Introduction to Scala

https://gitter.im/ScalaTaiwan/ScalaTaiwan

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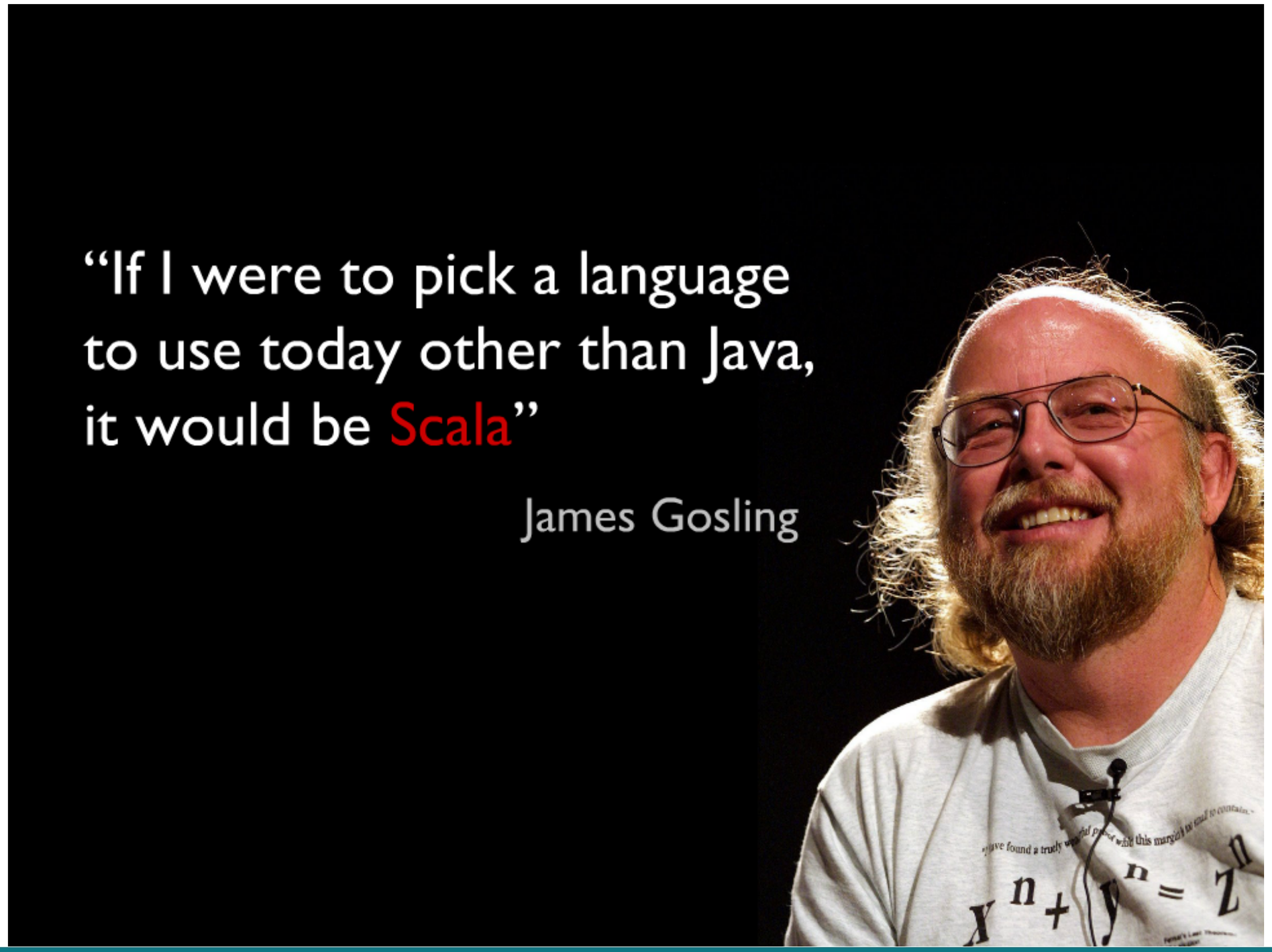
Agenda

- Why Scala?
- Scala concept
- Program with Scala
- Imperative
- Object-Oriented
- Functional
- Collections
- Summary of Scala
- Further Reading & Reference
- Special Thanks

Why Scala?


"If I were to pick a language
to use today other than Java,
it would be Scala"
James Gosling

Why Scala?

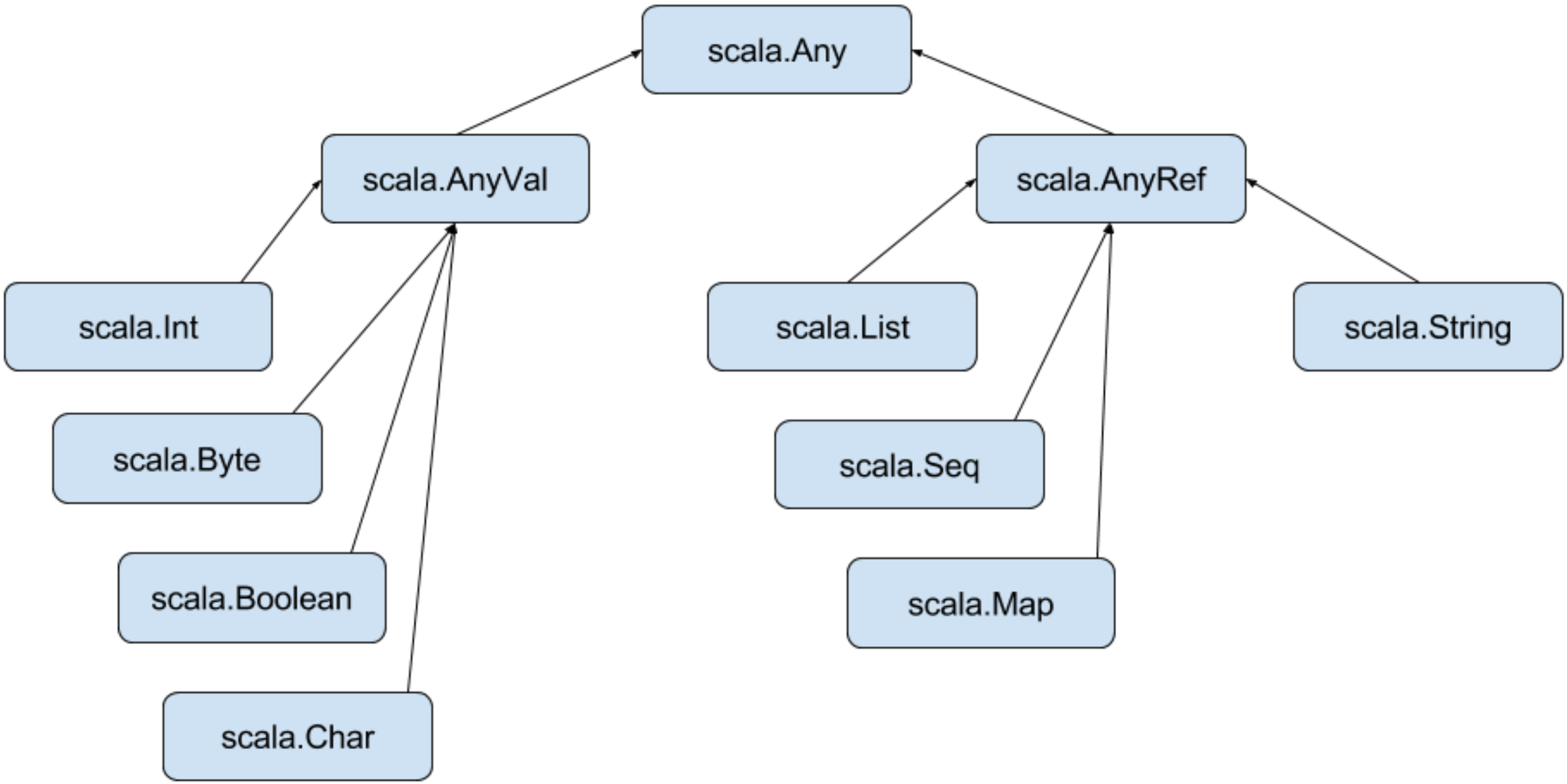
"I can honestly say **if someone had shown me the Programming in Scala book** by Martin Odersky, Lex Spoon & Bill Venners back in 2003 **I'd probably have never created Groovy**."

James Strachan, creator of Groovy

Scala concept

- Everything is an object.
  - Not everything is an object in Java.
    - There is primitive type in Java.
      - int, float, boolean, char…etc
- Scala is an object-oriented language in **pure** form: **every value** is an object and **every operation** is a method call.
  - Numeric types and Function are object too.
  - “+”, “-”, “*”, “/” are methods too.

Scala Class Hierarchy



Scala concept

- Everything is expression.
  - Expression - an instruction to execute something that will return a value. from Wiki
- You can also say that an expression ***evaluates*** to a result or results in a value.
- You will hear evaluation from some of Scala geeks, it means the same thing.

Scala concept

- Advanced type system
  - static
  - strong
  - **inferred**
  - structural

Scala concept

- Avoid to use null.
- Less error prone.
  - NullPointerException
- You don’t need to use Null Object pattern.

Program with Scala(Main)

```
object Demo1 {
  val todayEvent = "JCConf"
  val workshop = "Introduction to Scala"
  lazy val fun = (0 to 4).map(x => "fun").mkString(" ")

  def main(args: Array[String]): Unit = {
    println("Hello everybody!")
    print("Welcome to " + todayEvent + "!\n")
    println("I hope you can enjoy this workshop - "
      + workshop + ". :P")
    print("Scala is so much " + fun + "!")
  }
}
```

Object with main method.

Program with Scala(App)


```
object Demo2 extends App {
  val todayEvent = "JCConf"
  val workshop = "Introduction to Scala"
  lazy val fun =
    (0 to 4).map(x => "fun").mkString(" ")

  println("Hello everybody!")
  print("Welcome to " + todayEvent + "!\n")
  println("I hope you can enjoy this workshop - "
    + workshop + ". :P")
  print("Scala is so much " + fun + "!")
}
```

Program with Scala(REPL)

- REPL - Read-Evaluate-Print Loop

```
Welcome to Scala 2.11.8 (OpenJDK 64-Bit Server VM, Java 1.8.0_102).
Type in expressions for evaluation. Or try :help.

scala> val language = "scala"
language: String = scala

scala> language.toUpperCase
res0: String = SCALA

scala>
```

Program with Scala(REPL)

- $ scala -Dscala.color

```
Welcome to Scala 2.11.8 (OpenJDK 64-Bit Server VM, Java 1.8.0_102).
Type in expressions for evaluation. Or try :help.

scala> val language = "scala"
language: String = scala

scala> language.toUpperCase
res0: String = SCALA

scala>
```

Program with Scala(Worksheet)

- Work with worksheet.
  - **IntelliJ**
    - https://www.jetbrains.com/help/idea/2016.2/working-with-scala-worksheet.html
- Scala IDE or Eclipse with Scala plugin
  - https://www.youtube.com/watch?v=For14hpg7kA

Imperative

- var, val, semicolons
- If expressions
- def
- Block expressions
- While-Loop
- For-Loop
- Nested Function
- Recursion vs Tail-recursion
- Concept of Pattern Matching
- Pattern Matching v1

var vs. val

- var - variable
  - Something that able or likely to change or be changed. **Not always the same**. Merriam-Webster
- val - value
  - A value is an expression which cannot be evaluated any further. Wiki
  - Opposite to var, val cannot be changed.
  - It's similar to **final** in Java.

Expression with semicolon?

```
val x = 5566
val y = 87
val java = "Java"; val scala = "scala"
```

If you have **multiple expressions** in one line,
you will need semicolon(;).
Otherwise you don't need it.

If expressions

- If has return value.(expression)
  - Scala have no ternary operator(?:).

```
// Java version
final int value = -1;
final boolean negative = value < 0 ? true : false;
```

```
// Scala version
val value = 0
val negative = if (value < 0) true else false
```

Everything is an expression.

def

"def" starts a function definition

result type of function

function name

parameter

equals sign

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

function body in curly braces

Programming in Scala, 3ed by Martin Odersky, Lex Spoon, and Bill Venners

def

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

def

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

No function's result type

def

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

No curly brackets

Summary of def

- You don't need return.
  - **Last expression** of block will be the return value.
- You don't need return type in method definition.
  - Scalac will **know your return type** in most case.
  - **It's a good habit to have return type, when your API is a public interface.**
- You don't need curly bracket.
  - **If you have multiple lines of code, using curly bracket({}) is a good habit.**

Block expressions(curly brackets)

```
val n = 5
val factorial = {
  var result = 1
  for (i <- 1 to n)
    result = result * i
  result
}
```

Last expression(**result**) in block will be the return value, then it will assign to factorial.

While-Loop

```
var n = 10
var sum = 0

while (n > 0) {
   sum = sum + 1
   n = n - 1
}
```

For-Loop

```
var sum = 0
for (i <- 1 to 10) {
   sum += 1
}
println(sum)
```

For-Loop

```
for (i <- 0 until 10) {
   println(i)
}
```

For-Loop

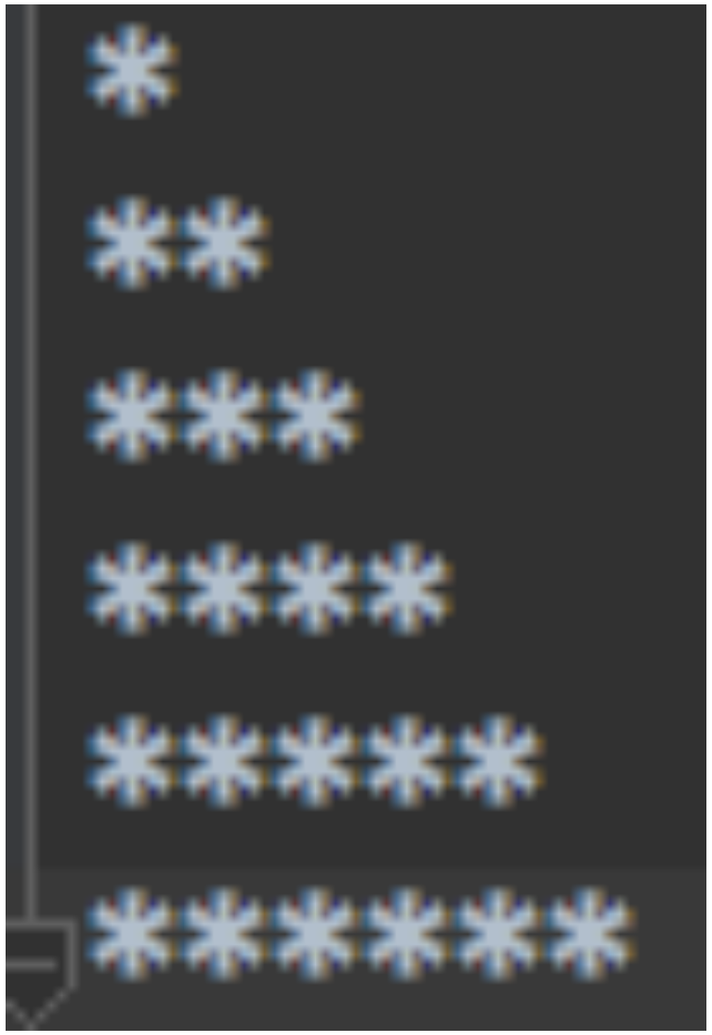
```
val n = 5
for {i <- 0 to n
     j <- 0 to n} {
   print("*")
   if (j == n)
      println("")
}
```

With curly bracket - “{}”,
you can use newlines without semicolon - “;”.

Demo11

Exercise of For-Loop

- Print out something like below.



Nested Function

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

  if (x == max(x, y))
    y
  else
    x
}
```

Nested Function(Closure)

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

  if (x == max) y else x
}
```

If your method is zero parameters, you don't need parentheses.

Recursion vs Tail-recursion

- Factorial number
  - 6! = 6 * 5 * 4 * 3 * 2 * 1

Recursion vs Tail-recursion

```
// Recursion
def factorial(n: Int): BigInt = {
  if (n == 0) 1
  else n * factorial(n - 1)
}

factorial(15000)
```

java.lang.StackOverflowError

Recursion vs Tail-recursion

```
def factorial(n: Int): BigInt = {
  // Tail-recursion
  def helpFunction(acc: BigInt, n: Int): BigInt = {
    if (n == 0)
      acc
    else
      helpFunction(acc * n, n - 1)
  }
  helpFunction(1, n)
}
```

Tail-recursion

Scalac will translate tail-recursion to **while-loop**.

```
factorial(15000)
```

Recursion vs Tail-recursion

Add annotation is a good habit.
Compiler can check whether or not can be optimise.

```
import scala.annotation.tailrec
def factorial(n: Int): BigInt = {
  @tailrec
  def helpFunction(acc: BigInt, n: Int): BigInt = {
    if (n == 0)
      acc
    else
      helpFunction(acc * n, n - 1)
  }
  helpFunction(1, n)
}
```

You have to add return type,
when the function is recursive.
Or Scalac would not know the return type.

Concept of Pattern Matching

- Pattern matching is similar to "switch-case", but it's **more general**.
- There are some differences.
  - No fall-through.
  - Each condition needs to return a value.
    - Everything is a expression in Scala.
  - It can match anything.

Pattern Matching v1

- Scala's pattern matching can match "Byte", "Character", "String", "Short" and "Integer". This is what Java's switch can do.
- But Scala can match **more** things than that. I will talk about this later.

Pattern Matching v1

```
def matchString(x: String) = {
  x match {
    case "Dog" => x
    case "Cat" => x
    case _ => "Neither Dog or Cat"
  }
}

matchString("Dog")
matchString("Human")
```

Exercise of tail-recursion

- Fibonacci numbers (0, 1, 1, 2, 3, 5…)

$$F_n = F_{n-1} + F_{n-2},$$

with seed values

$$F_0 = 0 \quad \text{and} \quad F_1 = 1.$$

www.leaningtowerofpisa.net/fibonacci.html

Object-oriented

- Class
- Extends, With, Override
- Abstract Class
- Object, Companion Object
- Trait
- Access Modifiers
- Case class
- Pattern matching v2

Class

Primary Constructor

```
class Employee(id: Int,
               val name: String,
               address: String,
               var salary: BigDecimal) {
  def this(id: Int, name: String, salary: BigDecimal) {
    this(id, name, "Earth", salary)
  }

  def getAddress = address
}
```

val in constructor will give you getter

var in constructor will give you setter and getter

Auxiliary Constructor

When your method without parameters, you don't need parentheses.

Extends, with, override

- Scala is single inheritance like Java.
- Scala - extends = Java - extends
- Scala - with = Java - implements
- Scala - override = Java - @Override

Abstract class

- Abstract class just likes normal class, but it can have **abstract methods** and **abstract fields** which means **methods and fields without implementation**.

- In Scala, **you don't need the keyword - abstract** for methods and fields in Abstract class. When you leave **methods and fields without body**, it means abstract methods and fields.

Abstract class

```scala
sealed abstract class Animal(val name: String) {
  val footNumber: Integer
  val fly: Boolean
  def speak: Unit
}

class Dog(name: String) extends Animal(name) {
  override val footNumber: Integer = 4
  override val fly = false
  override def speak: Unit = println("Spark")
}

class Bird(name: String) extends Animal(name) {
  val footNumber: Integer = 2
  val fly = true
  def speak: Unit = println("chatter")
}
```

Sealed classes

1. Subclasses should be in the same file.
2. Compiler can check you have covered all of cases in pattern matching.

Object

- Object is a singleton.
- It likes normal class.
  - You have **only one instance** in your application's life cycle.
  - Singleton objects **cannot** take **class parameters**.
- Scala **does not have static class members** like Java but has object instead.
- You don't need to worry about how to write a thread-safe singleton.
- What's advantage of Object?
  - http://programmers.stackexchange.com/a/179402

Object

```
object MathUtil {
  def doubleHalfUp(precision: Int,
                   origin: Double): Double = {
    val tmp = Math.pow(10, precision)
    Math.round(origin * tmp) / tmp
  }
}
```

Companion object

- It's like normal object, but it **shares the same name with class name** and locates with class **in the same source file**.
- The class and its companion object can **access each other's private methods or fields**.

Traits

- Traits are like interface in Java.
  - You cannot pass class parameters
- But there are differences.
  - It can **contain fields** and **concrete methods**.
  - Traits can **enrich a thin interface**(**mixin**) which can make a rich interface.

Trait - Mixin

```scala
trait Iterator[A] {
  def hasNext: Boolean
  def next: A
}
```

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

```scala
class CharIterator(s: String)
  extends Iterator[Char] {
  var i = 0
  def hasNext = i < s.length
  def next = {
    val c = s(i)
    i += 1
    c
  }
}

val ci = new CharIterator("hello")
  with RichIterator[Char]
ci.foreach(println)
```

https://scalafiddle.io/sf/i3KWOvf/0

Access Modifiers

- public
  - anyone
  - There is **no explicit modifiers** for public fields and methods.
- protected
  - only allow subclass access
- private
  - In the same scope of Scala file.
- protected[X] or private[X]
  - access is private or protected “up to” X

Case Classes

- Case classes are a special kind of classes that are **optimised for use in pattern matching**.
- Each of the constructor parameters becomes a **val**.

Scala for the Impatient by Cay Horstmann

Case Classes

- It creates the **companion object**.
  - It contains an **apply** method used to construct instance without "**new**". (Factory pattern)
  - It contain an **unapply** method work as extractor to extract values from apply method.
  - Each instance contains toString, **equals**(==), hashCode, and copy.

Scala for the Impatient by Cay Horstmann

Pattern Matching v2

```
sealed abstract class Expr
case class Add(first: Expr, second: Expr) extends Expr
case class Sub(first: Expr, second: Expr) extends Expr
case class Multi(first: Expr, second: Expr) extends Expr
case class Div(first: Expr, second: Expr) extends Expr
case class Value(n: Int) extends Expr

def calculate(combination: Expr): Int = {
  combination match {
    case Add(first, second) => calculate(first) + calculate(second)
    case Sub(first, second) => calculate(first) - calculate(second)
    case Multi(first, second) => calculate(first) * calculate(second)
    case Div(first, second) => calculate(first) / calculate(second)
    case Value(n) => n
  }
}
// (((2 + 1) * 3) - 1) / 4
val exp = Div(Sub(Multi(
  Add(Value(1), Value(2)), Value(3)), Value(1)), Value(4))
calculate(exp)
```

Pattern Matching v2

```
def calculate(combination: Expr): Int = {
  combination match {
    case Add(Multi(a, x), Multi(b, y)) if (x == y) =>
      (calculate(a) + calculate(b)) * calculate(x)
    case Add(first, second) =>
      calculate(first) + calculate(second)
    case Sub(first, second) =>
      calculate(first) - calculate(second)
    case Multi(first, second) =>
      calculate(first) * calculate(second)
    case Div(first, second) =>
      calculate(first) / calculate(second)
    case Value(n) =>
      n
  }
}

calculate(Add(Multi(Value(3), Value(2)), Multi(Value(4), Value(2))))
```

Summary of object-oriented

- If it might be reused in multiple, unrelated classes, make it a trait.
- If you plan to distribute it in compiled form and you expect outside groups to write classes inheriting from it, you might lean towards using an abstract class.
- ……..
- If you are not so sure abstract class or trait, then use trait. Trait keeps more options open.

Programming in Scala, 3ed by Martin Odersky, Lex Spoon, and Bill Venners

Functional

- Functional concept
- First-class functions
- Anonymous functions
- High-order functions

Functional Concept

- Immutability (Referential transparency)
  - **No side effect**.
- Functions as values
  - **Functions as objects**
- Higher-order functions
  - Input: takes one or more functions as parameters
  - Output: return a function as result

First-class functions

- Functions are **first-class** values.
- Function is a value of **the same status as an integer or string**.

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Anonymous functions(Lambdas)

```
(0 until 10).map((value: Int) => value * value)
```

```
(0 until 10).map(value => value * value)

(0 until 10).map(value => value + 1)
(0 until 10).map(_ + 1)
```

Placeholder syntax

High-order functions

```
def calculateTax(rate: BigDecimal => BigDecimal,
                 salary: BigDecimal): BigDecimal = {
  rate(salary)
}

val usaTax = (salary: BigDecimal) => {
  if (salary > 413201)
    salary * 0.396
  else
    salary * 0.3
}

val twTax: BigDecimal => BigDecimal = _ * 0.25

calculateTax(usaTax, 413202)
calculateTax(twTax, 100)
```

High-order functions

```
def calculateTax(rate: BigDecimal => BigDecimal,
                 salary: BigDecimal): BigDecimal = {
  rate(salary)
}

def usaTax(salary: BigDecimal) = {
  calculateTax(x =>
    if (x > 413201) x * 0.396
    else x * 0.3,
    salary)
}
def twTax(salary: BigDecimal) =
  calculateTax(_ * 0.25, salary)

usaTax(413202)
twTax(100)
```

High-order functions

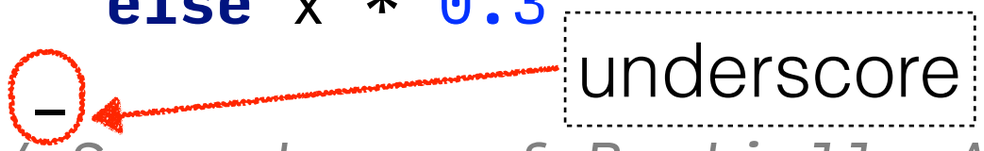
```
def calculateTax(rate: BigDecimal => BigDecimal)
: (BigDecimal) => BigDecimal = {
  rate
}

def usaTax = calculateTax(x =>
  if (x > 413201) x * 0.396
  else x * 0.3
)
def twTax = calculateTax(x => x * 0.25)

usaTax(413202)
twTax(100)

calculateTax(usaTax)(413202)
calculateTax(twTax)(100)
```

High-order functions - Curry

```
def calculateTax(rate: BigDecimal => BigDecimal)
                (salary: BigDecimal): BigDecimal = {
  rate(salary)
}

def usaTax(salary: BigDecimal) =
  calculateTax(x =>
    if (x > 413201) x * 0.396
    else x * 0.3)(salary)
def twTax(salary: BigDecimal) =
  calculateTax(x => x * 0.25)(salary)

usaTax(413202)
twTax(100)
```

High-order functions - Partially Applied Function

```
// Curry
def calculateTax(rate: BigDecimal => BigDecimal)
                (salary: BigDecimal): BigDecimal = {
  rate(salary)
}

// First way of Partially Applied Function
def usaTax = calculateTax(
  x =>
    if (x > 413201) x * 0.396
    else x * 0.3
) _
// Second way of Partially Applied Function
def twTax: BigDecimal => BigDecimal = calculateTax(_ * 0.25)

usaTax(413202)
twTax(100)
```



Exercise of High-order functions

```
def summation(fun: Int => Int, start: Int, end: Int): Int = ???

def number(n: Int): Int = ???
def cube(n: Int): Int = ???
// 5 * 4 * 3 * 2 * 1
def factorial(n: Int): Int = ???

def sumNumber(start: Int, end: Int): Int = ???
def sumCubes(start: Int, end: Int): Int = ???
def sumFactorials(start: Int, end: Int): Int = ???
```

Functional Programming Principles in Scala, Martin Odersky

Exercise of High-order functions

```
// hint: nest function
def summation(fun: Int => Int): (Int, Int) => Int = ???

def sumNumber = ???
def sumCubes = ???
def sumFactorials = ???
```

Functional Programming Principles in Scala, Martin Odersky

Exercise of Curry

```
// Curry
def summation(fun: Int => Int)(start: Int, end: Int): Int = ???

def sumNumber = ???
def sumCubes = ???
def sumFactorials = ???
```

Functional Programming Principles in Scala, Martin Odersky

Collections

- Concept of Collections
- Collection Traits
- Hierarchy of Collections
  - Immutable
  - Mutable
- Immutable List
- Immutable HashMap
  - Tuple
  - Option
- Pattern Matching v3
- Time Complexity

Concept of Collections

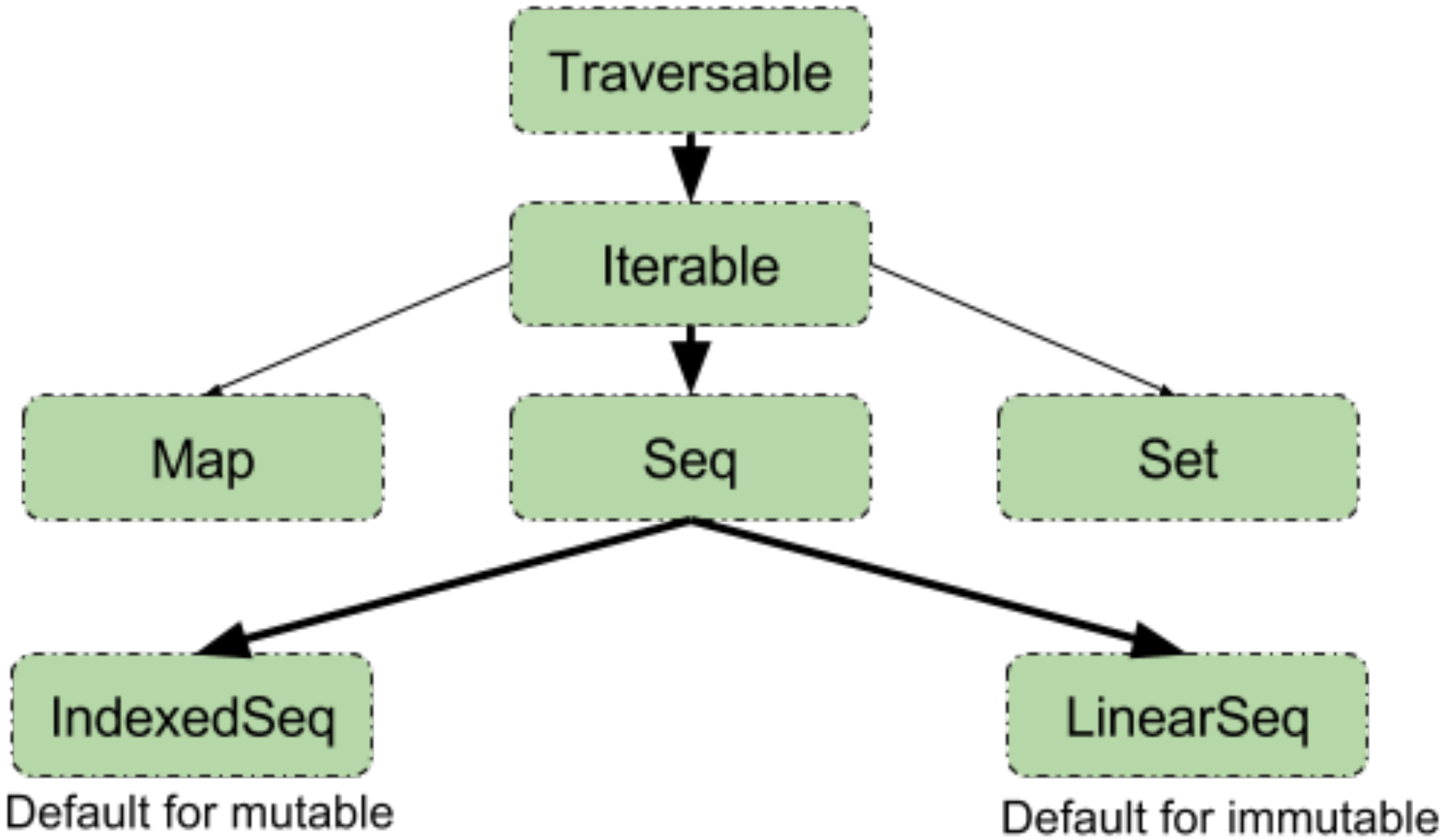
- In most programming language, they only support mutable collections.
- Scala supports mutable collections and **immutable** collections.
  - It means you **cannot change the data** that inside of collections.
  - When you operate on a collection, it will **return a new collection** than **keep origin collection**.
- Almost every method is **left associativity**.
  - Unless method that ends in a "**:**"(**colon**) is **right associativity**.

Concept of Collections

	val	var
Immutable Collection	Best	Not Bad
Mutable Collection	Danger	~~Very Danger~~

The Mutability Matrix of Pain by Jamie Allen

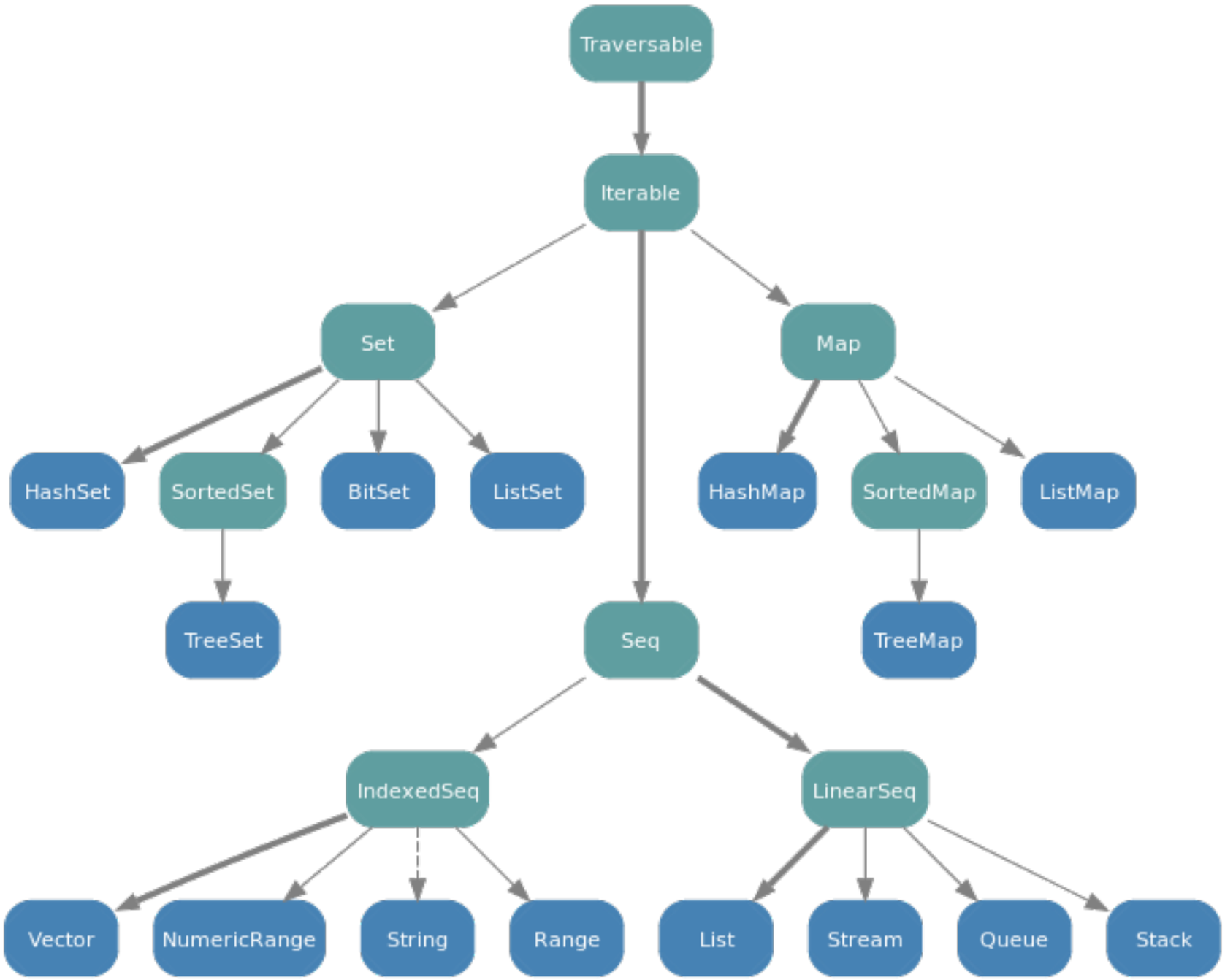
Hierarchy of Collections



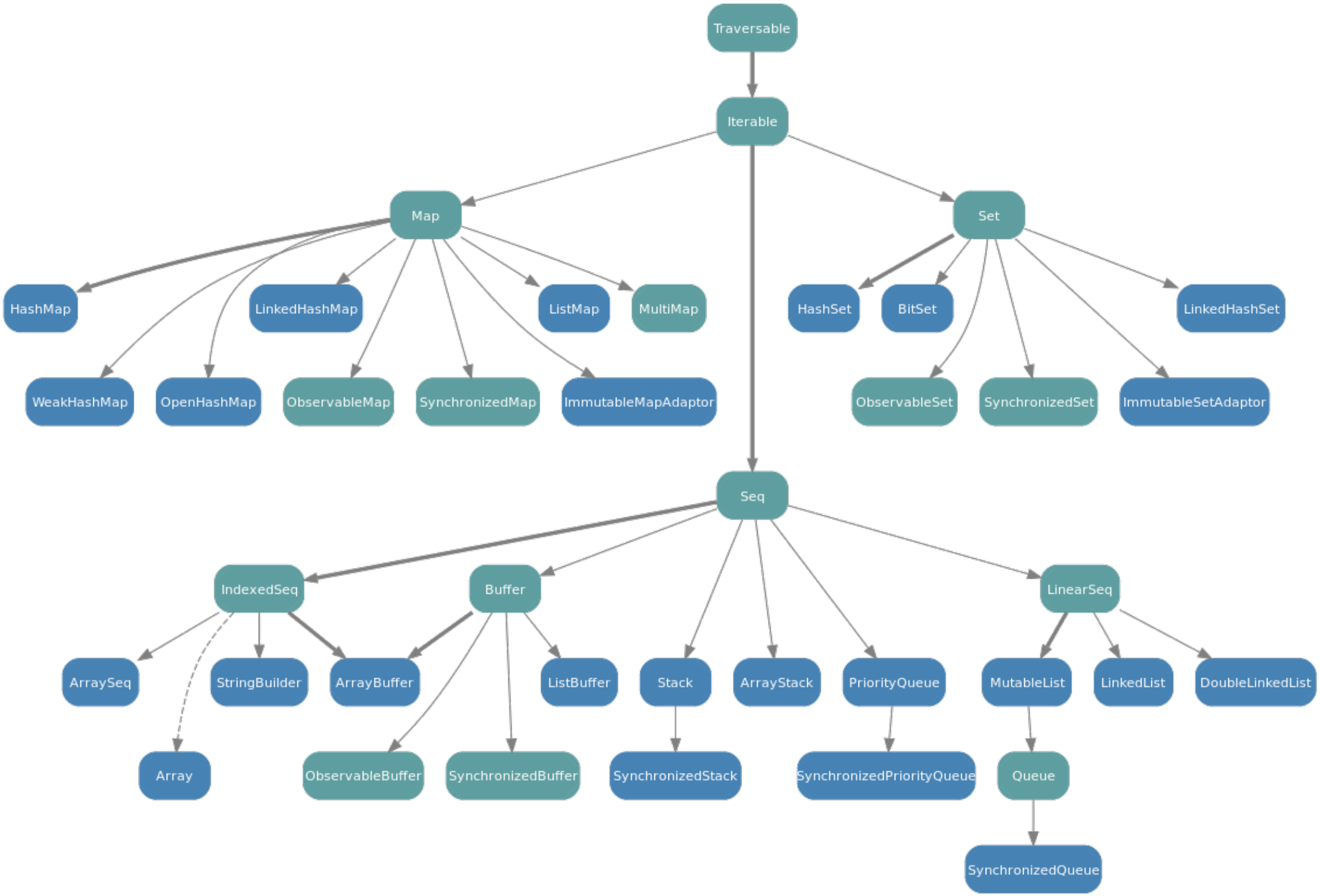
Collection Trait

- Traversable - traverse whole collection.
- Iterable - traverse whole collection **with sooner stop**.
- Seq
  - IndexedSeq - Array
  - LinearSeq - List
- Map - key pairs with value.
- Set - no duplicated item

Hierarchy of Immutable Collections

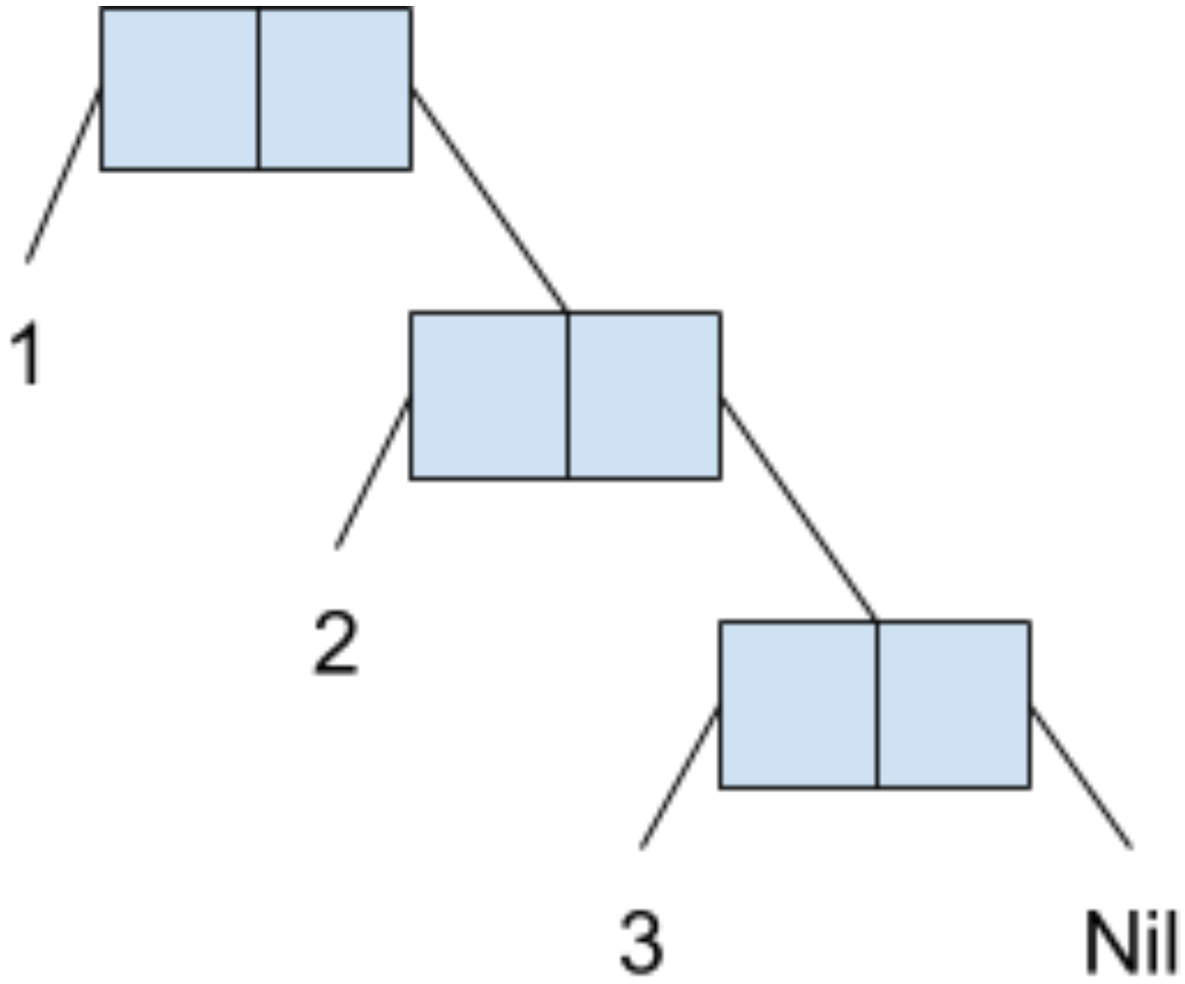


Hierarchy of Mutable Collection



Concept of Immutable List

- Nil
  - The empty list.
    - Avoid null.



Work with List

```
// Construct List
val list1 = List(1, 2, 3)
// Element prepends to List
val list2 = 1 :: 2 :: 3 :: Nil
val list3 = 1 :: (2 :: (3 :: Nil))
val list4 = Nil.::(3).::(2).::(1)
// List prepends to List
val list5 = List(5, 5, 6, 6) ::: List(8, 7)
val list6 = List(8, 7).:::(List(5, 5, 6, 6))
```

API of List

```
val list =
  List(4, 3, 0, 1, 2)
list.head
list.tail
list.length
list.max
list.min
list.sum
list.contains(5)
list.mkString(",")
list.drop(2)
list.reverse
```

```
list.sortWith(_ > _)
list.map(x => x * 2)
list.map(_ * 2)
list.reduce((x, y) => x + y)
list.reduce(_ + _)
list.filter(x => x % 2 == 0)
list.filter(_ % 2 == 0)
list.groupBy(x => x % 2 == 0)
list.groupBy(_ % 2 == 0)
list.indices zip list
list.zipWithIndex
```

List with high-order function

```
val list =
  List(4, 3, 0, 1, 2)

val twoDim = list.map(_ + 1) ::
  list.map(_ - 1) ::
  list.map(_ * 2) ::
  Nil
twoDim.flatten
// map + flatten
twoDim.flatMap(x => x.filter(_ % 2 == 1))
```

Concept of Immutable HashMap

- Tuple
- Option
  - Some
  - None

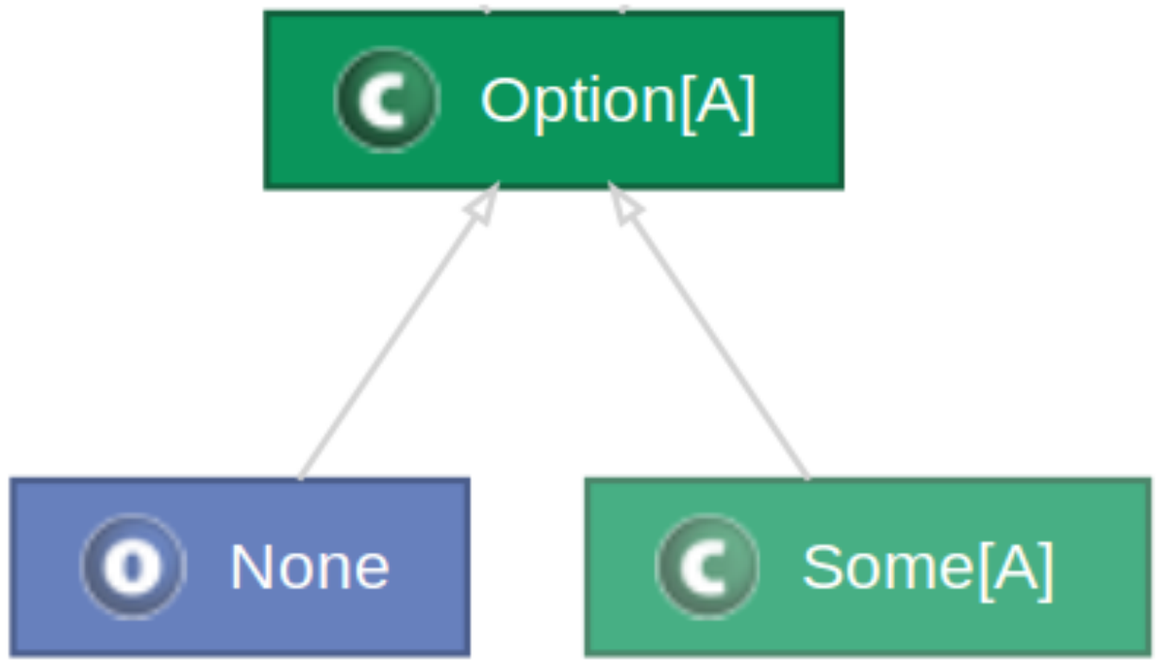
Tuple

- Immutable
- Contain **different type** of elements
  - You don't need Java-Bean
- It can contain to 22 elements.
- Tuple2 = Pair

```
val people =
  ("Martin", 58)
people._1
people._2
```

Option

- Use to avoid null.
  - Null is error prone.
    - You code need to check whether or not it is null.
- Option type will be Some **or** None.



http://betehess.github.io/talks/2014/06/06-cata-visitor-adt#14

Work with HashMap

```
val countryCode =
  Map("Taiwan" -> 886,
    "United States" -> 1,
    "Japan" -> 81)
val countryCode1 =
  Map(("Taiwan", 886),
    ("United States", 1),
    ("Japan", 81))

// 886
countryCode("Taiwan")
// Some(886)
countryCode.get("Taiwan")
```

```
// NoSuchElementException
countryCode("Canada")
// None
countryCode.get("Canada")
// add
countryCode + ("China" -> 86)
// delete
countryCode - ("Japan")
// update
countryCode + ("Taiwan" -> 5566)
countryCode.getOrElse("China", 0)
```

More Option

```
val list = List(0, 1, 2, 3, 4, 5)
def odd(n: Int) =
  if (n % 2 == 1) Some(n)
  else None
list.map(odd(_))
list.flatMap(odd(_))

val list1 =
  List(Some(1), None, Some(2), None, Some(3))
Some(5566).map(x => x * 2)
list1.flatMap(x => x.map(y => y * 2))
list1.flatMap(_.map(_ * 2))
```

Advanced Option

```scala
case class People(
                   id: String,
                   firstName: String,
                   lastName: String,
                   age: Int,
                   countries: List[String],
                   gender: Option[String]
                 )

object PeopleRepository {
  private val peoples = Map(
    1 -> People("1", "John", "Doe", 30,
List("TW", "USA"), Some("male")),
    2 -> People("2", "Janie", "Doe", 10,
List("Japan"), Some("female")),
    3 -> People("3", "", "Doe", 50, List("TW"),
None))

  def find(id: Int): Option[People] =
peoples.get(id)
  def getAll = peoples.values
}
```

```scala
// None
for {
  people <- PeopleRepository.find(2)
  gender <- people.gender
} yield gender

// Some(female)
for {
  people <- PeopleRepository.find(3)
  gender <- people.gender
} yield gender
// None
for {
  people <- PeopleRepository.find(4)
  gender <- people.gender
} yield gender
```

The Neophyte's Guide to Scala Part 5: The Option Type

For-comprehensions

```
// List of People has TW passport
for {
  people <- PeopleRepository.getAll
  if (people.countries.contains("TW"))
} yield people

(for {
  people <- PeopleRepository.getAll
  country <- people.countries
} yield country).toSet
```

Exercise of Collection

```
// only use collection's API(combinator)

// find the maximum number of Seq with fun
def larges(fun: Int => Int,
           inputs: Seq[Int]): Int = ???

// find the maximum number of index of Seq with fun
def largesIndex(fun: Int => Int,
                inputs: Seq[Int]): Int = ???
```

Scala for the Impatient by Cay Horstmann

Pattern Matching v3

```
val list = (0 to 5).toList
def sum(list: List[Int]): Int = {
  list match {
    case Nil => 0
    case head :: tail => head + sum(tail)
  }
}
sum(list)
```

Pattern Matching v3

```scala
import scala.annotation.tailrec

val list = (0 until 9).toList
def sumTail(list: List[Int]): Int = {
  @tailrec
  def help(list: List[Int],
           previous: Int): Int = list match {
    case Nil => 0
    case List(onlyOne) => previous + onlyOne
    case head :: tail => help(tail, previous + head)
  }
  help(list, 0)
}
sumTail(list)
```

Time complexity

- C: constant time, O(1)
- eC: effectively constant time
- aC: amortised constant time
  - Some of operation take longer. On average, it is constant time.
- Log: O(log n)
- L: linear time, O(n)

Collection Performance - Immutable Sequence

	head	tail	apply	update	prepend	append	insert
List	**C**	**C**	L	L	C	**L**	
Stream	**C**	**C**	L	L	C	**L**	
Vector	eC	eC	eC	eC	eC	eC	
Stack	C	C	L	L	C	C	L
Queue	aC	aC	L	L	L	C	
Range	C	C	C				
String	C	L	C	L	L	L	

http://docs.scala-lang.org/overviews/collections/performance-characteristics.html

Collection Performance - Mutable Sequence

	head	tail	apply	update	prepend	append	insert
ArrayBuffer	C	L	C	C	**L**	aC	L
ListBuffer	C	L	L	L	**C**	**C**	L
StringBuilder	C	L	C	C	**L**	aC	L
MutableList	C	L	L	L	C	C	L
Queue	C	L	L	L	C	C	L
ArraySeq	C	L	C	C			
Stack	C	L	L	L	C	L	L
ArrayStack	C	L	C	C	aC	L	L
Array	C	L	C	C			

http://docs.scala-lang.org/overviews/collections/performance-characteristics.html

Collection Performance - Set & Map

	lookup	add	remove	min
immutable				
HashSet/HashMap	eC	eC	eC	L
TreeSet/TreeMap	Log	Log	Log	Log
BitSet	C	L	L	eC*
ListMap	L	L	L	L
mutable				
HashSet/HashMap	eC	eC	eC	L
WeakHashMap	eC	eC	eC	L
BitSet	C	aC	C	eC
TreeSet	Log	Log	Log	Log

http://docs.scala-lang.org/overviews/collections/performance-characteristics.html

Summary of Scala

- Keep it simple.
- **Don't pack too much in one expression.**
- Find meaningful names.
  - If you are hard to find meaningful names, maybe you have wrong abstraction.
- Prefer functional.
- **But don't diabolise local state.**
- Careful with mutable objects.

Scala with Style by Martin Odersky

Further Reading & Reference

- Video
  - Scala for the Intrigued by Venkat Subramaniam
  - Scala with Style by Martin Odersky
- Online Tutorial
  - Scala School by Twitter
  - Creative Scala by Underscore
  - Scala Official Tutorial
  - Scala 101 by Lightbend
  - Scala Exercises
- Other
  - Scala 2.11.8 API Documentation

Further Reading & Reference

- Book
  - Jason Swartz. Learning Scala. Available from http://shop.oreilly.com/product/0636920030287.do
  - Cay Horstmann. **Scala for the Impatient**. Available from http://www.informit.com/store/scala-for-the-impatient-9780321774095
    - (Beginning)
  - Martin Odersky, Lex Spoon, and Bill Venners. **Programming in Scala, 3rd**. Available from http://www.artima.com/shop/programming_in_scala_3ed
    - (Beginning, Intermediate, Advance)
  - Joshua D. Suereth. Scala in Depth. Available from https://www.manning.com/books/scala-in-depth
    - (Advance)

Further Reading

- SBT
  - SBT Basic Concepts by Pishen Tsai
  - SBT Official Document
- Design
  - Functional Patterns in Scala by Walter Chang
  - Functional Programming in Scala by Paul Chiusano and Rúnar Bjarnason
- Test
  - ScalaTest Official Guild

Further Reading

- **S**tructure and **I**nterpretation of **C**omputer **P**rograms by Harold Abelson, Gerald Jay Sussman, Julie Sussman
  - Books - https://mitpress.mit.edu/sicp/full-text/book/book.html
  - Videos - http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-001-structure-and-interpretation-of-computer-programs-spring-2005/video-lectures/
- It's not teach you Scala, but it teaches **the principles of computer programming**. Even Martin's Coursera courses borrow concepts from this material.

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