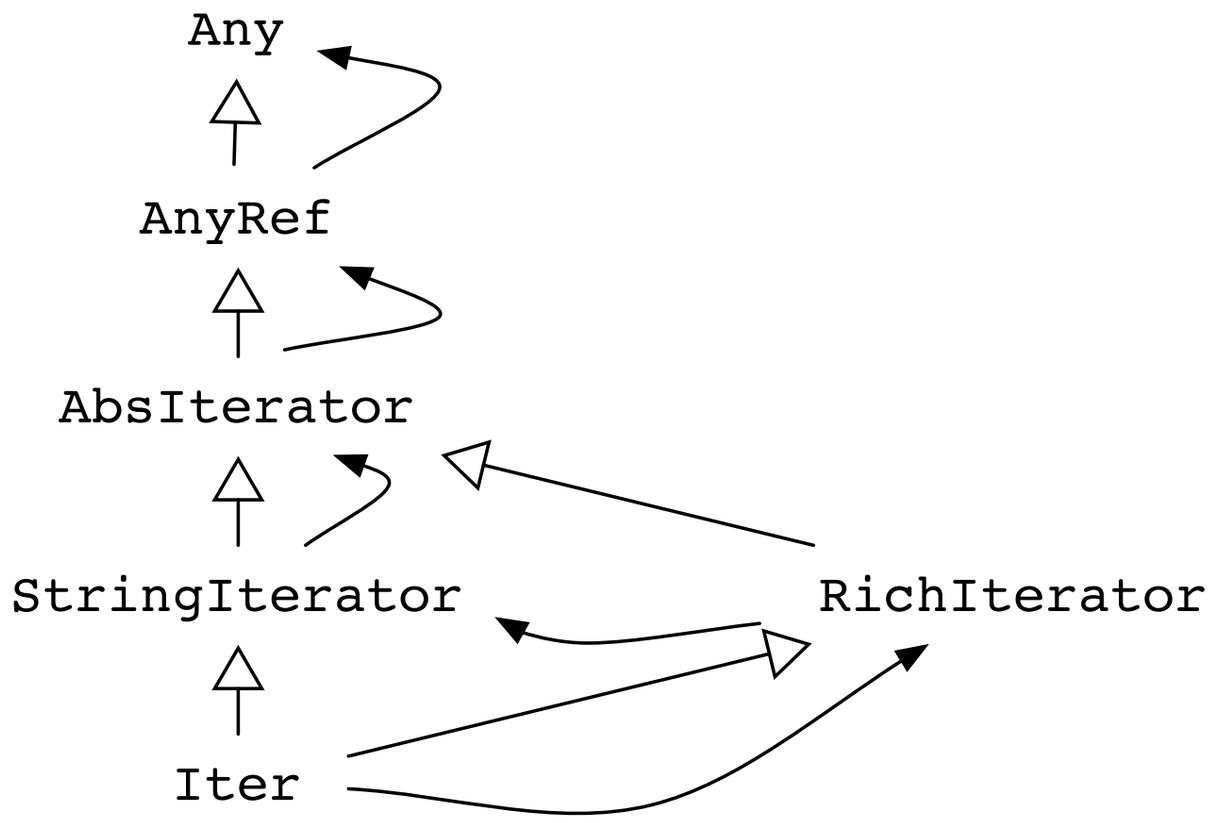
- Start by linearizing the “superclass”
- This is the last part of the linearization

Linearization - 2



- Linearize the mixins from left to right, excluding the parents already linearized

Linearization - 3



- Add the root of the DAG

Stackable modification trait

```
trait SyncIterator[T] extends AbsIterator[T] {
  abstract override def hasNext: Boolean =
    synchronized(super.hasNext)
  abstract override def next: T =
    synchronized(super.next)
}
```

- Chain of supercalls (not available with multiple inheritance)
- Binding of `super` deferred to mixin time
- The existence of a super method has to be checked

Traits as (true) interfaces

```
trait Queue[T] {
  def head: T
  def tail: Queue[T]
  def append(x: T): Queue[T]
}

object Queue {
  def apply[T](xs: T*): Queue[T] =
    new QueueImpl[T](xs.toList, Nil)
  private class QueueImpl[T](
    private val leading: List[T],
    private val trailing: List[T]
  ) extends Queue[T] {
    def head: T = mirror.leading.head
    ...
}
```

Traits as (true) interfaces

```
scala> val q = Queue(1)
q: Queue[Int] = Queue$QueueImpl@36e2c698

scala> val q1 = q append 2
q1: Queue[Int] = Queue$QueueImpl@56ccaefe
```

```
scala> import Queue.QueueImpl
import Queue.QueueImpl

scala> new QueueImpl
<console>:11: error: class QueueImpl
cannot be accessed in object Queue
       new QueueImpl
           ^
```

Abstract members

```
trait Abstract {
  type T
  def transform(x: T)
  val initial: T
  var current: T
}

class Concrete extends Abstract {
  type T = String
  def transform(x: String) = x + x
  val initial = "hi"
  var current = initial
}
```

Type Parameterization

- Backtrack

The need for nonvariance (imperative features)

```
class cell[+T](init: T) {
  private var current = init
  def get = current
  def set(x: T) { current = x }
} // won't compile
```

```
val c1 = new Cell[String]("abc")
val c2: Cell[Any] = c1
c2.set(1)
val s: String = c1.get
```

The need for abstract types

```
class Food
class Grass extends Food

abstract class Animal {
  def eat(foo: Food)
}
class Cow extends Animal {
  override def eat(food: Grass) {}
}
```

A case for abstract types

```
scala> class Food
class Grass extends Food

abstract class Animal {
  def eat(foo: Food)
}
class Cow extends Animal {
  override def eat(food: Grass) {}
}

<console>:7: error: class Cow needs to be abstract,
since method eat in class Animal of type (Food)Unit
is not defined
       class Cow extends Animal {
             ^
<console>:8: error: method eat overrides nothing
         override def eat(food: Grass) {}
                      ^
```

What about allowing covariant parameters?

```
class Food
class Grass extends Food
class Fish extends Food

abstract class Animal {
  def eat(food: Food)
}
class Cow extends Animal {
  override def eat(foo: Grass) {} // assume it compiles
}
val bessy: Animal = new Cow
bessy eat (new Fish) // ok as bessy is an Animal!!!
```

Using abstract types

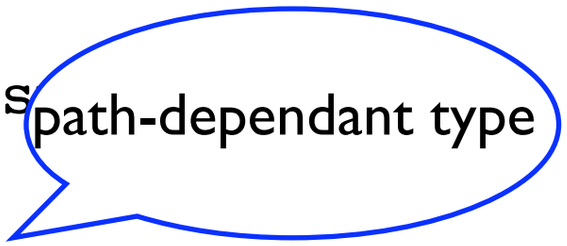
```
class Food
class Grass extends Food
abstract class Animal {
  type SuitableFood <: Food // abstract type with upper bound
  def eat(food: SuitableFood)
}
class Cow extends Animal {
  type SuitableFood = Grass // concrete type
  override def eat(food: Grass) {}
}
```

Using abstract types

```
scala> class Fish extends Food
defined class Fish

scala> val bessy: Animal = new Cow
bessy: Animal = Cow@2f2379f2

scala> bessy eat (new Fish)
 <console>:11: error: type mismatch;
 found   : Fish
 required: bessy.SuitableFood
       bessy eat (new Fish)
                  ^
```

Using abstract types

```
scala> class Fish extends Food
defined class Fish

scala> val bessy: Animal = new Cow
bessy: Animal = Cow@2f2379f2

scala> bessy eat (new Fish)
 <console>:11: error: type mis
 found   : Fish
 required: bessy.SuitableFood
       bessy eat (new Fish)
                  ^
```



Path-dependent types

```
package animals

object Main {
  def main(args: Array[String]) {
    val bessy = new Cow
    bessy eat (new Grass)
    val marguerite = new Cow
    marguerite eat (new bessy.SuitableFood)
  }
}
```

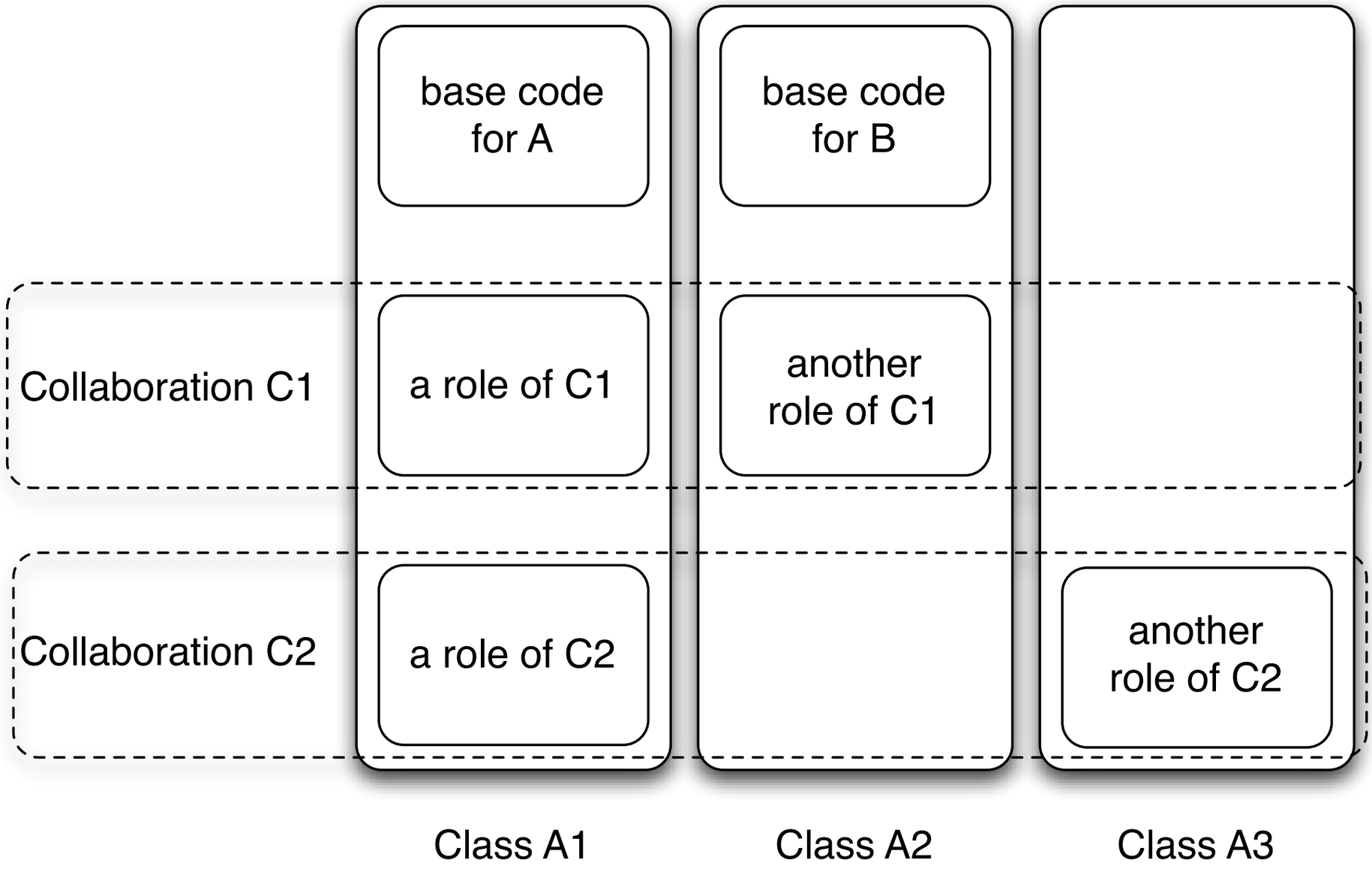
Path-dependent types and inner classes

```
scala> class Outer {
  class Inner
  }
}
defined class Outer
scala> val o1 = new Outer
o1: Outer = Outer@2029a303
scala> val i1 = new o1.Inner
i1: o1.Inner = Outer$Inner@200069ed
scala> val o2 = new Outer
o2: Outer = Outer@badfba
scala> val i2 = new o2.Inner
i2: o2.Inner = Outer$Inner@6ec4786e
scala> val l = List(i1, i2)
l: List[Outer#Inner] = List(Outer$Inner@200069ed,
Outer$Inner@6ec4786e)
```

Aliasing `this`

```
scala> class Outer { outer =>
  class Inner
    println(Outer.this eq outer)
  }
}
```

Traits and trait layers



The observer pattern

```
abstract class SubjectObserver {
  trait Subject {
    private var observers: List[Observer] = List()
    def subscribe(obs: Observer) =
      observers = obs :: observers
    def publish =
      for (val obs <- observers) obs.notify(this)
    }
  trait Observer {
    def notify(sub: Subject): Unit
  }
}
```

Example slightly modified from An Overview of the Scala Programming Language Tech. Report LAMP-REPORT-2006-001

The observer pattern

```
object SensorReader extends SubjectObserver {
  abstract class Sensor extends Subject {
    val label: String
    var value: Double = 0.0
    def changeValue(v: Double) = {
      value = v
      publish
    }
  }
  class Display extends Observer {
    def notify(sub: Sensor) =
      println(sub.label + " has value " + sub.value)
    }
  }
}
```

What does Scala say?

```
abstract class SubjectObserver {
  trait Subject {
    private var observers: List[Observer] = List()
    def subscribe(obs: Observer) =
      observers = obs :: observers
    def publish =
      for (val obs <- observers) obs.notify(this)
    }
  trait Observer {
    def notify(sub: Subject): Unit
  }
}
```

```
object SensorReader extends SubjectObserver {
  abstract class Sensor extends Subject {
    val label: String
    var value: Double = 0.0
    def changeValue(v: Double) = {
      value = v
      publish
    }
  }
  class Display extends Observer {
    def notify(sub: Sensor) =
      println(sub.label + " has value " + sub.value)
    }
  }
}
```

```
<console>:26: error: class Display needs to be abstract,
since method notify in trait Observer of type
(SensorReader.Subject)Unit is not defined
        class Display extends Observer {
                    ^
```

What does Scala say?

```
abstract class SubjectObserver {
  trait Subject {
    private var observers: List[Observer] = List()
    def subscribe(obs: Observer) =
      observers = obs :: observers
    def publish =
      for (val obs <- observers) obs.notify(this)
    }
  trait Observer {
    def notify(sub: Subject): Unit
  }
}
```

```
object SensorReader extends SubjectObserver {
  abstract class Sensor extends Subject {
    val label: String
    var value: Double = 0.0
    def changeValue(v: Double) = {
      value = v
      publish
    }
  }
  class Display extends Observer {
    def notify(sub: Sensor) =
      println(sub.label + " has value " + sub.value)
  }
}
```

Type mismatch

```
<console>:26: error: class Display needs to be abstract,
since method notify in trait Observer of type
(SensorReader.Subject)Unit is not defined
        class Display extends Observer {
                    ^
```

Fixing the problem

```
abstract class SubjectObserver {
  type S <: Subject
  type O <: Observer
  trait Subject {
    private var observers: List[O] = List()
    def subscribe(obs: O) =
      observers = obs :: observers
    def publish =
      for (val obs <- observers) obs.notify(this)
    }
  trait Observer {
    def notify(sub: S): Unit
  }
}
```

Fixing the problem

```
object SensorReader extends SubjectObserver {
  type S = Sensor
  type O = Display
  abstract class Sensor extends Subject {
    val label: String
    var value: Double = 0.0
    def changeValue(v: Double) = {
      value = v
      publish
    }
  }
  class Display extends Observer {
    def notify(sub: Sensor) =
      println(sub.label + " has value " + sub.value)
    }
  }
}
```

What does Scala say?

```
abstract class SubjectObserver {
  type S <: Subject
  type O <: Observer
  trait Subject {
    private var observers: List[O] = List()
    def subscribe(obs: O) =
      observers = obs :: observers
    def publish =
      for (val obs <- observers) obs.notify(this)
    }
  trait Observer {
    def notify(sub: S): Unit
  }
}

<console>:12: error: type mismatch;
 found   : SubjectObserver.this.Subject
 required: SubjectObserver.this.S
             for (val obs <- observers) obs.notify(this)
                                                   ^
```

Fixing the problem with a self type

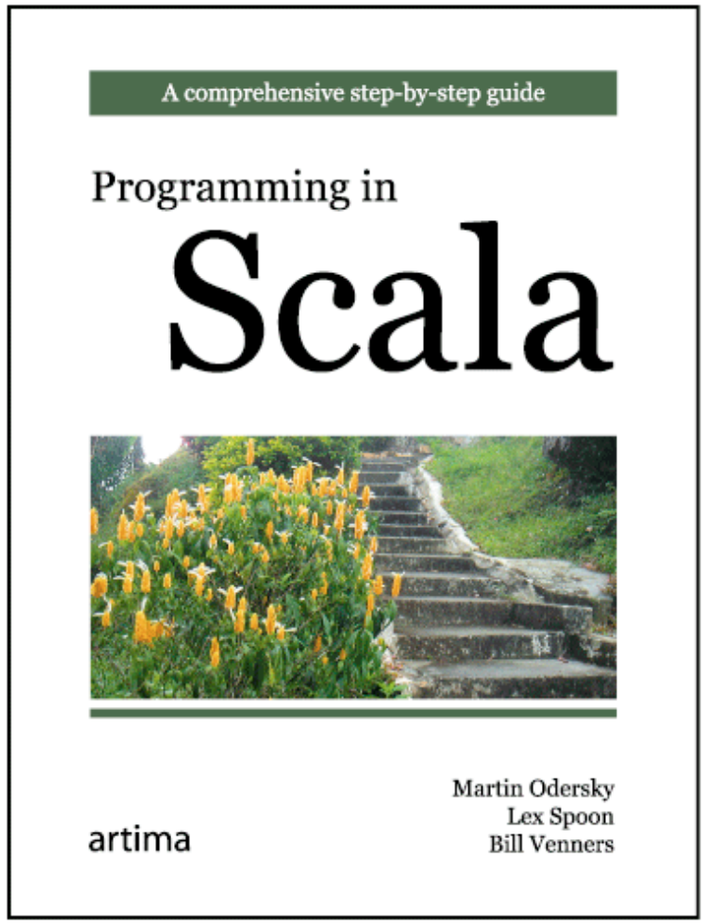
```
abstract class SubjectObserver {
  type S <: Subject
  type O <: Observer
  trait Subject {
    this: S =>
    private var observers: List[O] = List()
    def subscribe(obs: O) =
      observers = obs :: observers
    def publish =
      for (val obs <- observers) obs.notify(this)
    }
  trait Observer {
    def notify(sub: S): Unit
  }
}
```

Fixing the problem

```
scala>import SensorReader._
val s1 = new Sensor { val label = "sensor1" }
val s2 = new Sensor { val label = "sensor2" }
val d1 = new Display; val d2 = new Display
s1.subscribe(d1); s1.subscribe(d2)
s2.subscribe(d1)
s1.changeValue(2); s2.changeValue(3)

sensor1 has value 2.0
sensor1 has value 2.0
sensor2 has value 3.0
```

Try it!

- http://www.scala-lang.org/
- On-line documentation
- Books
- Tools: emacs support, Eclipse plugin...
- Advanced reading: *Scalable Component Abstractions*, OOPSLA 2005, by M. Odersky and M. Zenger



Source of most of the examples
The mistakes are mine

Estrecho de Magallanes, November 2008