Essentials of Scala

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Disclaimer

- This is **not** a survey of the features of Scala.
- There are many important features we will not cover.
- The goal **is** to make you sufficiently literate in Scala to understand a few key features -- features that are probably missing from your current programming language.

Runs on Java Virtual Machine (JVM)

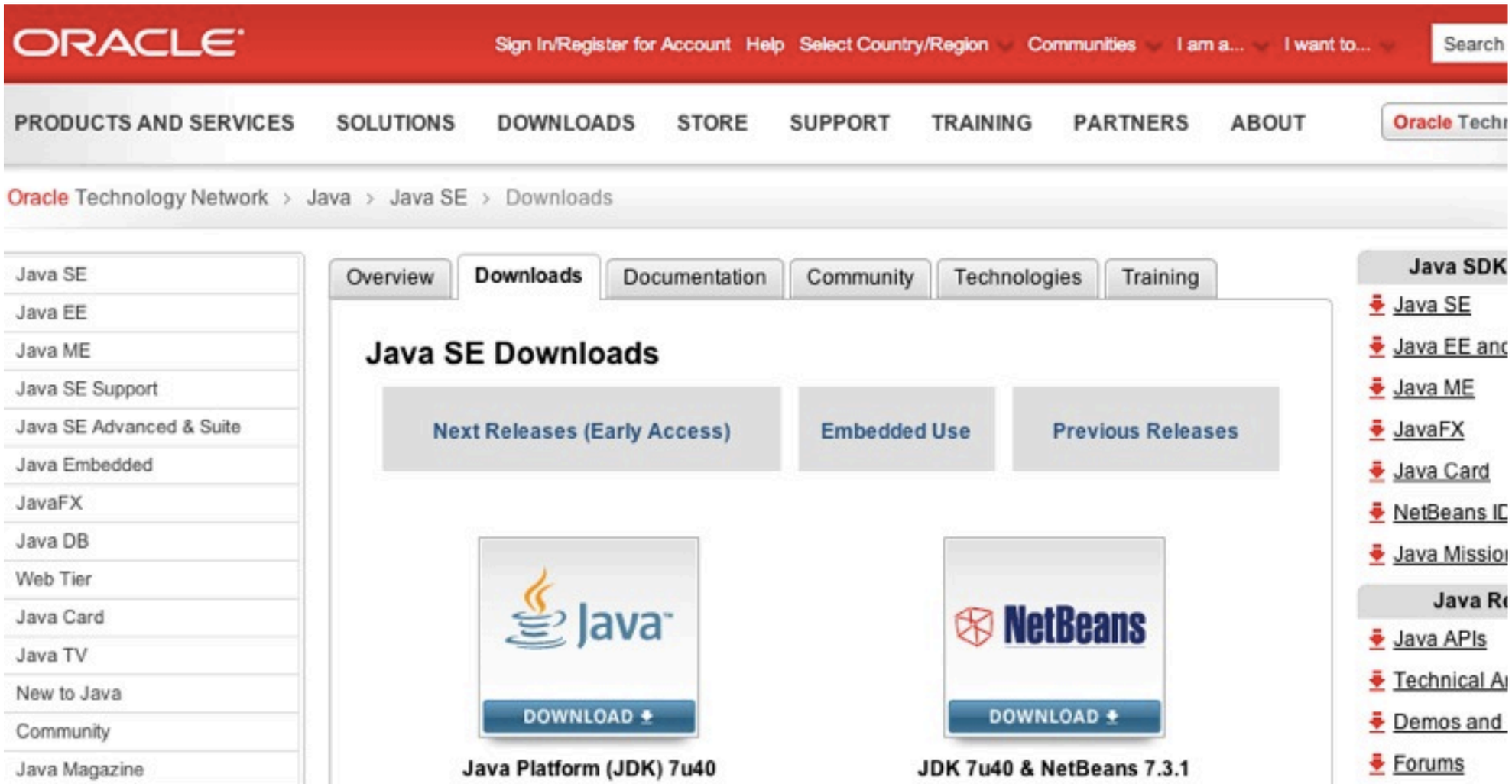
- JVM is a “virtual” processor that runs as a process on a host OS. It abstracts away hardware and OS implementation. Manages memory, threading, input/output.
- User programs are compiled to “byte code” which is executed by the virtual processor.
- “Just-in-time” (JIT) compilation -- compiled code can be optimized during execution to run almost as fast as “native” machine code.

Check if you have Java Development Kit (JDK)

```
 ~ $ java -version
java version "1.6.0_37"
Java(TM) SE Runtime Environment (build 1.6.0_37-b06-434-11M4406)
Java HotSpot(TM) 64-Bit Server VM (build 20.12-b01-434, mixed mode)
 ~ $
```

Download Java Development Kit (JDK)

- http://www.oracle.com/technetwork/java/javase/downloads/
- Or search for “jdk downloads”



Choose JDK installer for OS

Java SE Development Kit 7u40

You must accept the Oracle Binary Code License Agreement for Java SE to download this software.

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Solaris SPARC 64-bit	18.18 MB	jdk-7u40-solaris-sparcv9.tar.gz
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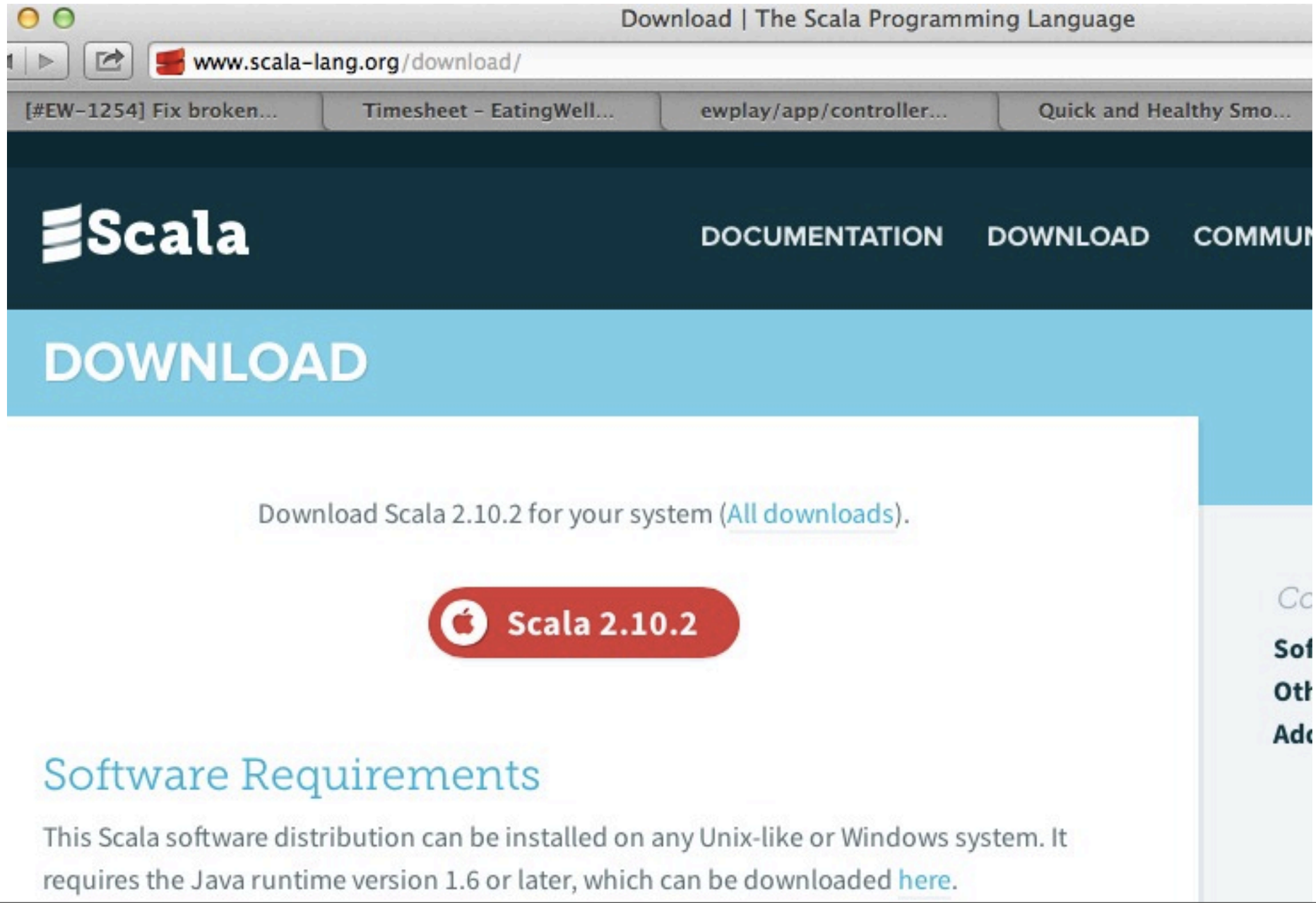
Java SE Development Kit 7u40 Demos and Samples Downloads

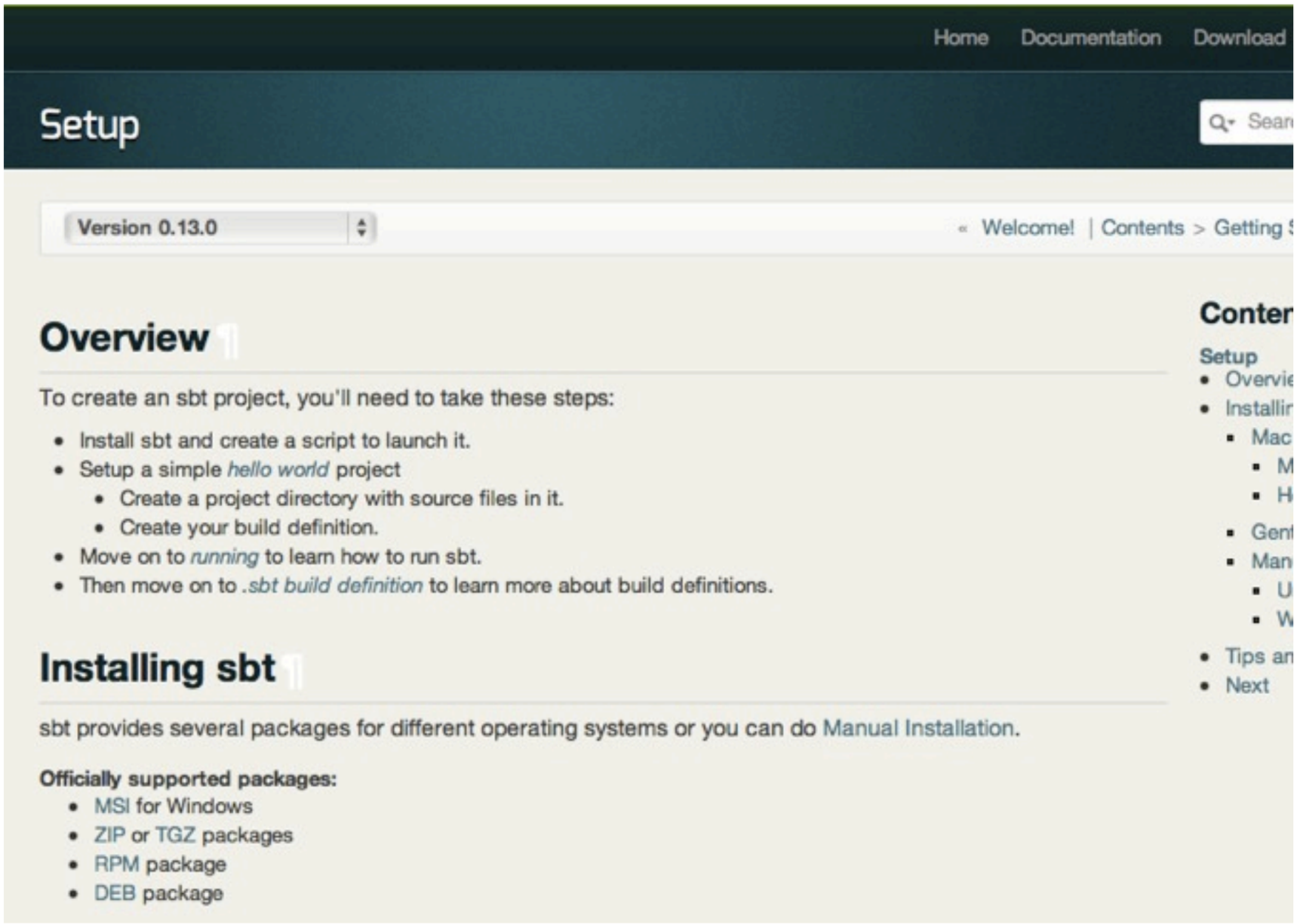
You could download Scala . . .

- http://www.scala-lang.org/download



. . . but we want the Simple Build Tool (SBT)

- http://scala-sbt.org



SBT

- MSI installer works great on Windows (sets PATH)
- ZIP/TGZ on Mac/BSD/Linux
    - Set PATH in .bashrc or .profile *to run from any folder*

```
export PATH=$HOME/Downloads/sbt/bin/:$PATH
```

- First time you run it, downloads a boatload of dependencies

SBT configuration

- Configure SBT in *build.sbt* in project folder
- Examples: by default, uses version of Scala used to build SBT itself
    - Set version of Scala explicitly:

        scalaVersion := “2.10.2”

SBT project folders

- SBT expects this directory structure.
- *We aren't going to use this until later.*

```
~/projects/sbtdemo $ mkdir -p src/{main,test}/{java,resources,scala}
~/projects/sbtdemo $ mkdir lib project target
~/projects/sbtdemo $
```

```
.
|-lib
|-project
|-src
|---main
|-----java
|-----resources
|-----scala
|---test
|-----java
|-----resources
|-----scala
|-target
```

Run SBT in project folder

- Type ‘sbt’
- SBT prompt is “>”

```
~/projects/sbtdemo $ sbt
[info] Loading global plugins from /Users/esmith/.sbt/plugins
[info] Set current project to default-38c8ae (in build file:/Users/esmith/projects/sbtdemo/)
>
```

Run Scala interpreter

- Type “console” at SBT prompt.
- “scala>” is the interpreter prompt.

```
 ~/projects/sbtdemo $ sbt
[info] Loading global plugins from /Users/esmith/.sbt/plugins
[info] Set current project to default-38c8ae (in build file:/Users/esmith/projects/sb
> console
[info] Updating {file:/Users/esmith/projects/sbtdemo/}default-38c8ae...
[info] Resolving org.scala-lang#scala-library;2.10.2 ...
[info] Done updating.
[info] Starting scala interpreter...
[info]
Welcome to Scala version 2.10.2 (Java HotSpot(TM) 64-Bit Server VM, Java 1.6.0_37).
Type in expressions to have them evaluated.
Type :help for more information.

scala>
```

Scala REPL

- Read-Eval-Print-Loop
- Value of expression you enter is assigned to an auto-generated variable:
  - Auto-created variable for value. Eg. ‘res2’
  - Type of value, separated by colon. Eg. ‘res2: Int’
  - Value of expression, separated by ‘=’, the assignment operator

```
scala> 42
res2: Int = 42

scala> 2 + 2
res3: Int = 4

scala> res2 + res3
res4: Int = 46

scala>
```

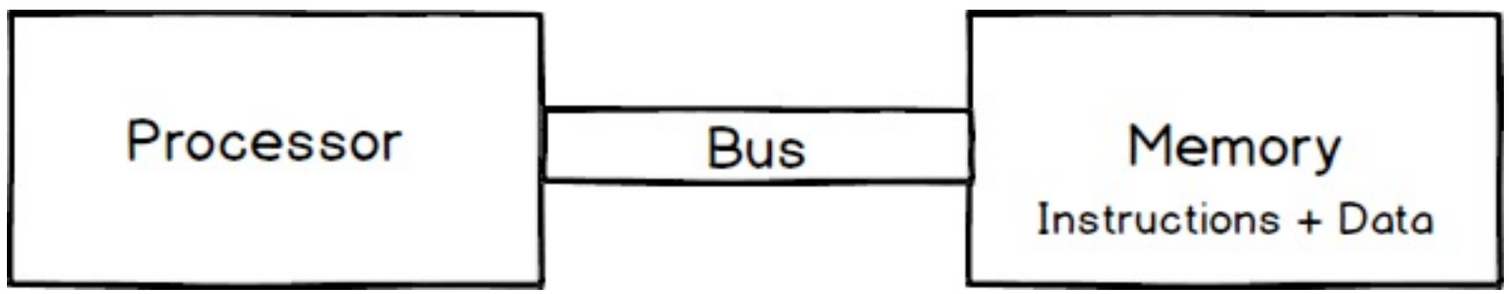
Variables

- Immutable variables with keyword “val”
- Mutable “variables” with keyword “var”

```
scala> val foo = 42
foo: Int = 42

scala> foo = 3
<console>:8: error: reassignment to val
       foo = 3
           ^

scala> var bar = 42
bar: Int = 42

scala> bar = 3
bar: Int = 3

scala> bar
res5: Int = 3

scala>
```

‘Mainstream’ programming: 1945 - 2015

- Imperative programming: thin abstraction layer over machine architecture
- “Von Neumann” computer:
  - Instructions & data stored as bits in volatile memory
  - Processor communicates with memory by fixed-width connection (“bus”)



- “Variables” in imperative programming imitate memory locations
- Assignment statements imitate fetch, store, and arithmetic
- Control structures imitate jump and test instructions
  - If/else, loop, break, return, etc.

Imperative programming - examples

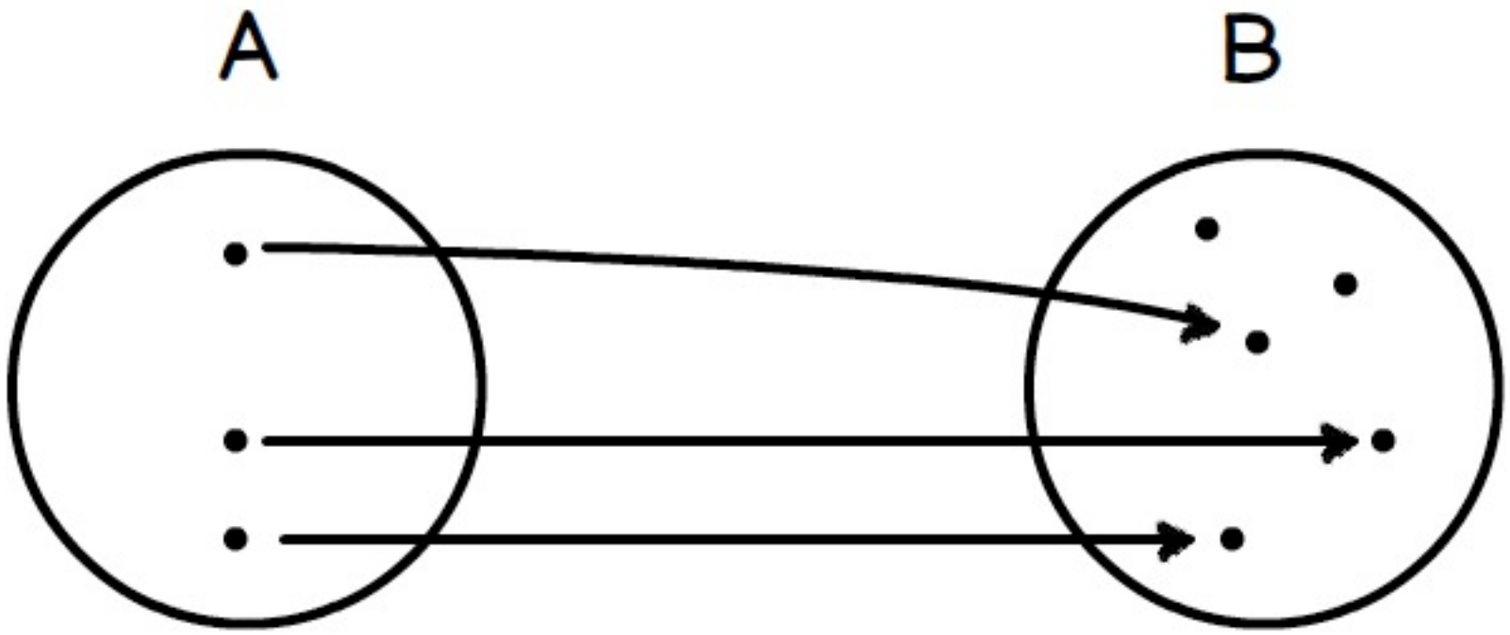
```
def is_palindrome(word):
  i = 0
  j = len(word)-1

  while i<j:
    if word[i] != word[j]:
      return False
    i = i + 1
    j = j - 1

  return True
```

```
is_palin:
        mov dl, [ebx]
        cmp [eax], dl
        jne not_palin
        inc ebx
        dec eax
        loop is_palin
        push msg1
        call puts
        add esp,4
        jmp done

not_palin:
        push msg2
        call puts
        add esp,4

done:
        ret
```

Functional programming - example

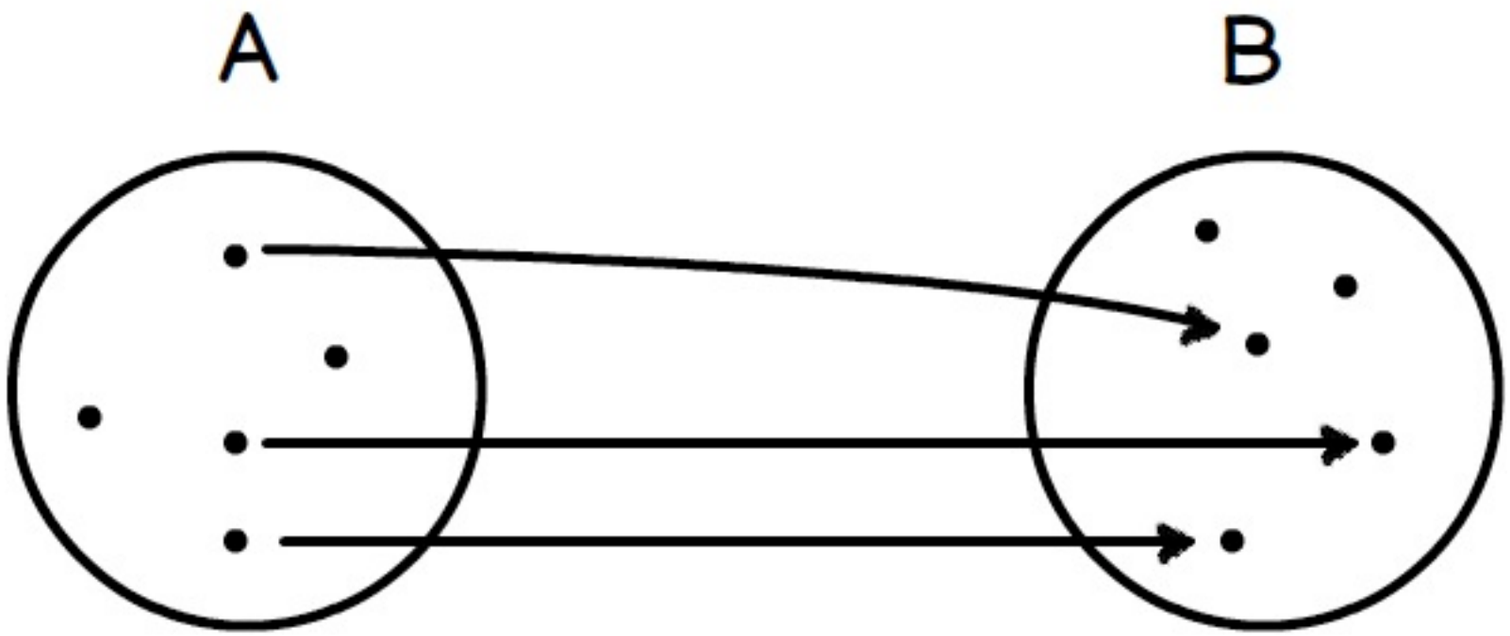
```
isPalin w = w == reverse w
```

Function

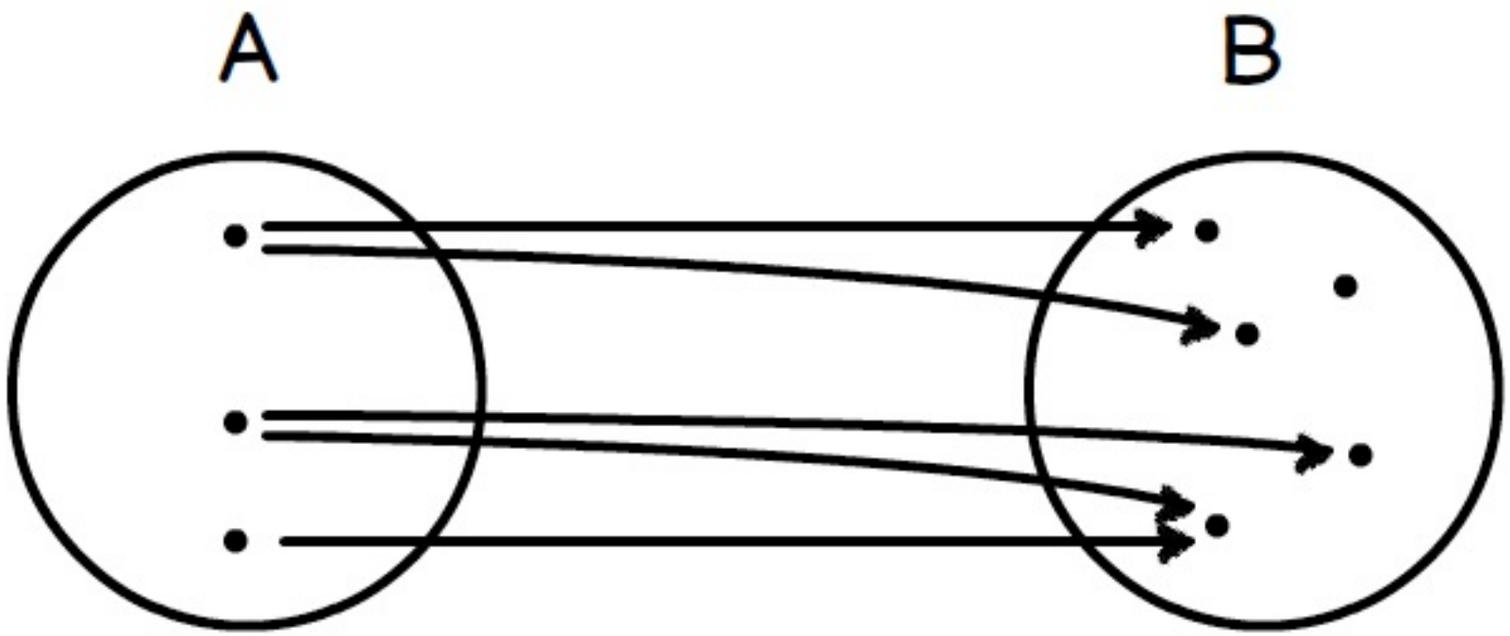


- “A function is a relation between two sets (or ‘types’) called the *domain* and *co-domain*. To each element in the domain the function assigns a unique element of the co-domain.”

Is this a function? No

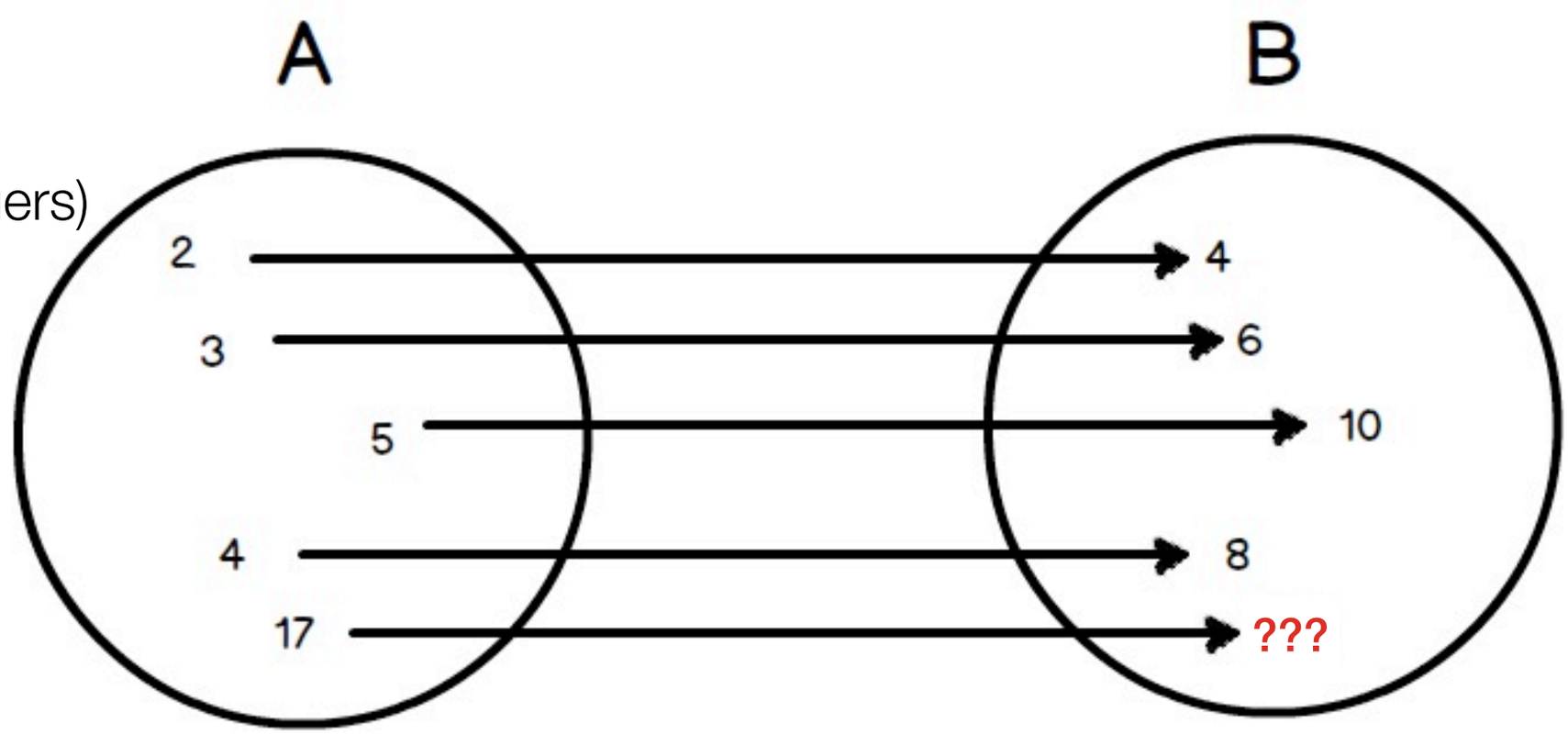


Is this a function? No



Abstraction

(All the integers)



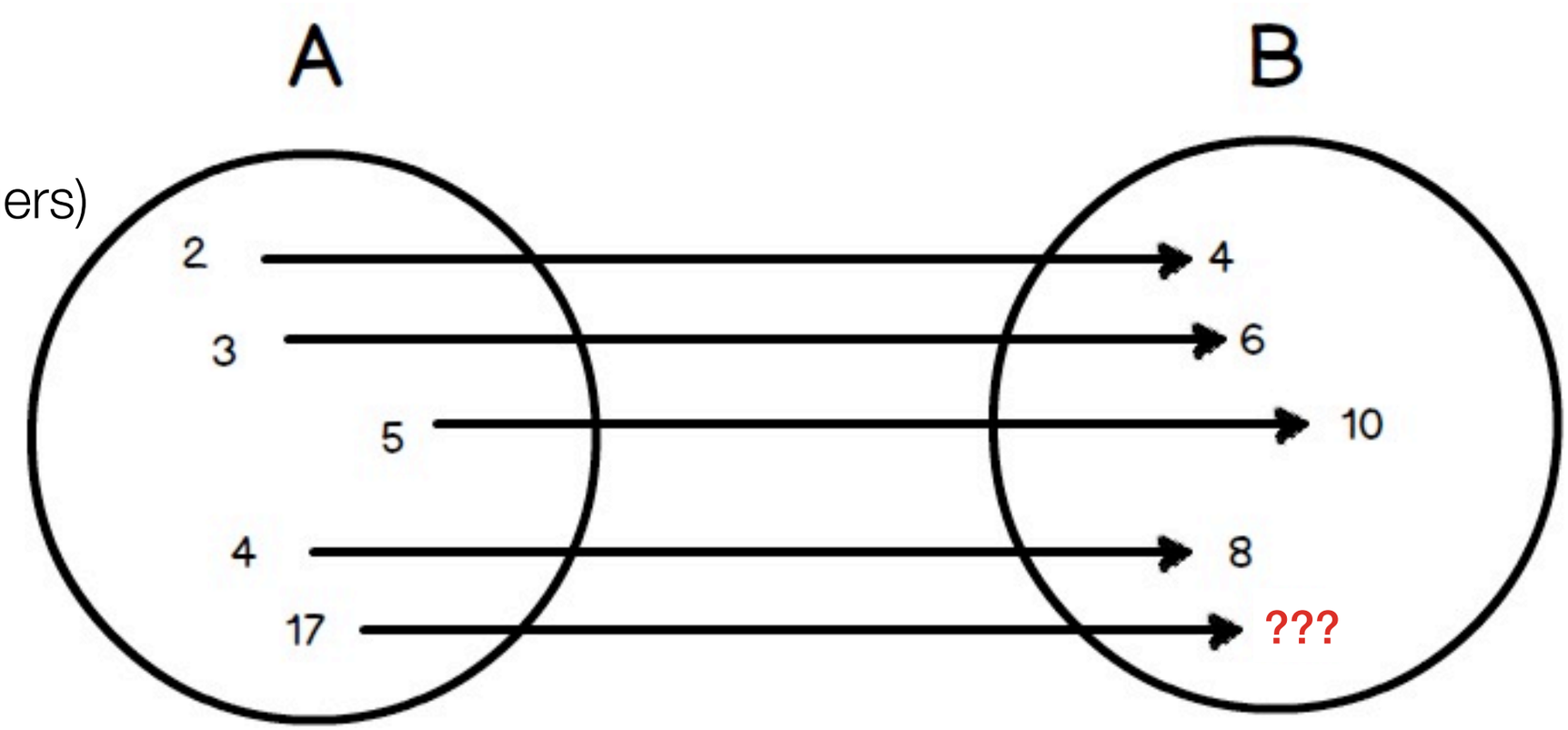
“twice”

$f(x) = x + x$

$f(x) = 2 * x$

Abstraction & Application

(All the integers)



“twice”

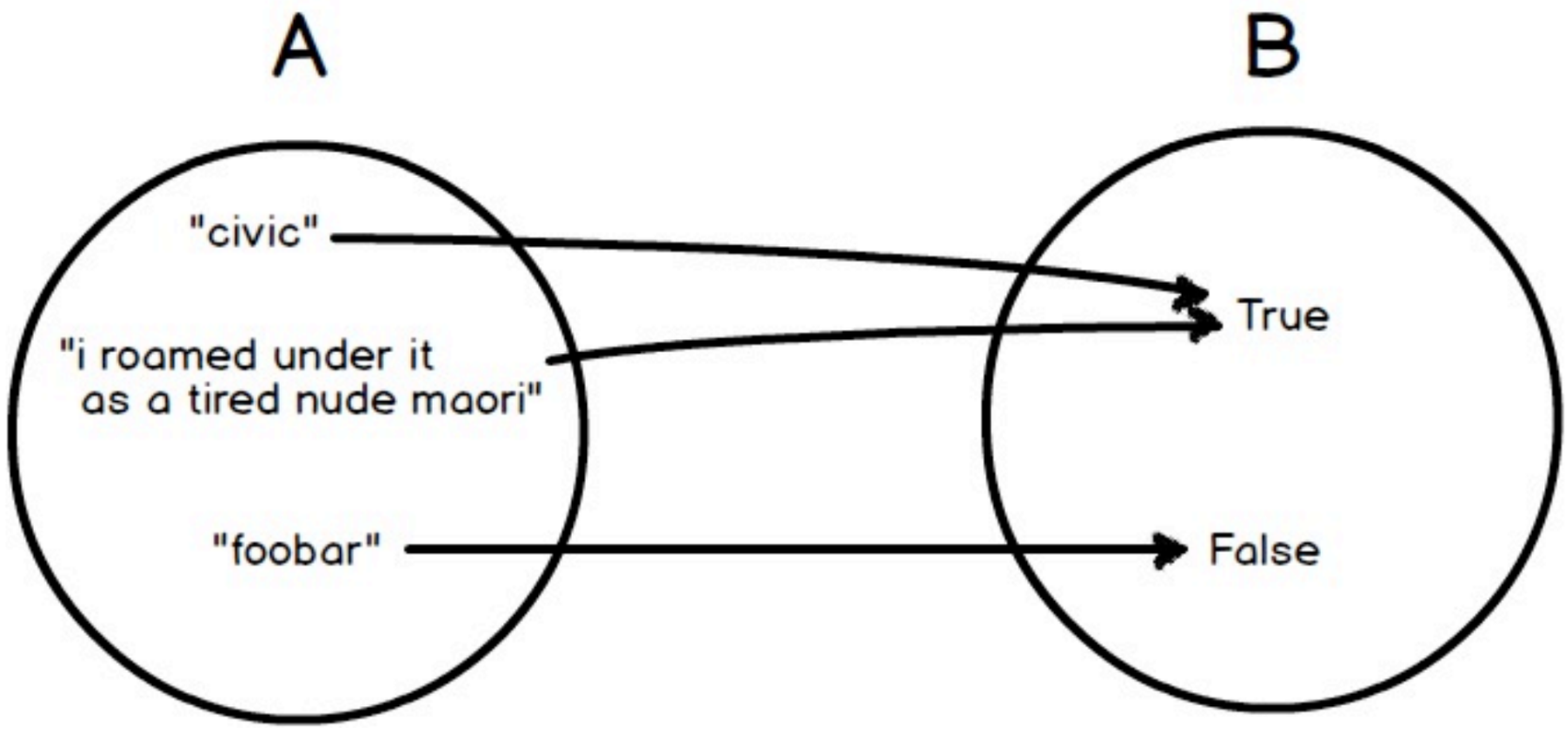
$f(x) = x + x$

$f(x) = 2 * x$

$f(17) = ???$

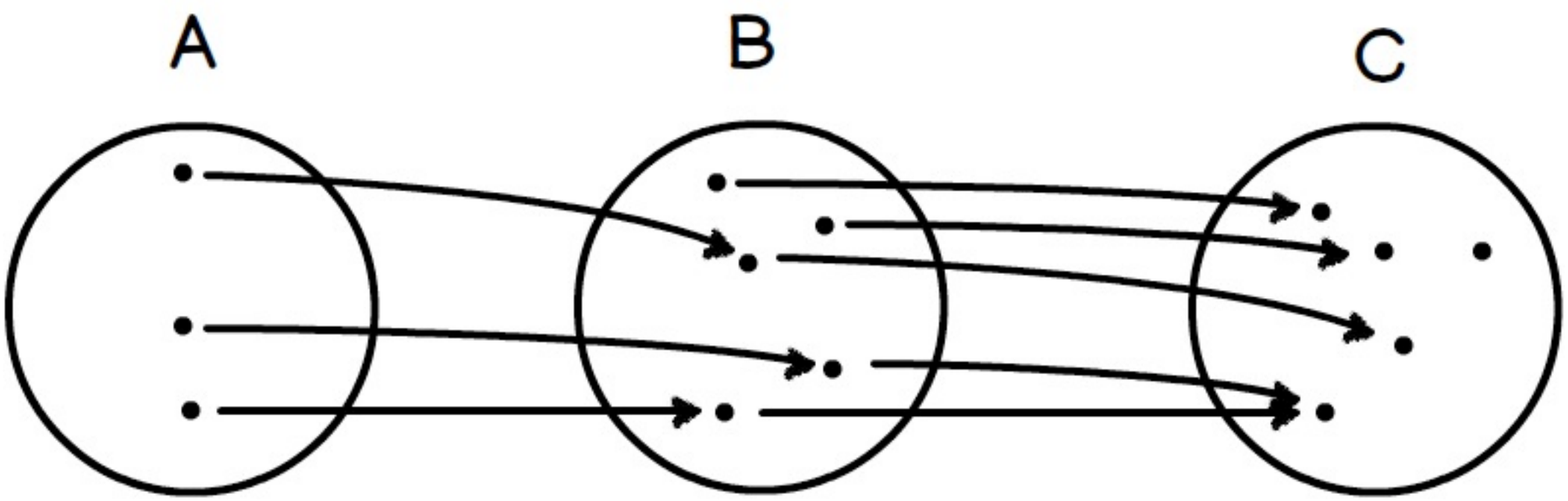
$f(17) = 34$

What is the relation?



Is the inverse of the string the same?

Why do we care?



- Does program match its specification?
- Should expect ‘mathematical’ properties in our computations.
- Variables do not change in the middle of a computation.
- Functions do not have “secondary” input or results.

Type inference

- The compiler ‘figures out’ the type based on the usage

```
scala> val myInt = 4
myInt: Int = 4

scala> val myDouble = 4.0
myDouble: Double = 4.0

scala> val myLong = 4L
myLong: Long = 4

scala> val myChar = '4'
myChar: Char = 4

scala> val myString = "4"
myString: String = 4
```

Type annotations

- May want to explicitly declare the type.
- Type annotation **follows** variable, separated with colon.

```
scala> val myNum = 4
myNum: Int = 4

scala> val myNum: Double = 4
myNum: Double = 4.0

scala> val myNum: Long = 4
myNum: Long = 4

scala> val myNum: BigDecimal = 4
myNum: BigDecimal = 4
```

Function - must specify parameter types

```
def add(a: Int, b: Int) = a + b
```

- Functions start with ‘def’ keyword.
- Parameters in parentheses, separated by commas.
- Body set off with ‘equals’.
- Last expression is returned; no ‘return’ keyword required.

- By convention, supply type of return value.
- Multi-line ‘blocks’ set off with curly braces.

```
def add(a: Int, b: Int): Int = {
  a + b
}
```

Function application

- Apply function to arguments in parentheses, separated by commas.

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

scala> add(42, 7)
res9: Int = 49
```

Multiple lines in REPL

- In REPL, multiple-line definitions are prefixed with ‘pipe’ characters.
- Can copy/paste code into REPL from editor.
- When pasting multiple definitions, use :paste in REPL.

```
scala> def add(a: Int, b: Int): Int = {
     |   a + b
     | }
add: (a: Int, b: Int)Int

scala>
```

Recursion

- Used for repeated computation.
- Functions calls ‘itself’ recursively toward a ‘base case’.
- Based on ‘inductive proof’.
- If/else is an expression and returns a value.

```
def sumSquare(a: Int, b: Int): Int = {
  if (a > b) {
    0
  } else {
    sumSquare(a+1, b) + (a * a)
  }
}
```

```
scala> sumSquare(1, 3)
res28: Int = 14
```

Recursion - step through

sumSquare(1, 3)

= sumSquare(1+1,3) + (1*1)

= ((sumSquare(2+1,3) + (2*2)) + (1*1)

= (((sumSquare(3+1,3) + (3*3)) + (2*2)) + (1*1)

= (((0 + (3*3)) + (2*2)) + (1*1)

= ((0 + 9) + (2*2)) + (1*1)

= ((0 + 9) + 4) + (1*1)

= ((0 + 9) + 4) + 1

= (9 + 4) + 1

```
def sumSquare(a: Int, b: Int): Int = {
  if (a > b) {
    0
  } else {
    sumSquare(a+1, b) + (a * a)
  }
}
```

Recursion

- Sum of consecutive squares

```
def sumSquare(a: Int, b: Int): Int = {
  if (a > b) {
    0
  } else {
    sumSquare(a+1, b) + (a * a)
  }
}
```

- Sum of consecutive cubes

```
def sumCube(a: Int, b: Int): Int = {
  if (a > b) {
    0
  } else {
    sumCube(a+1, b) + (a * a * a)
  }
}
```

Higher-order functions

- Functions that take other functions as arguments.
- Function type from input to output given with ‘=>’

```
def sumPower(fn: Int => Int, a: Int, b: Int): Int = {
  if (a > b) {
    0
  } else {
    sumPower(fn, a+1, b) + fn(a)
  }
}
```

Higher-order functions

- Pass ‘square’ and ‘cube’ functions as arguments

```
scala> def square(n: Int): Int = n * n
square: (n: Int)Int

scala> def cube(n: Int): Int = n * n * n
cube: (n: Int)Int

scala> sumPower(square, 1, 3)
res12: Int = 14

scala> sumPower(cube, 1, 3)
res13: Int = 36
```

Anonymous functions

- Don’t have to assign name to functions.
- Also known as ‘functional literal’ or ‘lambda’.
- Parameters set off from function body with ‘=>’

```
scala> sumPower(x => x * x, 1, 3)
res14: Int = 14

scala> sumPower(x => x * x * x, 1, 3)
res15: Int = 36
```

Curried function

- Turn a function that takes two arguments into a function that takes one argument and returns a function that takes the other argument.

```
scala> def add(x: Int, y: Int) = x + y
add: (x: Int, y: Int)Int

scala> add(1, 2)
res42: Int = 3

scala> def curriedAdd(x: Int) = (y: Int) => x + y
curriedAdd: (x: Int)Int => Int

scala> curriedAdd(1)(2)
res43: Int = 3

scala> def curriedAddShort(x: Int)(y: Int) = x + y
curriedAddShort: (x: Int)(y: Int)Int

scala> curriedAddShort(1)(2)
res44: Int = 3
```

Scala is a “pure” object-oriented language

- All values are objects.
- Objects are values that combine both data **and** operations on data.

Class

- A “class” is a template for the creation of objects.
- The definition of a class creates a type, and at the same time, defines what it means to construct values of that type.
- To define a class, use keyword “class”.
- Create an object from a class with keyword “new”. Can assign to a variable.
- Variable’s value is of type ‘Elephant’ and is a reference to created object.

```
scala> class Elephant
defined class Elephant

scala> val elmer = new Elephant
elmer: Elephant = Elephant@1ae0f136
```

Fields

- Classes can contain variables. Called “fields”.
- Access field in object using ‘dot’ and the name of the field.

```
class Sloth {
  val numToes = 3
}
```

```
scala> val sam = new Sloth
sam: Sloth = Sloth@2369f54d

scala> sam.numToes
res16: Int = 3
```

Methods

- Classes can contain “methods”. Methods are *practically* the same as functions.
- Access method in object with “dot” and the name of the method.

```
class Dog {
  def speak(): String = "Woof!"
}
```

```
scala> val fido = new Dog
fido: Dog = Dog@2747b1c8

scala> fido.speak
res17: String = Woof!
```

Uniform Access Principle

- The notation to access a feature of a class should not depend on whether it's implemented through storage (field) or computation (method).

```
class Dog {
  def speak(): String = "Woof!"
}
```

```
class Cat {
  def speak = "Meow!"
}
```

```
class Mouse {
  val speak = "Squeak!"
}
```

```
scala> val fido = new Dog
fido: Dog = Dog@277663d6

scala> fido.speak
res0: String = Woof!

scala> val kitty = new Cat
kitty: Cat = Cat@67439515

scala> kitty.speak
res1: String = Meow!

scala> val mickey = new Mouse
mickey: Mouse = Mouse@3ba102ef

scala> mickey.speak
res2: String = Squeak!
```

Primary constructor

- Class definitions can have parameters.
- If prefixed with “val” or “var”, get automatic field.

```
scala> class Employee(val name: String, var salary: Int)
defined class Employee

scala> val emp1 = new Employee("Joe", 42000)
emp1: Employee = Employee@4424f1a9

scala> emp1.name
res3: String = Joe

scala> emp1.salary
res4: Int = 42000

scala> emp1.salary = 84000
emp1.salary: Int = 84000

scala> emp1.salary
res5: Int = 84000
```

Class inheritance

- A class can “inherit” the fields and methods of another class using the keyword “extends”.
- Primary constructor parameters can be passed to the superclass.
- The subclass type is a “subtype” of the superclass type: Its type can be used where the type of the superclass is expected.

```
scala> class Person(val name: String)
defined class Person

scala> class Employee(name: String, var salary: Int) extends Person(name)
defined class Employee

scala> val emp1 = new Employee("Joe", 42000)
emp1: Employee = Employee@39d12be

scala> def sayName(p: Person): String = p.name
sayName: (p: Person)String

scala> sayName(emp1)
res7: String = Joe
```

Abstract class

- If subclasses will have their own unique implementation of methods, make the superclass “abstract” and declare the method type signature without a body.
- Implement the methods in the subclasses.
- The abstract class cannot be instantiated into an object.

```
abstract class Animal {
  def speak: String
}

class Dog extends Animal {
  def speak = "Woof"
}

class Cat extends Animal {
  def speak = "Meow"
}
```

```
scala> val fido = new Dog
fido: Dog = Dog@6faa3306

scala> def saySomething(a: Animal): String = {
     |   a.speak
     | }
saySomething: (a: Animal)String

scala> saySomething(fido)
res9: String = Woof
```

Trait

- Traits are more common than abstract classes.
- Traits cannot have constructor parameters.

```
trait Animal {
  def speak: String
}

class Dog extends Animal {
  def speak = "Woof"
}

class Cat extends Animal {
  def speak = "Meow"
}
```

```
scala> val kitty = new Cat
kitty: Cat = Cat@66be9fc1

scala> def saySomething(a: Animal): String = {
     |   a.speak
     | }
saySomething: (a: Animal)String

scala> saySomething(kitty)
res2: String = Meow
```

Mixin

- Inherit from traits using “with”.

```
trait Vehicle {
  def maxSpeed: String
}

trait Motorcycle extends Vehicle {
  val wheels = 2
}

trait GasVehicle {
  def noise() = "Vrooom"
}
```

```
scala> class SportsBike extends Motorcycle with GasVehicle {
     |   def maxSpeed = "150mph"
     | }
defined class SportsBike

scala> val ninja = new SportsBike
ninja: SportsBike = SportsBike@6d8f5c10

scala> ninja.noise
res2: String = Vrooom

scala> ninja.wheels
res3: Int = 2

scala> ninja.maxSpeed
res4: String = 150mph
```

Mixin during instantiation

- Can also mixin while creating an object.

```
trait Vehicle {
  def maxSpeed: String
}

trait Motorcycle extends Vehicle {
  val wheels = 2
}

trait GasVehicle {
  def noise() = "Vrooom"
}

trait ElectricVehicle {
  def noise() = "Whirrrr"
}
```

```
scala> class Scooter extends Motorcyle {
     |   def maxSpeed = "65mph"
     | }
defined class Scooter

scala> val vespa = new Scooter with ElectricVehicle
vespa: Scooter with ElectricVehicle = $anon$1@6fb05c54

scala> vespa.maxSpeed
res6: String = 65mph

scala> vespa.noise
res7: String = Whirrrr
```

Singleton object

- Declares a class and its only instance. Use keyword “object” instead of “class”.
- Often used as placeholder for functionality (including entry point of programs)

```
object Demo {

  def main(args: Array[String]) = {
    println(sayGreeting)
  }

  def sayGreeting = "Guten Tag"

}
```

```
scala> Demo.sayGreeting
res0: String = Guten Tag
```

```
> ~run
[info] Running Demo
Guten Tag
[success] Total time: 0 s, completed Sep 19, 2013 9:38:16 AM
1. Waiting for source changes... (press enter to interrupt)
```

Case class

- Prefix class (or object) definition with “case”.
- Constructor parameter automatically becomes a “val” (i.e, you get an immutable field).
- Don’t need “new” to create objects.
- Used in pattern matching.

```
scala> case class Person(fname: String, lname: String)
defined class Person

scala> val joe = Person("Joe", "Smith")
joe: Person = Person(Joe,Smith)
```

Pattern matching

- A pattern is a syntactic expression that exposes the structural properties of a value.
- Patterns can be compared against values.
- Patterns can be used to decompose complex values and bind the component values to variables.

Types of patterns

- Literal pattern-- 0, “hello”, Nil, True
- Variable pattern -- x, _
- Type pattern -- x: Int (include a variable)
- Tuple pattern -- (42, x), (42, _)
- Other extractor patterns -- Array(x, y), Array(42, _*), head :: tail

```
scala> val (x,y) = (1, 2)
x: Int = 1
y: Int = 2

scala> val Array(first, second, _*) = Array(1,2,3,4,5)
first: Int = 1
second: Int = 2
```

Pattern matching - *match* expression

- Used to select a branch of code based on pattern match.
- Keyword ‘match’ for pattern matching expression.
- A sequence of alternative patterns to compare against a value. Each begins with ‘case’. Followed by ‘=>’ and the block of code to execute.

```
scala> val foo = (42, 0)
foo: (Int, Int) = (42,0)

scala> foo match {
     |   case (0, _) => "Zero first"
     |   case (y, 0) => y + " then zero"
     |   case _ => "No zero"
     | }
res29: String = 42 then zero
```

Pattern matching - function dispatch

- Patterns are compared against function arguments to decide among possible results of the same type.

```
def take(m: Int, ys: List[Any]): List[Any] = {
  (m, ys) match {
    case (0, _) => Nil
    case (_, Nil) => Nil
    case (n, head :: tail) => n :: take(n-1, tail)
  }
}
```

```
scala> take(2, List(1,2,3,4))
res20: List[Any] = List(1, 2)

scala> take(3, List('a','b','c'))
res21: List[Any] = List(a, b, c)
```

Pattern matching - case classes

- Case classes automatically get a hidden method (called “unapply”) that extracts the values from an object that were used to construct it.

```
scala> case class Droid(name: String, model: String)
defined class Droid

scala> val r2d2 = Droid("R2-D2", "Astromech")
r2d2: Droid = Droid(R2-D2,Astromech)

scala> val c3p0 = Droid("C-3P0", "Protocol")
c3p0: Droid = Droid(C-3P0,Protocol)

scala> r2d2 match {
     |   case Droid("C-3P0", m) => "Gotcha, you " + m + "droid"
     |   case Droid("R2-D2", m) => "Come with us " + m + " droid"
     |   case _ => "Not the droids we are looking for"
     | }
res23: String = Come with us Astromech droid
```

Parametric polymorphism (generics)

- Classes, traits, methods, functions can have type parameters.
- Type parameters go after the name, enclosed in square brackets.
- Type parameters are used in definitions to specify the types of parameters and return values.

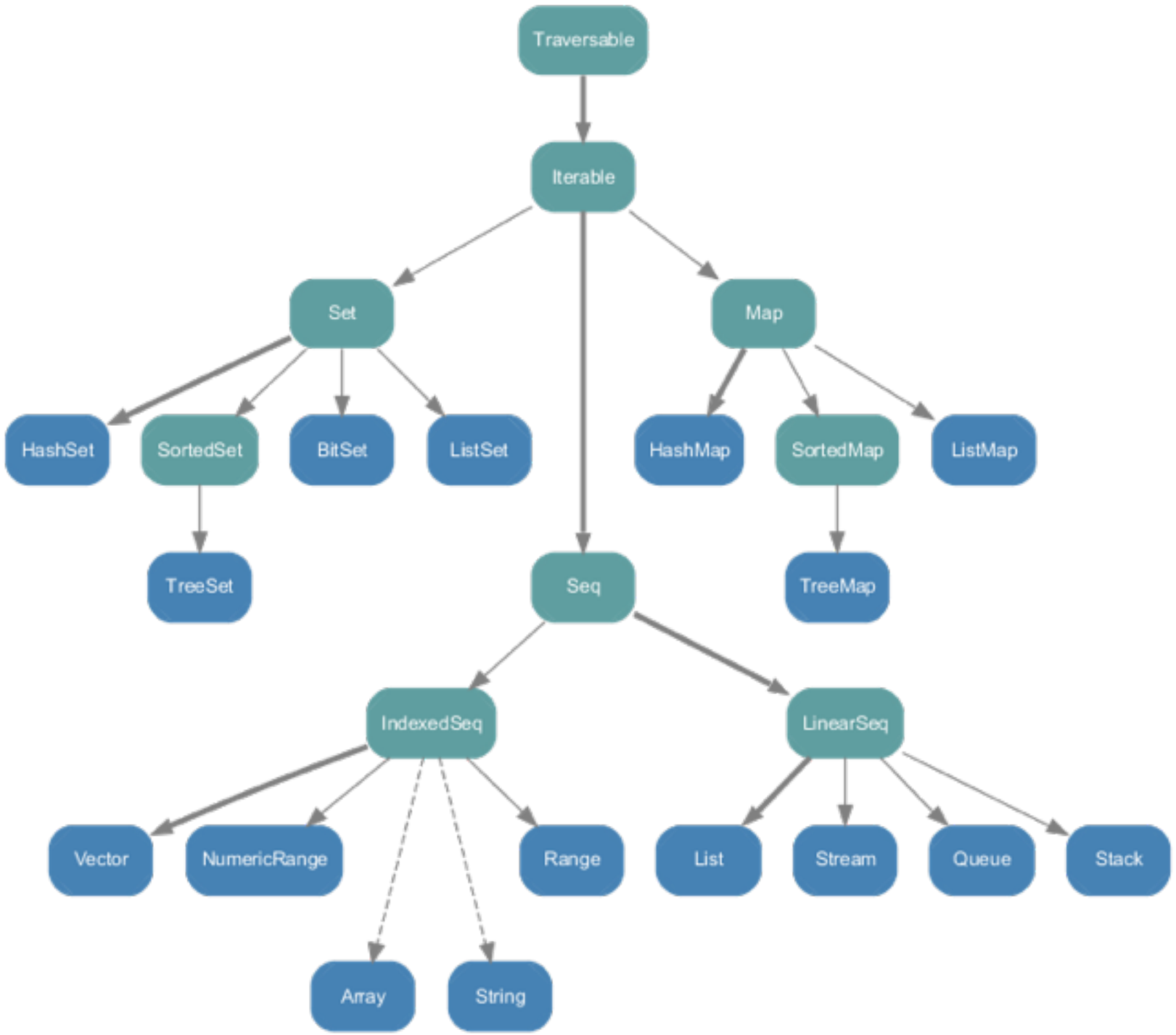
```
scala> case class Pair[T, S] (fst: T, snd: S)
defined class Pair

scala> val p = Pair('b', 42)
p: Pair[Char,Int] = Pair(b,42)

scala> p.fst
res26: Char = b

scala> p.snd
res27: Int = 42
```

Covariance annotation

- Used to make subtype relationship explicit in parametric polymorphism.
- Can Pair[Student] be used where Pair[Person] is expected when Student is a subclass of Person?
- Annotate type parameters with “+” to mean “covariant in T”.

```
scala> class Person(val name: String)
defined class Person

scala> case class Student(fullName: String) extends Person(fullName)
defined class Student

scala> case class Pair[+T](fst: T, snd: T)
defined class Pair

scala> def makeFriends(p: Pair[Person]) = p.fst.name + " likes " + p.snd.name
makeFriends: (p: Pair[Person])String

scala> val bff = Pair[Student](Student("Kathy"), Student("Jane"))
bff: Pair[Student] = Pair(Student(Kathy),Student(Jane))

scala> makeFriends(bff)
res0: String = Kathy likes Jane
```

Collections (immutable) hierarchy



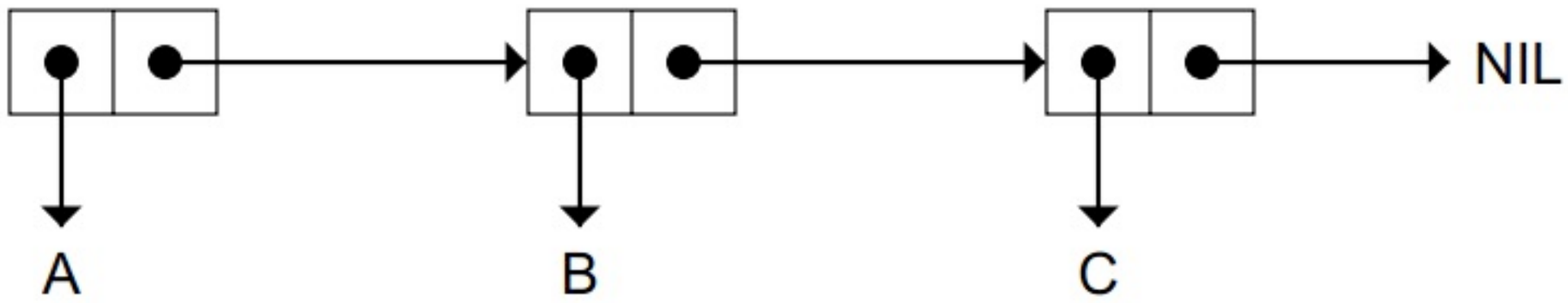
Combinators - examples

- *Combinator* is used informally to refer to (often higher-order) functions that create, manipulate, and combine values, and themselves are combined to produced more complex behavior.

```
scala> List(1,2,3).map(x => x * x).sum
res33: Int = 14

scala> List(1,2,3).map(x => x * x).reduce((x,y) => x + y)
res34: Int = 14

scala> List(1,2,3).map(x => x * x).reduce(_ + _)
res35: Int = 14

scala> List(1,2,3).map(x => x * x).foldLeft(0)(_ + _)
res36: Int = 14

scala> List(1,2,3).map(x => x * x).foldRight(0)(_ + _)
res37: Int = 14

scala> (1 to 3).map(x => x * x).sum
res38: Int = 14
```

Cons - making a singly linked list, functionally

- *Cons* is a two-argument function that constructs a list. The second argument is a list or Nil (ie, the empty list).
- The values in a list must be of the same type.



Cons(A, Cons(B, Cons(C, Nil)))

Combinator library example

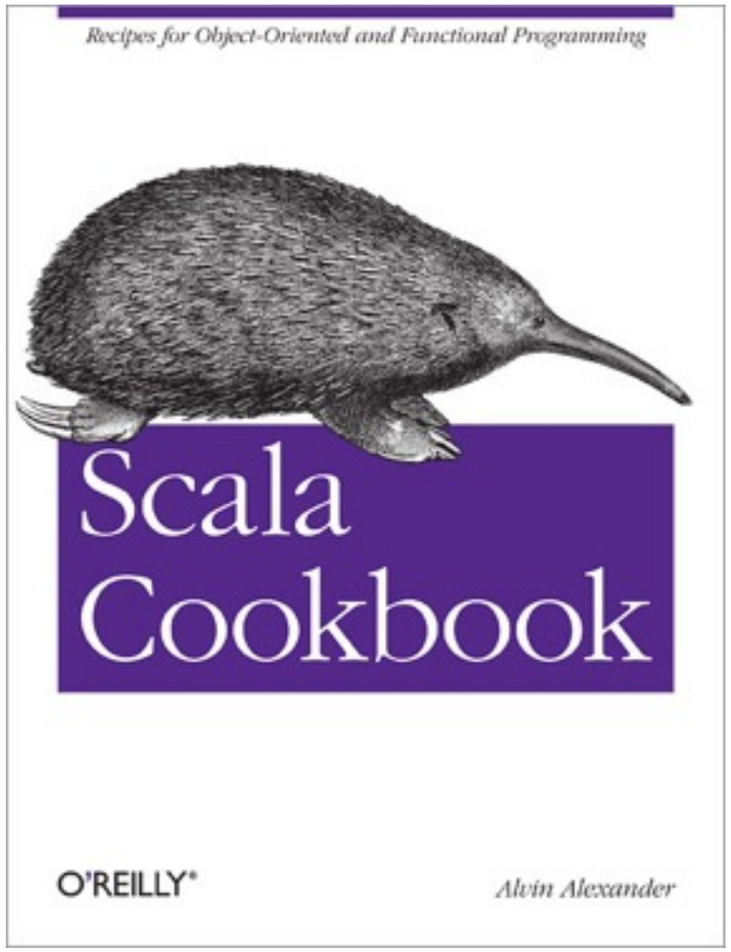
```
trait ZList[+T]
case object Empty extends ZList[Nothing]
case class Cons[+T](first: T, rest: ZList[T]) extends ZList[T]

object ZList {

  def zmap[T,S](fn: T => S, lst: ZList[T]): ZList[S] = {
    (fn, lst) match {
      case (fn, Empty) => Empty
      case (fn, Cons(x,xs)) => Cons(fn(x), zmap(fn, xs))
    }
  }

  def zfoldRight[T,S](lst: ZList[T], z: S)(fn: (T, S) => S): S = {
    lst match {
      case Empty => z
      case Cons(x, xs) => fn(x, zfoldRight(xs, z)(fn))
    }
  }

  def apply[T](xs: T*): ZList[T] = {
    if (xs.isEmpty)
      Empty
    else
      Cons(xs.head, apply(xs.tail: _*))
  }
}
```

Combinator library - usage

```
scala> import ZList._
import ZList._

scala> val foo = ZList(1,2,3)
foo: ZList[Int] = Cons(1,Cons(2,Cons(3,Empty)))

scala> val bar = zmap((x: Int) => x * x, foo)
bar: ZList[Int] = Cons(1,Cons(4,Cons(9,Empty)))

scala> zfoldRight(bar, 0)((x,y) => x+y)
res1: Int = 14
```

“Transition” books

- Most accessible when coming from an ‘old-school’ (i.e., imperative) language.



http://typesafe.com/resources/free-books

Thank you!