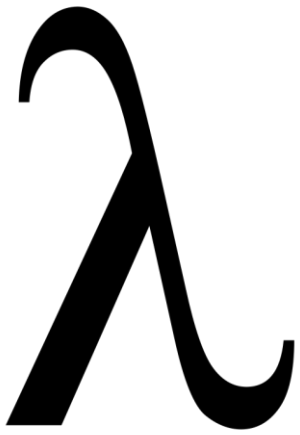

Introduction to Scala

Programmazione Funzionale

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Università di Trento

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Today

- Introduction to Scala
- The basics of the language
- Data Types
- Control structures
- OOP Domain modeling

Introduction to Scala

A bit of history

- The design of Scala started in 2011 at the EPFL (École Polytechnique Fédérale de Lausanne) by Martin Odersky
- He decided to take some ideas from functional programming and moving them into the Java space.
- The result was in 1996 a language called Pizza.
- It was quite successful: functional language features can be implemented on a JVM platform.

Why a new programming language?

- Scalable Language
  - Designed to grow with the users' demand
- Multi-paradigm Language
  - Combining object-oriented and functional programming

Scala in few words

- A combination of functional and object-oriented programming

FP is good at isolating state change
Immutability, repeatability, concurrency

OOP is good at structuring code
Interfaces, classes, encapsulation, delegation, singleton

Multi-paradigm

Object-oriented paradigm

- Every value is an object
- Types and behaviour of objects are described by classes
- Mechanisms of class abstractions

Functional paradigm

- Every function is a value (including methods)
- Lightweight syntax for anonymous functions, higher-order functions, nested functions, currying
- Pattern matching

Why Scala?

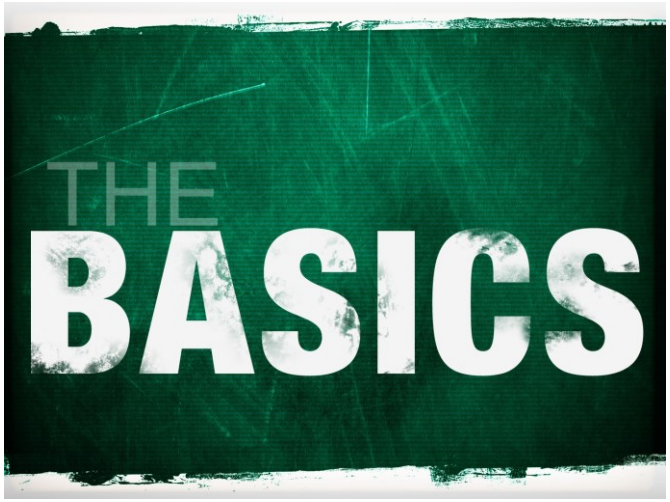
- Concise. Fewer lines of code means less typing and less effort at reading and understanding and less opportunities to make errors
- High-level. OOP and FP let you write more complex programs
- Statically typed. Verbosity is avoided through type inference so it looks like a dynamic language but it is not
- And also
  - Concurrency and parallelism
  - Integration with Java

Scala use cases

- Big data and data science
- Web Application Development, REST API Development
- Distributed System, Concurrency and Parallelism
- Scientific computation like NLP, Numerical Computing and Data Visualization
- Financial applications

Scala users


airbnb
twitter
intel
databricks
Linked in
the guardian
UniCredit
coursera
SAMSUNG
Walmart



The basics of the language

Getting started

```
C:\> scala
Welcome to Scala 3.3.1 (11.0.21, Java OpenJDK
64-Bit Server VM).
Type in expressions for evaluation. Or try
:help.

scala> 10 + 5.2
val res0: Double = 15.2
scala> :quit
```

Differently from ML, in Scala we have automatic type conversion

REPL (Read-Evaluate-Print-Loop)

- The REPL is a command-line interpreter used as a “playground” to test the Scala code.

```
user@DESKTOP-UN3PBAM:~$ scala
Welcome to Scala 3.3.1 (11.0.21, Java OpenJDK 64-Bit Server VM).
Type in expressions for evaluation. Or try :help.

scala> 1 + 1
val res0: Int = 2

scala> val x = res0 *10
val x: Int = 20

scala> def sum(a: Int, b: Int): Int = a + b
def sum(a: Int, b: Int): Int
```

Compiling and executing scala programs

- You can compile and execute your scala programs from command line by typing `scala`

- `C:\> scala script.scala`

Program Entry point

- The main method is the entry point of a Scala Program
- In Scala 3, we can directly use the `@main` annotation

```
@main def hello() = println("Hello, Scala developer!")
```

Expressions

- You can output the results using `println`:

```
scala> println(10+5.2);
15.2

scala> println("Hello world");
Hello world

scala> println("Hello“ + " world");
Hello world
```

String interpolation & multiline

- String interpolation with s and $
  - precede the string with the letter s and put a $ symbol before variable names

```
val firstName = "Donald"
val lastName = "Duck"
println(s"Name: $firstName $lastName")   // "Name: Donald Duck"
```

  - enclose arbitrary expressions in curly brackets

```
println(s"2 + 2 = ${2 + 2}")   // prints "2 + 2 = 4"
val x = -1
println(s"x.abs = ${x.abs}")   // prints "x.abs = 1“
```

- Multiline strings with three double quotes

```
val quote = """The essence of Scala:
               Fusion of functional and object-oriented
               programming in a typed setting."""
```

Values

- We can name the results of an expression with the keyword `val`

```
scala> val x = 2+3
val x: Int = 5
scala> println(x)
5
```

- Values, however cannot be reassigned: values are immutable

```
scala> x = 3
-- [E052] Type Error: ----------------------------------------------
--------
1 |x = 3
  |^^^^^
  |Reassignment to val x
  |
  | longer explanation available when compiling with ‘-explain‘
1 error found
```

Variables

- Variables can be defined with the keyword `var`. They are like values, but we can reassign them

```
scala> var x = 2 + 3
var x: Int = 5
scala> println(x)
5
scala> x = 3
x: Int = 3
scala> println(x)
3
scala> x = 2.0;
-- [E007] Type Mismatch Error: ----------------------------------------------
1 |x = 2.0;
  |    ^^^
  |    Found:    (2.0d : Double)
  |    Required: Int
  |
  | longer explanation available when compiling with ‘-explain‘
1 error found
```

Type can be automatically inferred and it cannot be changed when we reassign the value

Specifying the type

- Both in case of values and variables we can explicitly specify the type – or we can omit it and it will be automatically inferred

```
scala> val x: Int = 2 + 3
val x: Int = 5

scala> var x: Int = 2 + 3
var x: Int = 5
```

Values and variables

```
scala> val ten:Int = 10
//ten is an immutable
value of type Int
val ten: Int = 10
scala> ten = 11
-- [E052] Type Error: ---
-------------------------
-------------------------
-----
1 |ten = 11
  |^^^^^^^^
  |Reassignment to val
ten
```

```
scala> var ten:Int = 10
//ten is a variable whose
value can change
var ten: Int = 10
scala> ten = 11 //ten is
set to 11
ten: Int = 11
```

Blocks

- Expressions can be combined in blocks by surrounding them with { }.
- The result of the last expression is the result of the overall block

```
scala> println({val x = 1+1
     |       x+1
     |  })
3
```

Question 1

- What is the value of `msg` after the two instructions?

```
scala> val msg = "Hello"
scala> msg += "world"
```

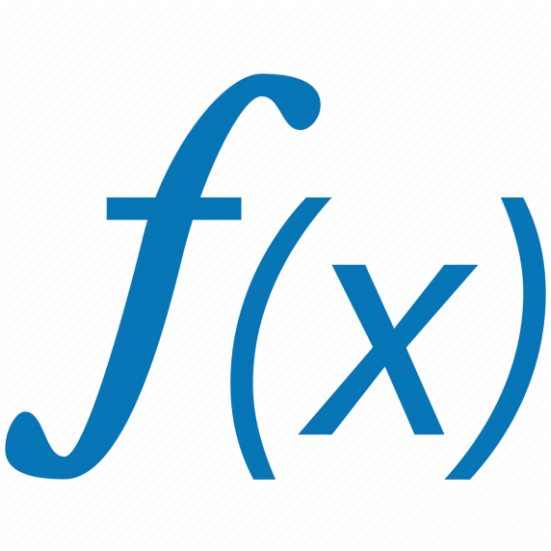
A. Hello world
B. The instructions raise an error
C. World
D. Hello

Question 2

- What is the value of `msg` after the two instructions?

```
scala> var msg = "Hello world"
scala> msg = 5
```

```
A. Hello world
B. The instructions
   raise an error
C. 5
D. Hello world 5
```



Functions

Functions

- Functions have a key role given the functional nature of Scala
- Functions are expressions that have parameters and take arguments
- Functions are defined by using => (similarly to ML)
  - On the left of =>, there is the list of parameters
  - On the right of =>, there is an expression involving the parameters

```
scala> val addOne = (x:Int) => x +1
val addOne: Int => Int =
Lambda$1400/0x00000008007ee040@4efe014f
scala> println(addOne(1))
2
```

Functions

- Functions can also have multiple parameters

```
scala> val add = (x: Int, y: Int) => x + y
val add: (Int, Int) => Int =
Lambda$1420/0x0000000800804040@73a116d
scala> println(add(1,2))
3
```

- Or no parameters

```
scala> val getanumber = () => 5
val getanumber: () => Int =
Lambda$1423/0x0000000800805440@430106cf
scala> println(getanumber())
5
```

Anonymous functions

- We can define anonymous functions, i.e., functions that have no name

```
scala> (x: Int) => x+1
val res0: Int => Int =
Lambda$1387/0x00000008007e5040@1d8dbf10
```

Higher order functions

- Function `map`

```
val salaries = List(20000, 70000, 40000)
val doubleSalary = (x: Int) => x * 2
val newSalaries = salaries.map(doubleSalary) // List(40000,
140000, 80000)
```

- We can also write it as

```
val newSalaries = salaries.map(x => x * 2) // List(40000,
140000, 80000)
```

- When we have a single parameter, and it appears only once in your anonymous function, we can replace it with _.

```
val newSalaries = salaries.map(_ * 2)// List(40000, 140000,
80000)
```

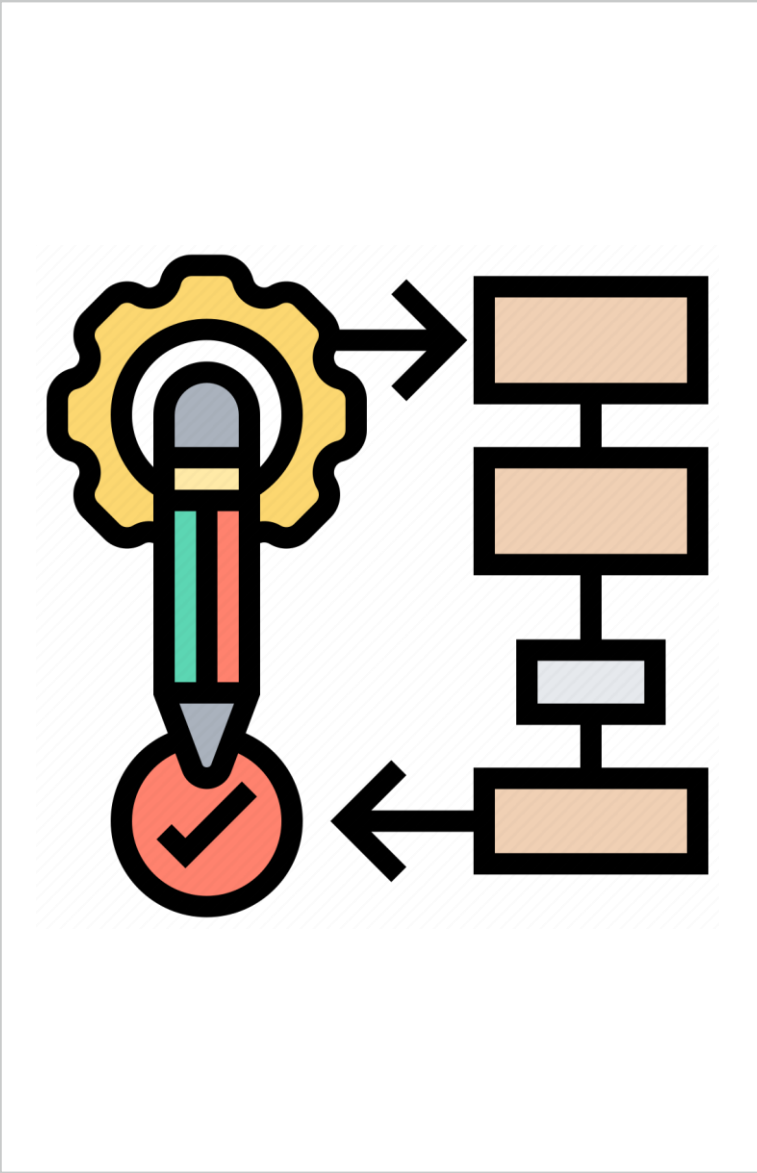
Higher-order functions

- Function `filter`

```
scala> val l = List ("aaa","bbbb","cc")
val l: List[String] = List(aaa, bbbb, cc)

scala> l.filter(s => s.length == 4)
val res: List[String] = List(bbbb)
```

- Alternative syntax

```
scala> l.filter(_.length ==4)
val res2: List[String] = List(bbbb)
```



Methods

Methods

- Methods look and behave very similar to functions, but there are some differences: methods are defined with the keyword `def`

```
def methodName(arg1: Type1, arg2: Type2, ...):returnType =
{
    lines of code
    result
}
```

In Scala 3.0 you do not need to use curly brackets

- Historically methods have been part of the definition of a class. However, in Scala 3, using eta-expansion it is possible to have methods outside of classes

Method examples

```
scala> def add(x: Int, y: Int): Int = x + y
def add(x: Int, y: Int): Int
scala> println(add(1, 2))
3

scala> def addThenMultiply(x: Int, y:
Int)(multiplier: Int): Int = (x + y) * multiplier
def addThenMultiply(x: Int, y: Int)(multiplier:
Int): Int
scala> println(addThenMultiply(1, 2)(3))
9
```

Currying

```
scala> def nDividesM(m:Int)(n:Int) = (n%m ==0)
def nDividesM(m: Int)(n: Int): Boolean
scala> nDividesM(4)(2)
val res: Boolean = false

scala> val isEven = nDividesM(2)
val isEven: Int => Boolean =
Lambda$1736/0x0000000800918840@56a6aadb
scala> println(isEven(4))
true
scala> println(isEven(5))
false
```

Question 3

- What does the following code print?

```
scala> def triple(x: Int): Int = x * 3
scala> val tripleCopy: (Int) => Int = triple
scala> println(tripleCopy(5))
```

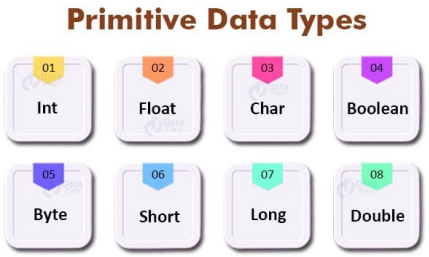
A. 15 15 15
B. The instructions raise an error
C. 5 5 5
D. 15

Question 4

- What does the following code print?

```
scala> val play=
(thing:String) =>  s"Let's
play with $thing"

scala> def funify(thing:
String, f: String => String):
String = {
  f(thing) + " and have fun"
}
scala> println(funify("cats",
play))
```

A. "Let's play with"
B. The instructions raise an error
C. "Let's play with cats and have fun"
D. "Let's play with and have fun"

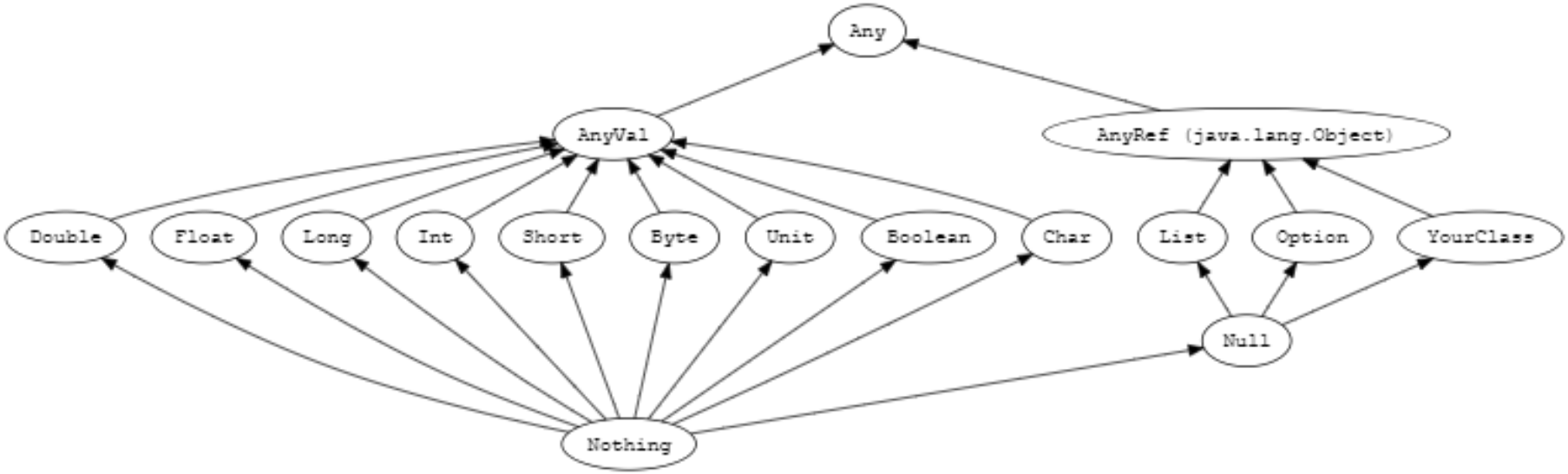


Data types

Unified type hierarchy

Scala types

- In Scala, all values have a type, including functions



Data types

- Byte
- Short
- Int
- Long
- Float
- Double
- Boolean
- String
- Char
- Unit

```
val b: Byte = 1
val i: Int = 1
val l: Long = 1
val s: Short = 1
val d: Double = 2.0
val f: Float = 3.0

val i = 123   // defaults to Int
val j = 1.0   // defaults to Double
val x = 1_000L   // val x: Long = 1000
val y = 2.2D     // val y: Double = 2.2
val z = 3.3F     // val z: Float = 3.3

val bool = true

val name = "Bill"   // String
val c = 'a'         // Char
```

Lists and arrays

Lists

- Lists are immutable (content cannot be changed)
- List [String] contains Strings

```
scala> val l = List ("a","b","c")
val l: List[String] = List(a, b, c)

scala> l.head
val res1: String = a

scala> l.tail
val res2: List[String] = List(b, c)
```

Cons operator and concatenation

- As in ML
  - The cons operator `::` prepend an element
  - The concatenation operator `:::` concatenate two lists

```
scala> val l2 = "a"::l
val l2: List[String] = List(a, a, b, c)

scala> val l3 = 1::2::3::Nil
val l3: List[Int] = List(1, 2, 3)

scala> val l4 = List(1,2,3):::List (4,5)
val l4: List[Int] = List(1, 2, 3, 4, 5)
```

List of union types and any type

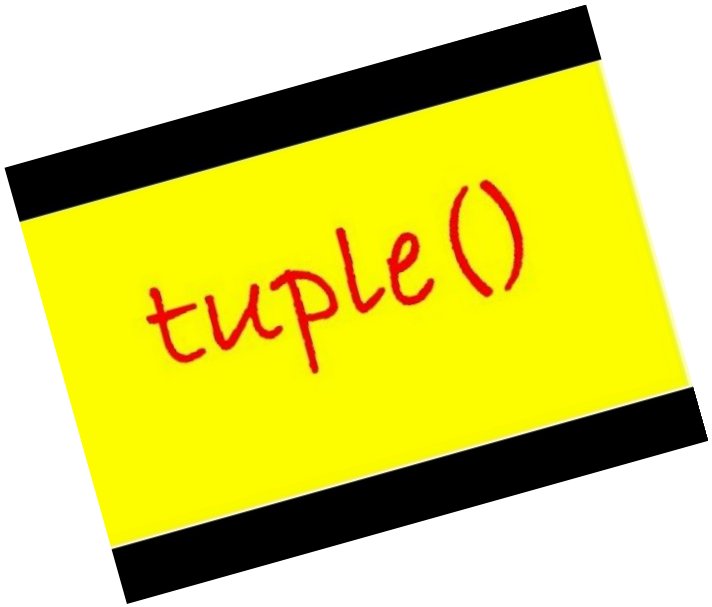
- It is possible to have mixed types in a list or a list of any type

```
val things: List[String | Int | Double] = List(1,
"two", 3.0) // with union types
val list: List[Any] = List(
     |   "a string",
     |   732,  // an integer
     |   'c',  // a character
     |   true, // a boolean value
     |   () => "an anonymous function returning a
string"
     | ) // with any
```

Arrays

- Lists are immutable, arrays are mutable

```
scala> val a = Array ("Java","Python")
val a: Array[String] = Array(Java, Python)
scala> a(0) = “Scala“

scala> val greets = new Array[String](2)
val greets: Array[String] = Array(null, null)
scala> greets(0) = "Hello"
scala> greets(1) = "world!“
```



Tuples

Tuples

- Sequence of (fixed number of) elements with different types

```
scala> (10, List('a','b'), "string")
val res: (Int, List[Char], String) =
(10,List(a, b),string)
```

Tuples

- Tuples are immutable

```
scala> val ingredient = ("Sugar", 25)
val ingredient: (String, Int) = (Sugar,25)
```

- For accessing elements

```
scala> println(ingredient(0))
Sugar
scala> println(ingredient(1))
25
```

In Scala 2.0 you should use ._X, e.g., println(ingredient._1)

Tuple usage

- Tuples are useful in particular for returning multiple values from a method

```
def divMod(x: Int, y: Int) = (x/y,x%y)
divMod(x: Int, y: Int): (Int, Int)

scala> val dm = divMod(10, 3)
val dm: (Int, Int) = (3,1)
scala> dm(1)
val res1: Int = 3
scala> dm(2)
val res2: Int = 1

scala> val (d,m) = divMod(10, 3)
val d: Int = 3
val m: Int = 1
```

Pattern matching on tuples

- A tuple can also be built using pattern matching

```
scala> val (name, quantity) = ingredient
val name: String = Sugar
val quantity: Int = 25
scala> println(name)
Sugar
scala> println(quantity)
25
```

Pattern matching on tuples

- A tuple can be used with pattern matching

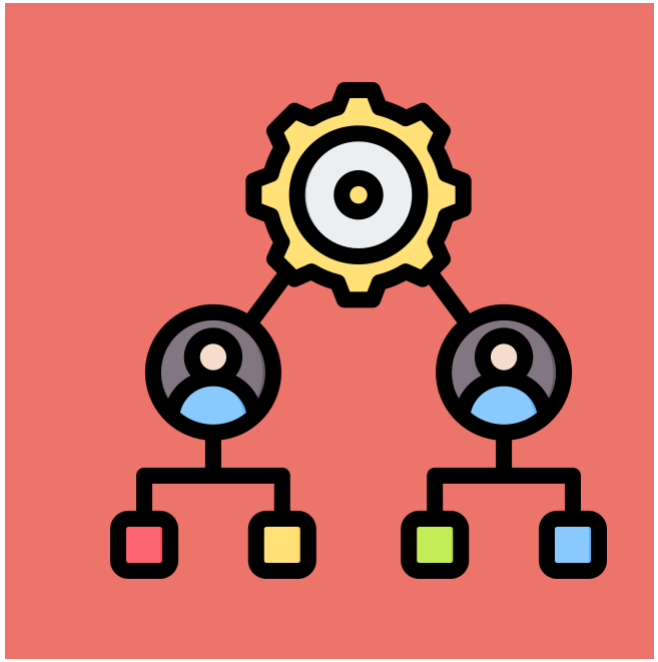
```
scala> val planets =  List(("Mercury", 57.9), ("Venus", 108.2),
("Earth", 149.6), ("Mars",  227.9), ("Jupiter", 778.3))
val planets: List[(String, Double)] = List((Mercury,57.9),
(Venus,108.2), (Earth,149.6), (Mars,227.9), (Jupiter,778.3))

scala> planets.foreach {
     |     case ("Earth", distance) => println(s"Our planet is
$distance million kilometer
s from the sun")
     |     case _ =>
     | }
Our planet is 149.6 million kilometers from the sun
```

Question 5

- What does the following code print?

```
val myList = List(1, "hello", "world")
println(myList.head)
```

```
A. "hello"
B. Error
C. 1
D. List(1, "hello")
```



Control structures

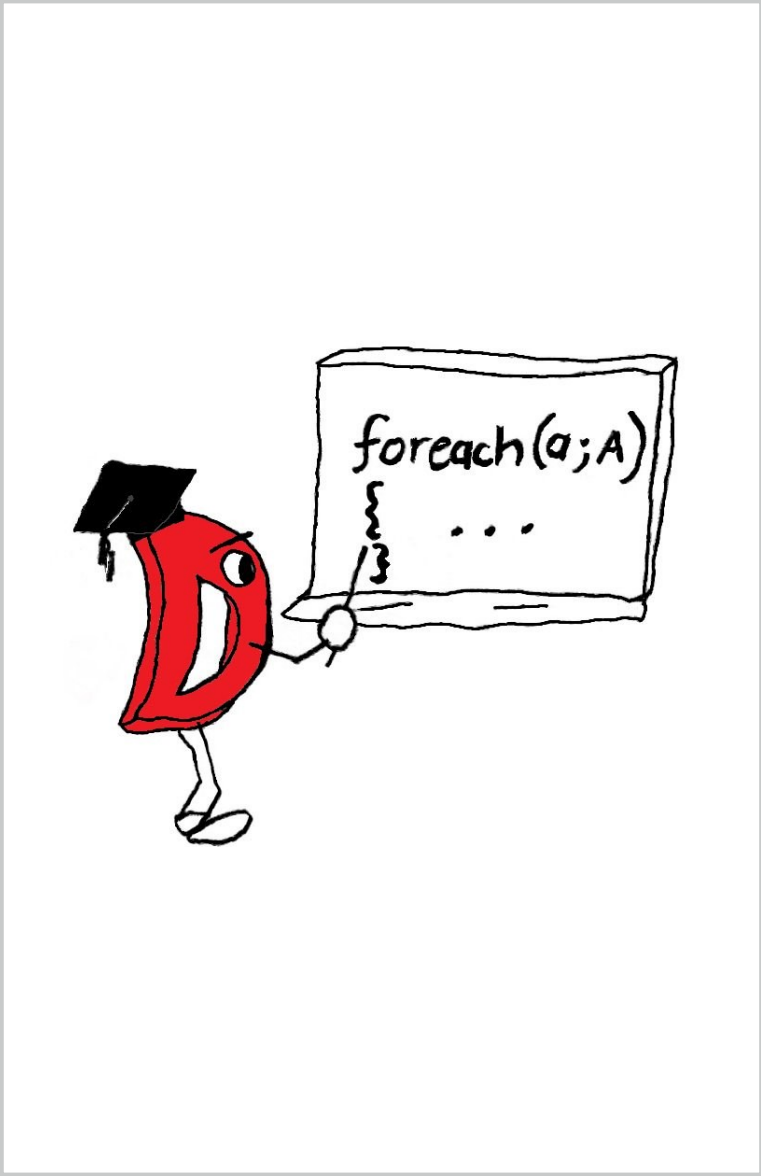
If/else

- Very similar to other languages

```
if x < 0 then
  println("negative")
else if x == 0 then
  println("zero")
else
  println("positive")
```

- As in ML this is a value and not a statement

```
val x = if a < b then a else b
```



For loops and for comprehension

For loops

- The `for` keyword is used to create a for loop – do can also be omitted

```
scala> val ints = List(1, 2, 3, 4, 5)
val ints: List[Int] = List(1, 2, 3, 4, 5)

scala> for i <- ints do println(i)
1
2
3
4
5
```

generator body of the loop

For loops: alternative syntax

- ```
  scala> for (i<-0
    until 10)
         | print(s"$i ")
  ```

- ```
  scala> for (i<-
    Range(0,20))
         | print(s"$i ")
  0 1 2 3 4 5 6 7 8 9
  ```

- ```
  scala> for (i<-0
    until 20 by 2)
         | print(s"$i ")
  ```

- ```
  scala> for (i<-
    Range(0,20,2))
         | print(s"$i ")
  0 2 4 6 8 10 12 14 16
  18
  ```

Guards

- We can use one or more `if` inside a for loop

```
scala> for
     |   i <- ints
     |   if i > 2
     | do
     |   print(s"$i ")
3 4 5
```

- We can also have multiple generators and guards

```
scala> for
     |   i <- 1 to 3
     |   j <- 'a' to 'c'
     |   if i == 2
     |   if j == 'b'
     | do
     |   println(s"i = $i, j = $j")
i = 2, j = b
```

Foreach

- Given

```
scala> val list1 = List ("s1","s2","s3")
val list1: List[String] = List(s1, s2, s3)
```

- The following 3 calls are equivalent
  - `list1.foreach((s:String)=>println(s))`
  - `list1.foreach(s => println(s))`
  - `list1.foreach(println)`

```
s1
s2
s3
```

For expressions (for comprehension)

- We can use `for` followed by `yield` (instead of `do`) to create for expressions used to calculate and yield results

```
scala>  val doubles = for i <- ints yield i * 2
val doubles: List[Int] = List(2, 4, 6, 8, 10)

scala> val names = List("chris", "ed", "maurice")
val names: List[String] = List(chris, ed, maurice)

scala> val capNames = for name <- names yield
name.capitalize
val capNames: List[String] = List(Chris, Ed, Maurice)
```

For comprehensions

```
scala> val userBase = List(
     |   User("Travis", 28),
     |   User("Kelly", 33),
     |   User("Jennifer", 44),
     |   User("Dennis", 23))
val userBase: List[User] = List(User(Travis,28), User(Kelly,33),
User(Jennifer,44), User(Dennis,23))

scala> val twentySomethings =
     |   for user <- userBase if user.age >=20 && user.age < 30
     |   yield user.name  // i.e., add this to a list
     |
val twentySomethings: List[String] = List(Travis, Dennis)

scala> twentySomethings.foreach(println)
Travis
Dennis
```

For comprehensions

```
scala> def foo(n: Int, v: Int) =
     |    for i <- 0 until n
     |        j <- 0 until n if i + j == v
     |    yield (i, j)
     |
def foo(n: Int, v: Int): IndexedSeq[(Int, Int)]

scala> foo(10, 10).foreach {
     |   (i, j) => println(s"($i, $j) ")
     | }
(1, 9)
(2, 8)
(3, 7)
(4, 6)
(5, 5)
(6, 4)
(7, 3)
(8, 2)
(9, 1)
```

Pattern matching

Pattern matching

- Like switch statement but much more powerful. It can be used in place of a series of if/else statements

```
value match
        case x
        case y
```

```
scala> val x: Int = Random.nextInt(10)
val x: Int = 7

scala> x match
     |   case 0 => "zero"
     |   case 1 => "one"
     |   case 2 => "two"
     |   case _ => "other"
     |
val res4: String = other
```

Pattern matching with types

- Differently from ML, in Scala we can have pattern matching with types

```
scala> def processElement(x: Any): String = x match {
     |  case s: String => s"It's a string: $s"
     |  case i: Int => s"It's an integer: $i"
     |  case d: Double => s"It's a decimal number: $d"
     |  case l: List[?] => s"It's a list of ${l.length} elements"
     |  case _ => "Unknown type"
     | }
def processElement(x: Any): String

scala> println(processElement("Hello"))
It's a string: Hello
scala> println(processElement(123))
It's an integer: 123
scala> println(processElement(3.14))
It's a decimal number: 3.14
scala> println(processElement(List(1, 2, 3)))
It's a list of 3 elements
scala> println(processElement(true))
Unknown type
```

Pattern matching with types

- A method that flattens a nested list

```
scala> def flatten(list: List[Any]): List[Any] =
       list match{
           case (x: List[Any])::xs =>
flatten(x)::flatten(xs)
           case x::xs => x::flatten(xs)
           case Nil => Nil
       };
def flatten(list: List[Any]): List[Any]

scala> val nested = List(1,List(2,3),4)
val nested: List[Int | List[Int]] = List(1, List(2, 3),
4)
```

Question 6

- What does the following code print?

```
val odds = List(3, 5, 7)
var result = 1
odds.foreach( (num: Int) => result *= num )
println(result)
```

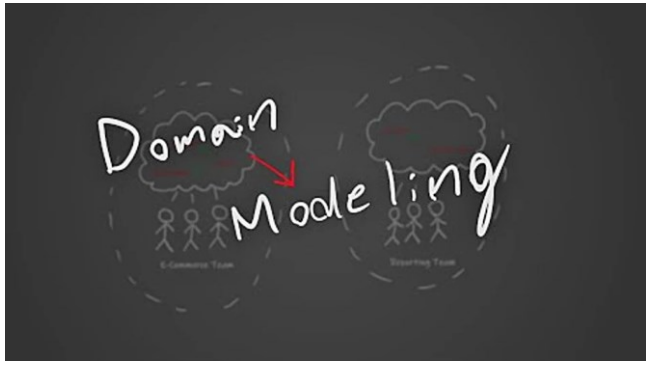
A. Error
B. 15
C. 1
D. 105

Question 7

- What does the following code print?

```
def fizzBuzz(num: Int) = (num % 3, num % 5) match {
  case (0, 0) => "FizzBuzz"
  case (0, _) => "Fizz"
  case (_, 0) => "Buzz"
  case _ => ""
}
println(fizzBuzz(3))
```

A. "Fizz“
B. "FizzBuzz"
C. Error
D. “Buzz"



OOP Domain modeling

Classes

- We can define classes with the keyword `class`

```
class className(par1: Type1, par2: Type2, ...):{
   Class definition
   }
```

In Scala 3.0 you do not need to use curly brackets

```
scala> class Greeter(prefix: String, suffix:
String):
     |   def greet(name: String): Unit =
     |     println(prefix + name + suffix)
     |
// defined class Greeter
```

Class instantiation

- An instance of the class can be done calling the constructor

```
val name = new class (arg1, arg2, ... )
```

```
scala> val greeter = Greeter("Hello, ", "!")
val greeter: Greeter = Greeter@107ebdad
scala> greeter.greet("Scala developer") //
Hello, Scala developer!
Hello, Scala developer!
```

In Scala 3.0 you do not need to use new

Case classes

Case classes

- Case classes are a special type of classes whose instances are immutable
- Differently from class instantiations that are compared by reference, they are compared by value
- We can define case classes with the keyword `case class`

```
case class name (par1: type1, par2: type2, ...)
```

```
scala> case class Point(x: Int, y: Int)
// defined case class Point
```

Case class instantiations

- Case classes can be instantiated

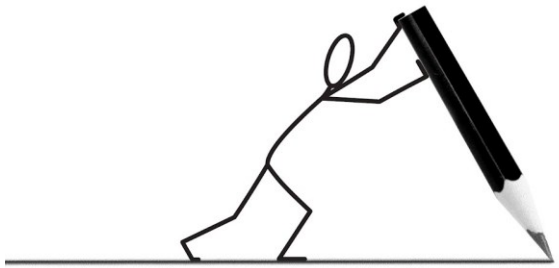
```
val name = case_class (arg1, arg2, ... )
```

```
scala> val point1 = Point(1, 2)
val point1: Point = Point(1,2)

scala> val point2 = Point(1, 2)
val point2: Point = Point(1,2)

scala> val yetAnotherPoint = Point(2, 2)
val yetAnotherPoint: Point = Point(2,2)
```

Case class instance comparisons

- Case class instances are compared by value and not by reference

```
scala> if point1 == point2 then
     |   println(s"$point1 and $point2 are the same.")
     | else
     |   println(s"$point1 and $point2 are different.")
Point(1,2) and Point(1,2) are the same.


scala> if point1 == yetAnotherPoint then
     |   println(s"$point1 and $yetAnotherPoint are the same.")
     | else
     |   println(s"$point1 and $yetAnotherPoint are different.")
Point(1,2) and Point(2,2) are different.
```



Traits

Traits

- Traits are abstract data types containing certain fields and methods. In Scala, a class can only extend one other class, but it can extend multiple traits
- We can specify a trait through the keyword `trait`

```
trait traitName:
        trait method definition

scala> trait Greeter:
     |   def greet(name: String): Unit
     |
// defined trait Greeter
```

Traits

```
scala> trait Greeter:
     |   def greet(name: String): Unit
     |
// defined trait Greeter
```

- Traits can also have default implementations

```
scala> trait Greeter:
     |   def greet(name: String): Unit =
     |     println("Hello, " + name + "!")
     |
// defined trait Greeter
```

Trait extensions

- Traits can be extended through the keyword `extends`

```
class className extends traitName
```

```
scala> class DefaultGreeter extends Greeter
// defined class DefaultGreeter
scala> class CustomizableGreeter(prefix: String, postfix: String) extends Greeter:
     |   override def greet(name: String): Unit =
     |     println(prefix + name + postfix)
// defined class CustomizableGreeter

scala> val greeter = DefaultGreeter()
val greeter: DefaultGreeter = DefaultGreeter@519e14f6
scala> greeter.greet("Scala developer")
Hello, Scala developer!

scala> val customGreeter = CustomizableGreeter("How are you, ", "?")
val customGreeter: CustomizableGreeter = CustomizableGreeter@23f9d0ce
scala> customGreeter.greet("Scala developer")
How are you, Scala developer?
```

DefaultGreeter can extend even more than one class

Traits with generic types and abstract methods

- Traits become useful with generic types and with abstract methods

```
scala> trait Iterator[A]:
     |   def hasNext: Boolean
     |   def next(): A
     |
// defined trait Iterator
```

Extending traits

- Extending `trait Iterator[A]` requires type `A` and implementations of the two methods

```
scala> class IntIterator(to: Int) extends Iterator[Int]:
     |   private var current = 0
     |   override def hasNext: Boolean = current < to
     |   override def next(): Int =
     |     if hasNext then
     |       val t = current
     |       current += 1
     |       t
     |     else
     |       0
     | end IntIterator
// defined class IntIterator

scala> val iterator = new IntIterator(10)
val iterator: IntIterator = IntIterator@343727b5
scala> iterator.next()  // returns 0
val res0: Int = 0
scala> iterator.next()  // returns 1
val res1: Int = 1
```

Summing up: Class

- As in Java
  - It can be instantiated with the keyword `new`
  - It can extend a single class or abstract class and it can implement more than one trait
- Typically used for modelling concrete objects with a proper state and behaviour with a mutable state

```
scala> class Person (val name:
String, var age: Int):
    def greet(): Unit =
          println(s"Hi, I am $name
and I am  $age years old.")
// defined class Person

scala> val p1 = new Person("Alice",
30)
val p1: Person = Person@46f32536
scala> p1.greet()
Hi, I am Alice and I am  30 years
old.
scala> p1.age = 31
```

Summing up: Abstract class

- As in Java
  - It cannot be directly instantiated. You need a concrete subclass that implement all its abstract methods
  - It can extend a single abstract class
- Typically used for representing a general base with different specific implementations

```
scala> abstract class Animal:
     |  val name: String // Abstract field
     |  def sound(): String // Abstract method
     |  def sleep(): Unit = println(s"$name is sleeping.")
     |
// defined class Animal

scala> class Dog(val name: String) extends Animal:
     |  override def sound(): String = "Woof!"
     |
// defined class Dog
scala> class Cat(val name: String) extends Animal:
     |  override def sound(): String = "Meow!"
     |
// defined class Cat

scala> val myDog = new Dog("Fido")
val myDog: Dog = Dog@7534b2a4
scala> println(myDog.sound())
Woof!
scala> myDog.sleep()
Fido is sleeping.
```

Summing up: Case class

- It can be instantiated (even without) the keyword `new`
- It can extend at most another class (or abstract class) and implement multiple traits
- It usually has concrete methods, either explicitly defined or implicitly generated
- Typically used for representing immutable data structures, leveraging pattern matching

```
scala> case class Point(x: Int, y: Int) {
     |   def move(dx: Int, dy: Int): Point = Point(x + dx, y + dy)
     | }
// defined case class Point

// Instantiation (without new)
scala> val p1 = Point(1, 2)
val p1: Point = Point(1,2)
scala> println(p1)
Point(1,2)

// Immutability and copy
scala> val p2 = p1.move(3, 4)
val p2: Point = Point(4,6)
scala> println(p2)
Point(4,6)

// Pattern matching
scala> p2 match {
     | case Point(x, y) => println(s"x: $x, y: $y") // Output: x: 4, y: 6
     | }
x: 4, y: 6

//Structural equality
scala> val p3 = Point(1, 2)
val p3: Point = Point(1,2)
scala> println(p1 == p3)
true
```

Summing up: Trait

- It cannot be directly instantiated. It has to be mixed into (implemented by) classes or other traits using the keyword `extends` (the first time) and `with` (after the first time).
- It can have both abstract and concrete methods
- It can extend other traits. It can also extend at most one class (or abstract class)
- Typically used for mixin composition. They allows for adding specific functionalities to multiple classes in an orthogonal way.

```
scala> trait Swimmer {
     |   def swim(): String = "I'm swimming!" // Concrete method (with default
implementation)
     |   def dive(): String // Abstract method
     | }
// defined trait Swimmer
scala> trait Jumper {
     |   def jump(): String = "I'm jumping!"
     | }
// defined trait Jumper
scala> class Frog extends Swimmer with Jumper {
     |   // The Frog class inherits behaviors from Swimmer and Jumper
     |   // and can implement its own specific methods
     |   override def dive(): String = "The frog dives into the pond."
     |   def croak(): String = "Croak!"
     | }
// defined class Frog

scala> val froggie = new Frog()
val froggie: Frog = Frog@5f1908c5
scala> println(froggie.swim())
I'm swimming!
scala> println(froggie.jump())
I'm jumping!
scala> println(froggie.dive())
The frog dives into the pond.
scala> println(froggie.croak())
Croak!
```

Summing up

Characteristic	Classes	Abstract Classes	Case Classes	Traits
Instantiable?	Yes	No (must be extended)	Yes (with/without new)	No (must be mixed in)
Inheritance	Single (max 1 class/abstract class)	Single (max 1 class/abstract class)	Single (max 1 class/abstract class)	Multiple (a class can extend multiple traits)
Can hold state?	Yes	Yes	Yes	Yes
Can have abstract methods?	No (unless declared abstract class)	Yes	No (typically)	Yes
Can have concrete methods?	Yes	Yes	Yes (explicitly defined or auto-generated)	Yes
Primary Use Case	Concrete entities, general OO modeling	Common base with partial implementation	Immutable data holders, pattern matching, ADTs	Mixin composition, reusable behavior, interfaces

Question 8

- What does the following code print?

```
class Kitchen(color: String, floorType: String = "tile") {
  def describe = {
    s"The kitchen has $floorType floors"
  }
}
var myKitchen = new Kitchen("purple")
println(myKitchen.describe)
```

A. The kitchen has tile floors
B. Error
C. The kitchen has purple floors
D. The kitchen has $floorType floors

Exercise 9.8

- Define a structure `Stack` representing a stack of elements of arbitrary type (that can be implemented as a list)
- Include the functions
  - `create` to create an empty stack
  - `push x s` that pushes x on top of the stack
  - `pop s` that returns the stack without the top or `EmptyStack` if the stack is empty
  - `isEmpty s` that checks whether the stack is empty
  - `top s` that returns element at the top of the stack or `EmptyStack` if the stack is empty
- Include exception `EmptyStack`

Summary

- Introduction to Scala
- The basics of the language
- Data Types
- Control structures
- OOP Domain modeling