An Introduction to Scala for Spark programming

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Slides of this course are prepared based on the book "Programming in Scala" and its presentations by Martin Odersky

What’s Scala

- Scala is a statically typed, object-oriented programming language that blends imperative and functional programming styles.
- It is designed to integrate easily with applications that run on modern virtual machines, primarily the Java virtual machine (JVM).
- Scala was developed starting in 2003 by Martin Odersky's group at EPFL.
- It is used for big-iron projects in industry.

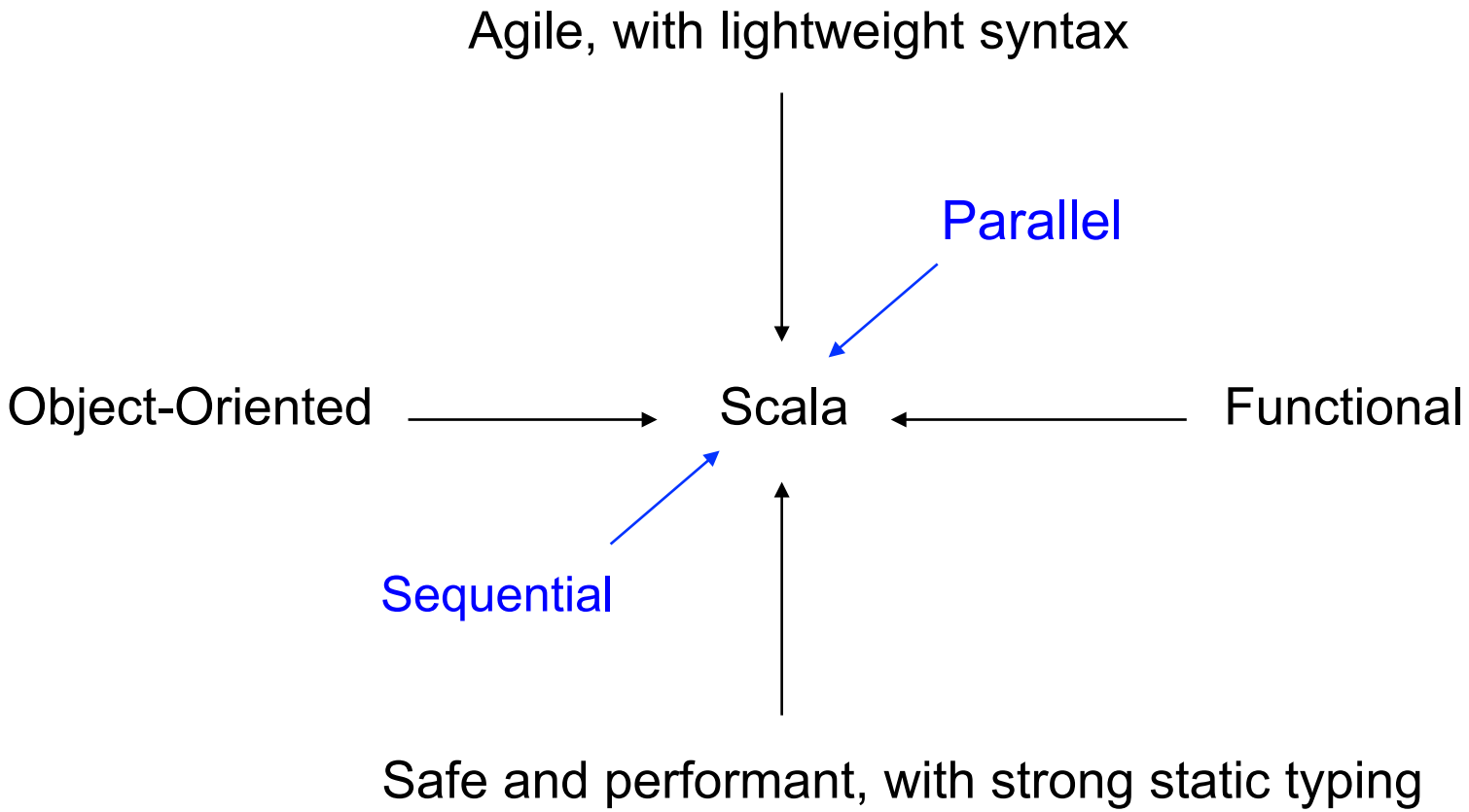

IBM
CREDIT SUISSE
LinkedIn
SONY
make.believe
twitter
xerox
SONY PICTURES
imageworks
SIEMENS
Novell
outside.in
NASA
foursquare
EDF
UBS
TOMTOM
amazon
Office
DEPOT
Taking Care
of Business
OPOWER
ENERGY EFFICIENCY. DELIVERED.
Bank of America
guardian.co.uk
yammer
Thatcham
Autodesk

Some adoption vectors:

- **Web platforms**
- **Trading platforms**
- **Financial modeling**
- **Simulation**
- **Big Data Analytics**

Fast to first product, scalable afterwards

Scala is a Unifier



“If I were to pick a language to use today other than Java, it would be Scala.”

- James Gosling, creator of Java

“Scala, it must be stated, is the current heir apparent to the Java throne. No other language on the JVM seems as capable of being a "replacement for Java" as Scala, and the momentum behind Scala is now unquestionable. While Scala is not a dynamic language, it has many of the characteristics of popular dynamic languages, through its rich and flexible type system, its sparse and clean syntax, and its marriage of functional and object paradigms.”

- Charles Nutter, creator of JRuby

“I can honestly say if someone had shown me the Programming in Scala book by Martin Odersky, Lex Spoon & Bill Venners back in 2003 I'd probably have never created Groovy.”

- James Strachan, creator of Groovy.

What makes Scala scalable?

- Many factors: strong typing, inference, little boilerplate,…
- But mainly, its tight integration of functional and object-oriented programming

Functional programming:

Makes it easy to build interesting things from simple parts, using

- immutable datatypes
- closures and higher-order functions,
- generic typing

Object-oriented programming:

Makes it easy to adapt and extend complex systems, using

- subtyping and inheritance,
- dynamic configurations,
- classes as partial abstractions.

The Philosophy behind Scala

Put productivity and creativity back in the hands of developers.

> *"Joy is underrated as a metric for a language's potential success in a development organization."* a3lx@twitter

- address professional developers
- trust them & value their expertise
- (don't tell them how they should do their job)

Scala Basics

Overview

In this course you will learn about

- Scala REPL
- Variable and method definitions
- Scala syntax
- Scala's type hierarchy
- How to construct functional objects
- Collections: sequences
- Function values and higher-order functions
- For loops and for expressions
- Collections: sets and maps

Download and install Scala

- Installation :
  - Go to http://www.scala-lang.org/downloads and follow the directions for your platform
  - Once you download an archive file, create a directory wherever you prefer and unzip (or untar, etc.) the archive file in that empty directory.
  - Among the subdirectories created will be the bin directory that contains the Scala executables, including the compiler and interpeter.
  - To make Scala convenient to use, add the full pathname of the bin directory to your PATH environment variable.

You can also use Scala via plug-ins for Eclipse and IntelliJ downloadable from the same link given above.

Using the Scala interpreter

The easiest way to get started with Scala is by using the Scala interpreter, which is an interactive “shell” for writing Scala expressions and programs.

The interactive shell for Scala is simply called scala.

```
scala> 1 + 2
res0: Int = 3

scala> res0 * 2
res1: Int = 6

scala> println("Hello, world!")
Hello, world!
```

Variables

Two forms:

`val`	immutable variable
`var`	reassignable variable

```
scala> val msg = "hello world!"
msg: String = hello world!

scala> var greeting = "hi!"
greeting: String = hi!

scala> greeting = "hi there!"
greeting: String = hi there!
```

Expressions

Languages like C and Java distinguish between *expressions* which return a result and *statements* which don't.

Scala does not: *every* statement is an expression that returns a value.

```
scala> if (msg contains 'a') msg else "no a"
res3: String = no a
scala> try { msg} finally { println("done") }
done
res4: String = hello world!
scala> { val x = 2; x * x }
res5: Int = 4
```

Functions

- Basic form:

```
def max(x: Int, y: Int): Int = {
  if (x < y) y else x
}
```

- Result type is required only for recursive functions.
- Right hand side may be simple expression without { ... }
- Short form:

```
def max(x: Int, y: Int) =
  if (x < y) y else x
```

```
def square(x: Double) = x * x
```

Recursion

- Recursive functions need an explicit return type

```
def power(x: Double, n: Int): Double =
  if (n == 0) 1.0
  else if (n % 2 == 0) square(power(x, n / 2))
  else x * power(x, n - 1)
```

```
def findIndex(str: String, chr: Char, from: Int): Int =
  if (str.charAt(from) == chr) from
  else findIndex(str, chr, from + 1)
```

The Unit Type

- Question: What's the type of the expression **`println("hi")`**?
- Try it out!

```
scala> val x = println("hi")
hi
x: Unit = ()
```

- Scala uses `Unit` as the type of expressions that are executed only for their side-effects.
- `Unit` has a value, written `()`.
- `Unit` corresponds roughly to `void` in Java.

Procedures

- Procedures are functions that return `Unit`.

```
scala> def sayHi(): Unit = println("hi!")
sayHi: ()Unit
```

- They have an alternative syntax, where the parameter list is immediately followed by a block, without return type or `=`.

```
scala> def sayHo { println("ho!") }
sayHo: Unit
```

Scala cheat sheet (1): Definitions

Scala method definitions:

```
def fun(x: Int): Int = {
  result
}
```

or

```
def fun(x: Int) = result
```

```
def fun = result
```

Scala variable definitions:

```
var x: Int = expression
val x: String = expression
```

or

```
var x = expression
val x = expression
```

Java method definition:

```
int fun(int x) {
  return result;
}
```

(no parameterless methods)

Java variable definitions:

```
int x = expression
final String x = expression
```

Scala cheat sheet (2): Expressions

Scala method calls:

```
   obj.meth(arg)
or obj meth arg
```

Scala choice expressions:

```
if (cond) expr1 else expr2
```

```
expr match {
  case pat1 => expr1
  ....
  case patn => exprn
}
```

Java method call:

```
obj.meth(arg)
```
(no operator overloading)

Java choice expressions, stats:

```
cond ? expr1 : expr2
```

```
if (cond) return expr1;
else return expr2;
```

```
switch (expr) {
    case pat1 : return expr1;
    ...
    case patn : return exprn ;
}  // statement only
```

Scala cheat sheet (3): Objects and Classes

Scala Class and Object

```
class Sample(x: Int) {
  def instMeth(y: Int) = x + y
}

object Sample {
  def staticMeth(x:Int, y:Int)
    = x * y
}
```

Java Class with static

```
class Sample {
  final int x;
  Sample(int x) {
    this.x = x
  }

  int instMeth(int y) {
    return x + y;
  }

  static
  int staticMeth(int x,int y) {
      return x * y;
  }
}
```

Scala cheat sheet (4): Traits

Scala Trait

```
trait T {
  def absMeth(x:String):String

  def concreteMeth(x: String) =
    x+field

  var field = "!"
}
```

Scala mixin composition:

```
class C extends Super with T
```

Java Interface

```
interface T {
  String absMeth(String x)

  (no concrete methods)


  (no fields)
}
```

Java extension + implementation:

```
class C extends Super
        implements T
```

Scala cheat sheet (5): Packages and Imports

Scala Package Clause

```
package org.project.module
```

or

```
package org.project
package module
```

Scala Import

```
import collection.mutable.Map
import collection.mutable._
import collection.mutable.{
  Map => mMap
}
```

Java Package Clause

```
package org.project.module;
```

Java import

```
import collection.mutable.Map;
import collection.mutable.*;
```

(no import renaming)

Functional Objects

	Conventional Wisdom	Scala
Objects have	identity	(definable)
	state	(maybe)
	behavior	

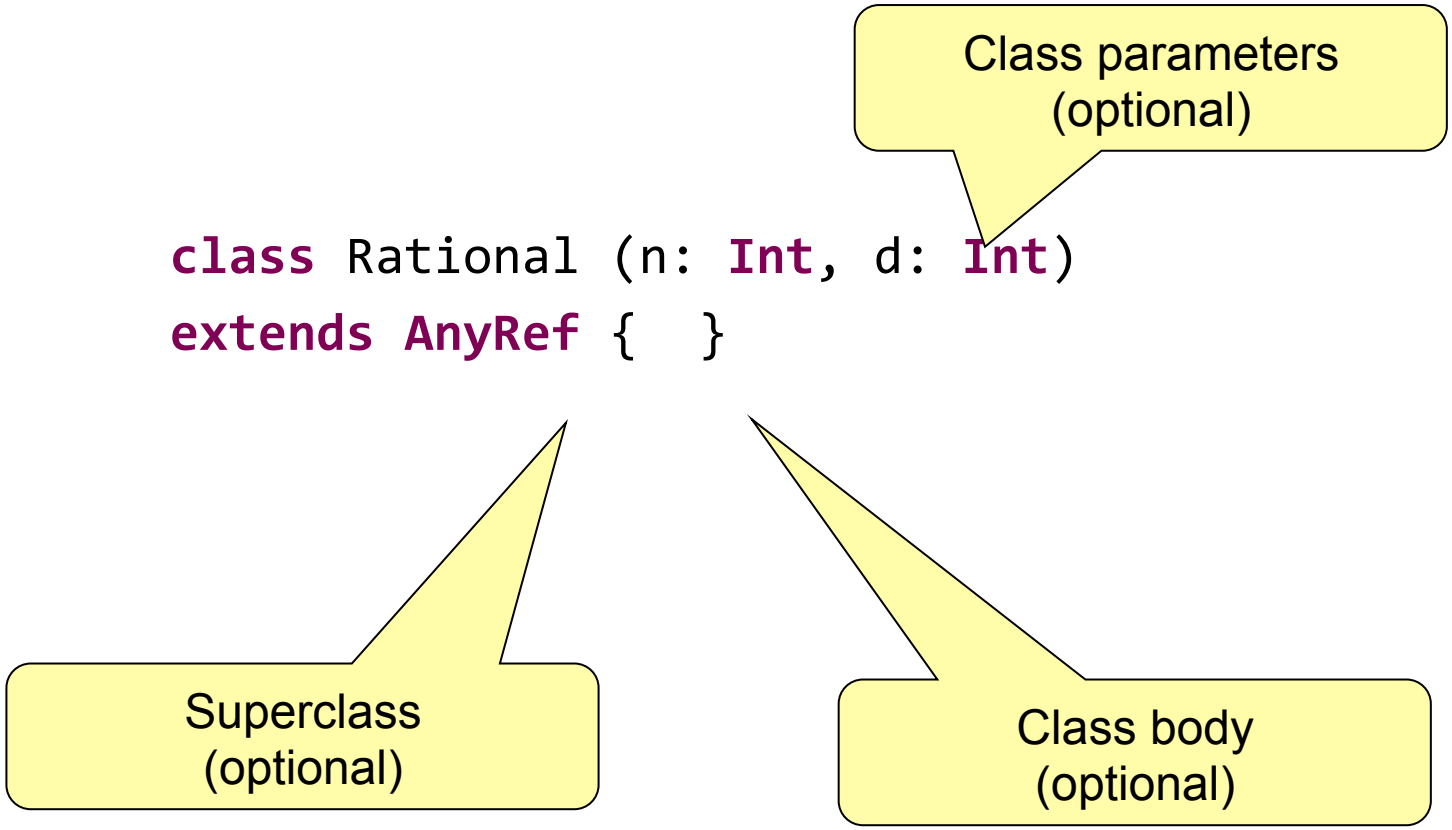
Objects without state are called *immutable*.

Such objects are ubiquitous: strings, numbers, polynomials, time-series functions, financial contracts, ...

Example: Rational Numbers

- Writing a class for rational numbers.

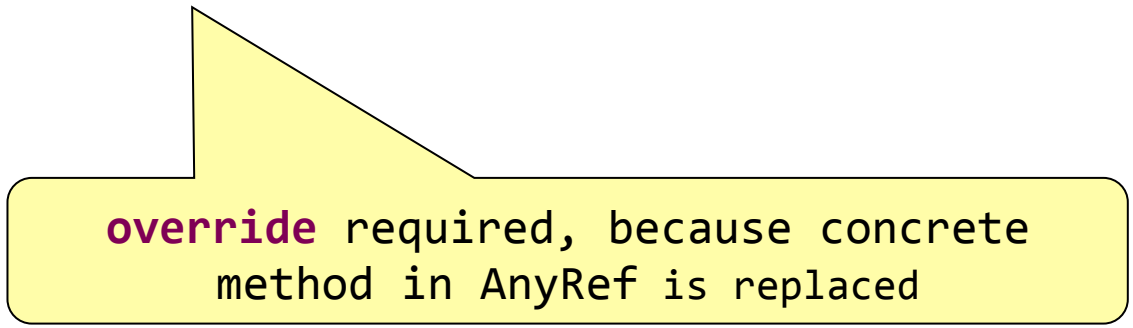
The Naked Class



Adding toString

- So far, `new Rational` displays strangely (something like `Rational@12ab3`)
- You can change the way objects display by overriding the `toString` method, which is defined in `Rational`'s superclass `java.lang.Object`, a.k.a `AnyRef`.

```
override def toString = n+"/"+d
```



Checking Preconditions

- The denominator of a rational number should be greater than zero.
- It's best to check this when `Rationals` are constructed, thereby establishing a useful *class invariant*:

```
require(d > 0)
```

- Require is a pre-defined method in Predef. It throws an `IllegalArgumentException` if the condition is `false`.
- You can use a two argument version:

```
require(d > 0, "denominator of Rational must
                    be greater than zero")
```

Auxiliary Constructors

- Unlike Java, Scala classes take parameters directly.

  ```
  class Rational(n: Int, d: Int)
  ```

  defines implicitly a two parameter constructor (called the *primary constructor*).

- Sometimes, you want more than one constructor.
- For instance for class Rational, you might want a constructor that takes only one nominator parameter and assumes 1 for the denominator.
- You can do this with an auxiliary constructor:

  ```
  def this(n: Int) = this(n, 1)
  ```

- Every auxiliary constructor must call a preceding constructor as its first action.

Defining Fields

- Fields of a class are defined like variables:

  `val` for immutable fields

  `var` for reassignable fields

- Example:

```
private val g = gcd(n, d)
val numer = n / g
val denom = d / g
```

Hiding fields and methods

- Class members are hidden to the outside with **`private`**.
- There's also **`protected`** (as in Java).
- There's no "public" modifier – all members without **`private`** or **`protected`** modifiers are public.

Binary Operations

- Here's a method to add two rational numbers.

```
def add (that: Rational) = new Rational(
  this.numer * that.denom + that.numer * this.denom,
  this.denom * that.denom)
```

- Notes:
  - Return type can be omitted, and is inferred.
  - Body can be a single expression or a block { ... }
  - If it's a block { ... }, the last expression is returned.
  - With these conventions, explicit `return`s are rare in Scala.

Mathematical Notation

- With add defined, we can write

```
val r = new Rational(1, 3)
r.add(r)
```

- But why is it `add` for `Rationals`, but `+` for `Int`s and `Float`s?

- In Scala, there's no need for this, because of two conventions:
  1. `+` is a legal identifier name just like `add`.
  2. A binary operation `a op b`
     is the same as a method call `a.op(b)`
- So you can alternatively define:

```
def + (that: Rational) = new Rational(...)
```

Forms of identifiers in Scala

Scala knows four forms of identifiers.

- Alphanumeric: A letter, followed by a sequence of letters or digits.
  - _ counts as a letter (but single _ is reserved)
  - $ is reserved for system use.
- Operator: One or more symbolic characters such as `+, -, %, #, !`
- Mixed: `alpha_!`
- Quoted: any character sequence in backquotes: `` `yield` ``

Precedence

Question: When you write

x + y * z

How does the compiler "know" that * binds stronger than +?

Scala arranges precedence of identifiers according to their first letter.

(all other special characters) *highest*

* / %

\+ -

:

= !

< >

&

^

|

(all letters)

(all assignment operators such as +=, -=, ...) *lowest*

Associativity

In Scala, every operation is a method call.

`a + b` is exactly the same as `a.+(b)`

So operators resolve to method calls of their left operand.

There's one exception to this rule:

If the operator ends with a ":", it resolves to a method call of its right operand.

So `x :: xs` is the same as `xs.::(x)`

This also extends to associativity.

`a + b + c` is `(a + b) + c`

But

`x :: y :: z` is `x :: (y :: z)`

Mixed Arithmetic

Challenge:

How to make

```
val x = new Rational(1, 2)
val y = x + 1
```

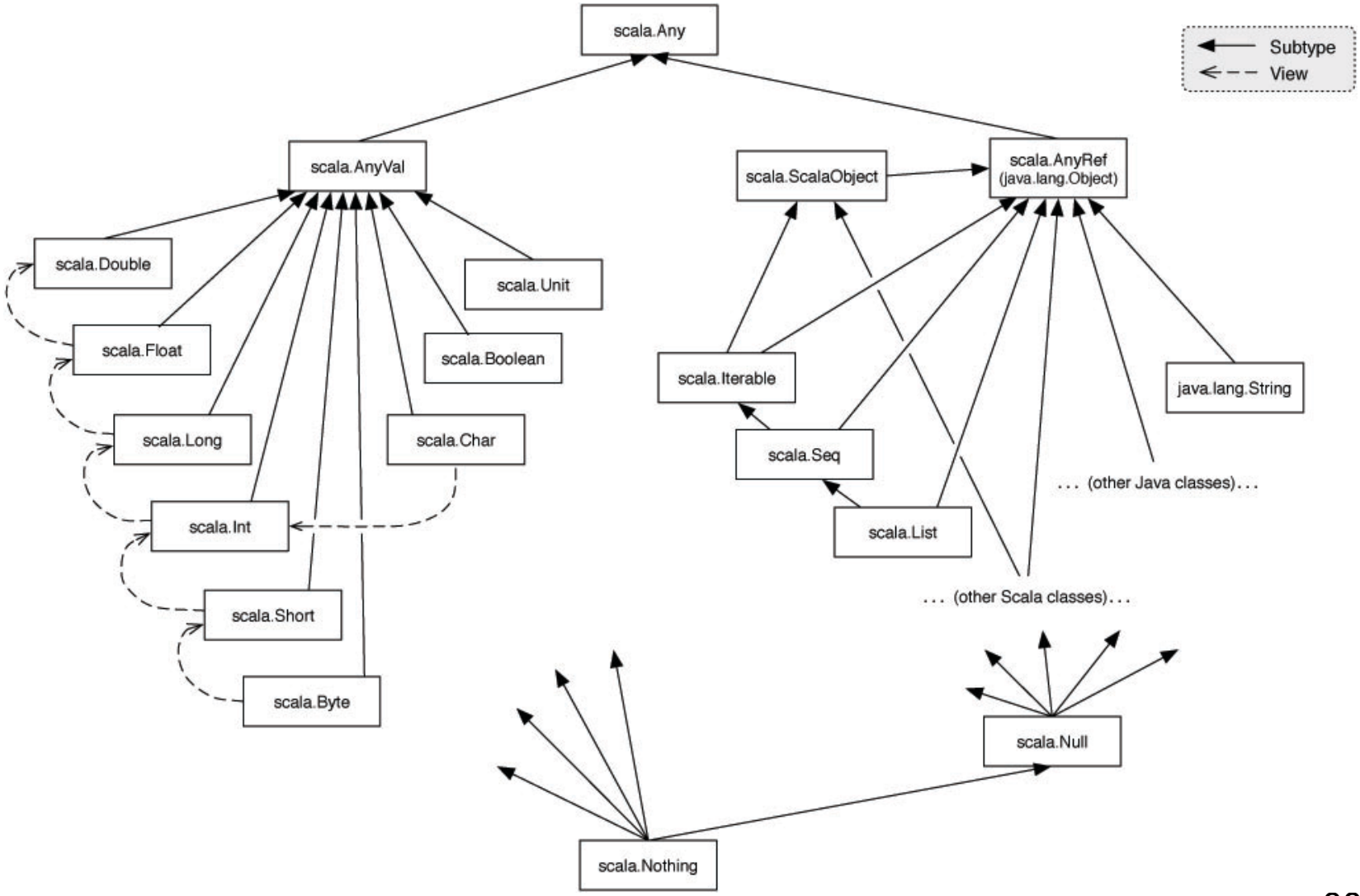
work?

What about

```
val z = 1 + x
```

?

Scala's Type Hierarchy



Top Types: Any, AnyRef, AnyVal

`Any` — The base type of all types

Methods: `==, !=, equals`
`##, hashCode`
`toString`
`asInstanceOf`
`isInstanceOf`

`AnyRef` — The base type of all reference types,
alias of `java.lang.Object`
Methods: `eq, ne`

`AnyVal` — The base types of all value types

The Nothing Type

- `Nothing` is a type without any values.
- Why is that useful?
  - To signal abnormal termination:
    `throw new Error()` has type `Nothing`
  - As an element of empty collections.
- The two meanings hang together: Taking an element of a `List[Nothing]` has type `Nothing`, and will not terminate normally.

The Null Type

- The null value also has a type in Scala; it is called `Null`

```
scala> val x = null
x: Null = null
```

- `Null` is a subtype of every reference type in Scala, but it is not compatible with value types.

```
scala> val x: String = null
x: String = null
scala> val x: Int = null
<console>:7: error: type mismatch;
 found   : Null(null)
 required: Int
       val x: Int = null
                    ^
```

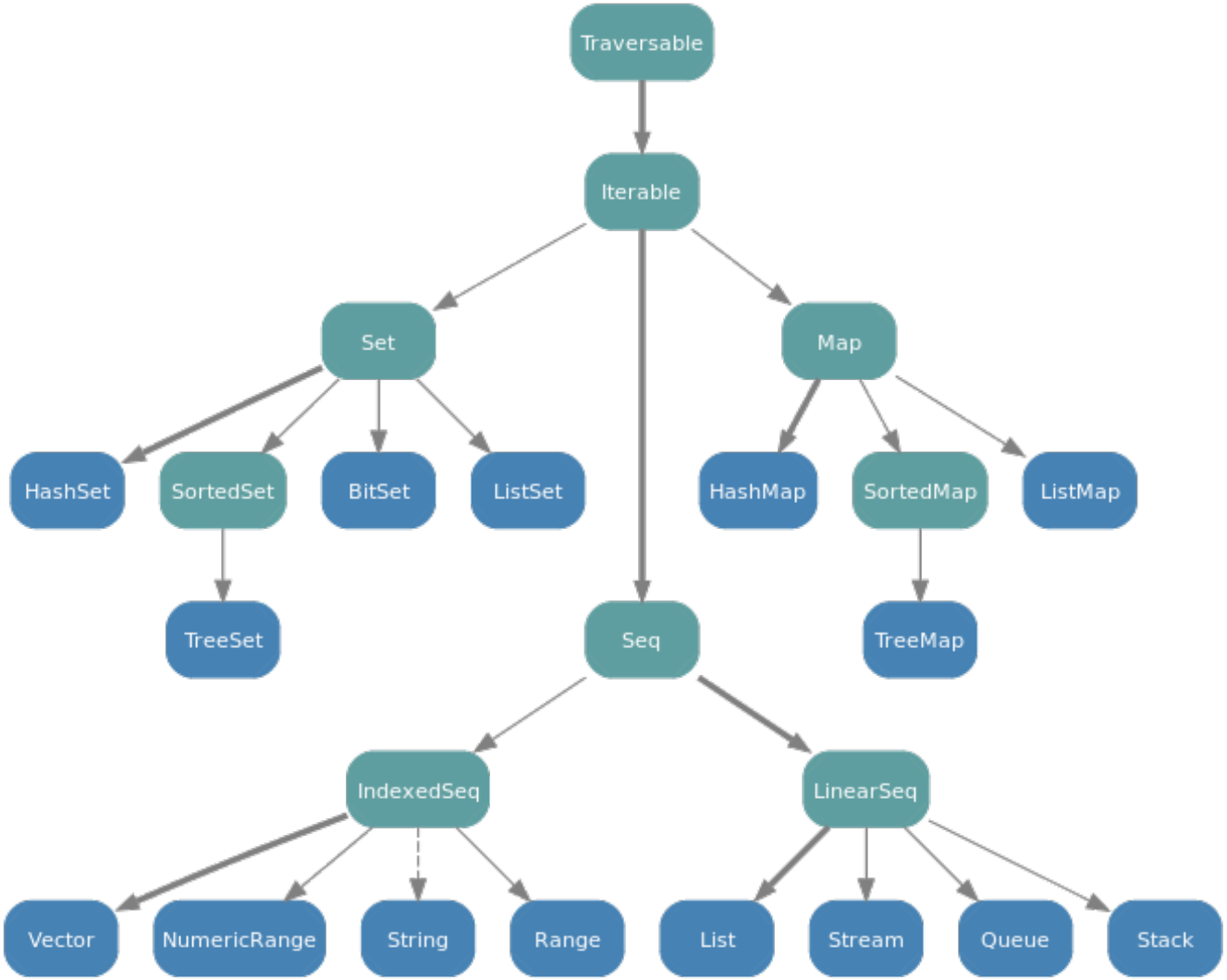
Scala collections: Mutable and Immutable

Scala collections systematically distinguish between mutable and immutable collections.All collection classes are found in the package `scala.collection`

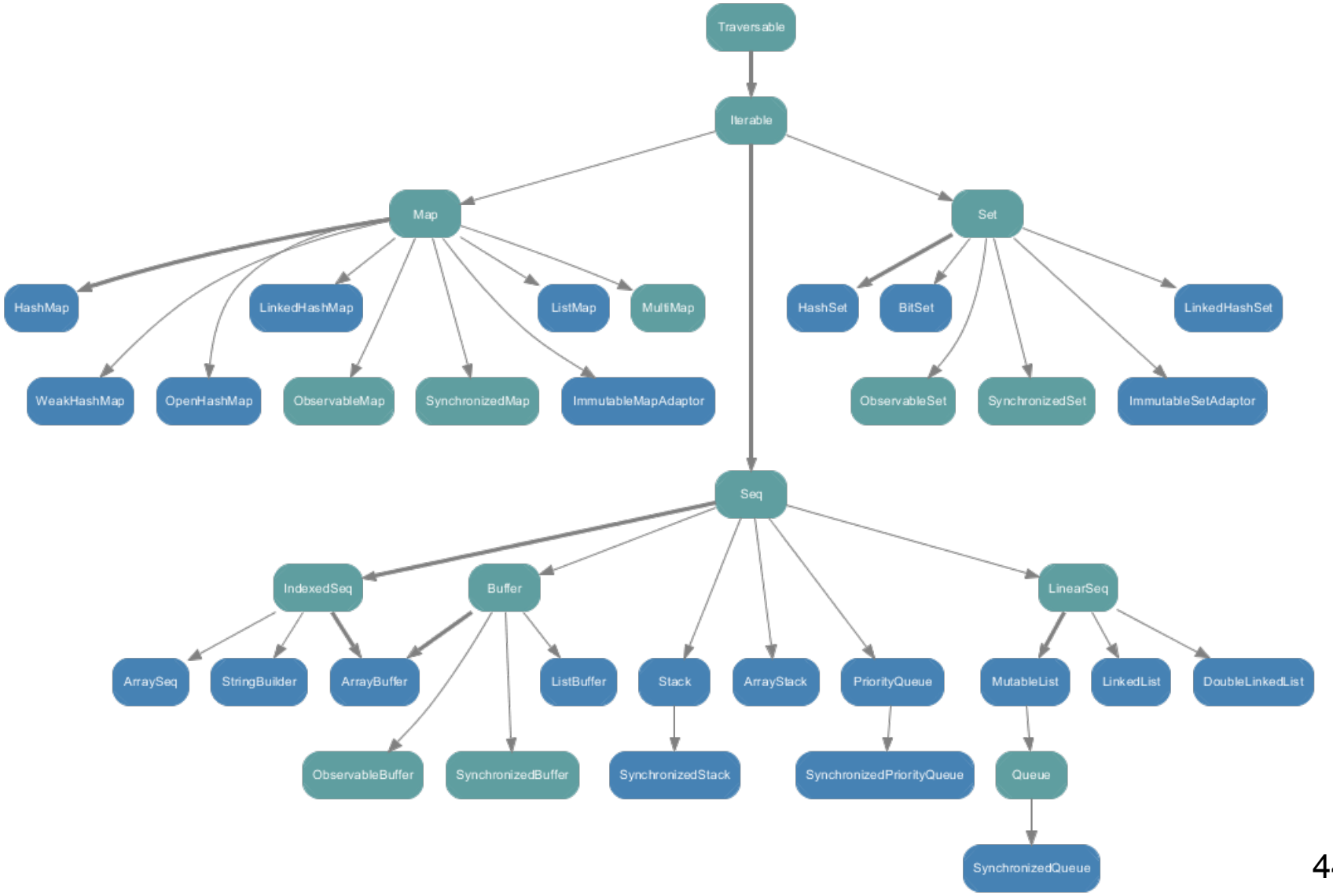
A *mutable* collection can be updated or extended in place. This means you can change, add, or remove elements of a collection as a side effect.
They are found in the package `scala.collection.mutable`

Immutable collections, by contrast, never change. You have still operations that simulate additions, removals, or updates, but those operations will in each case return a new collection and leave the old collection unchanged.
They are found in the package `scala.collection.immutable`

Scala Immutable collection



Scala Mutable collection



Lists

The List is one of the most important data types in Scala.

Here are some examples of Lists.

```
val fruit = List("apples", "oranges", "pears")
val nums = List(1, 2, 3, 4)
val diag3 =
  List(
    List(1, 0, 0),
    List(0, 1, 0),
    List(0, 0, 1)
  )
val empty = List()
```

Sequences

Lists in Scala are just one implementation of the general abstraction of sequences. Other sequence types are `Array`, `ArrayBuffer`, `String` and `Vector`.

```
val fruit = List("apples", "oranges", "pears")
val nums = ArrayBuffer(1, 2, 3, 4)
val diag3 =
  Array(
    Array(1, 0, 0),
    Array(0, 1, 0),
    Array(0, 0, 1)
  )
val empty = Vector()
val v = Vector(1, 2, 3)
```

Vector versus List

- Lists are very efficient when the algorithm processing them is careful to only process their heads.
- Accessing, adding, and removing the head of a list takes only constant time, whereas accessing or modifying elements later in the list takes time linear in the depth into the list.
- Vector is a collection type that addresses the inefficiency for random access on lists. Vectors allow accessing any element of the list in “effectively” constant time.

Sequence Types

`List[T]`, `Vector[T]`, etc are the type of sequences with elements of type `T`. They are parameterized types - in Java it would be `List<T>`, `Vector<T>`. Here are the previous definitions again, with types given.

```
val fruit: List[String] = List("apples", "oranges", "pears")
val nums: ArrayBuffer[Int] = ArrayBuffer(1, 2, 3, 4)
val diag3: Array[Array[Int]] =
  Array(
    Array(1, 0, 0),
    Array(0, 1, 0),
    Array(0, 0, 1)
  )
val empty: Vector[Nothing] = Vector()
```

Sequence Type Hierarchy

All* sequence types are subtypes of type `Seq[T]`.

* Except for `Array[T]`, `String` which, coming from Java, can only be implicitly convertible to `Seq[T]`

So we can also type-annotate as follows:

```
val fruit: Seq[String] = List("apples", "oranges", "pears")
val nums: Seq[Int] = ArrayBuffer(1, 2, 3, 4)
val diag3: Seq[Array[Int]] =
  Array(
    Array(1, 0, 0),
    Array(0, 1, 0),
    Array(0, 0, 1)
  )
val empty: Seq[Nothing] = Vector()
```

Functions on Sequences

`xs.isEmpty`	is sequence empty?
`xs.length`	length
`xs.head, xs.last`	first / last element
`xs.tail, xs.init`	all elements except first / last
`xs take n`	first n elements
`xs drop n`	all elements except first n
`xs slice (start, end)`	same as `xs.drop(start).take(end-start)`
`xs splitAt n`	split into (`xs.take(n), xs.drop(n)`)
`xs.reverse`	reversal
`xs(n), xs.apply(n)`	n'th element (indices start at 0)
`xs contains x`	does `xs` contain an element equal to `x`?
`xs ++ ys`	concatenation
`xs zip ys`	a sequence of pairs of corresponding elements from `xs` and `ys`.

Even more functions on sequences

`xs.zipWithIndex`	Zips a sequence with its indices (starting from 0)
`xs.iterator`	An iterator yielding list elements one by one.
`xs.unzip`	Split a sequence of pairs into two sequences.
`xs.flatten`	Concatenates a sequence of sequences into a single sequence
`xs.sum`	The sum of all elements of a sequence of numeric values
`xs.max`	The maximal element of a sequence of numeric values
`xs.min`	The minimal element of a sequence of numeric values
`xs.mkString(start, sep, end), xs mkString sep`	Assemble elements in string.
`xs.toArray`	Conversions
`xs.toList`	
`xs.toStream`	
`xs.toSet`	
`xs.toMap`	

Exercises

1) Find the last but one element of a list.

Example:

```
scala> penultimate(List(1, 1, 2, 3, 5, 8))
res0: Int = 5
```

2) Find out whether a list is a palindrome.

Example:

```
scala> isPalindrome(List(1, 2, 3, 2, 1))
res0: Boolean = true
```

3) Remove the Kth element from a list. Return the list and the removed element in a Tuple. Elements are numbered from 0.

Example:

```
scala> removeAt(1, List('a', 'b', 'c', 'd'))
res0: (List[Symbol], Char) = (List(a, c, d), b)
```