FOUNDATION

Function

Functional Programming

First class function

```scala
def inc(x: Int): Int = x + 1
```

```
scala> inc(10)
res0: Int = 11
```

```scala
val inc: Int => Int = (x: Int) => x + 1
```

```
scala> inc(10)
res1: Int = 11
```

First class function

```scala
val inc   : Int => Int = (x: Int) => x + 1
val dec   : Int => Int = (x: Int) => x - 1
val double: Int => Int = (x: Int) => x * 2


val list = List(inc, dec, double)

val map = Map(
  "foo"  -> inc,
  "bar"  -> dec,
  "fizz" -> double,
)
```

First class function: higher order

```
def map(xs: List[Int])(f: Int => Int): List[Int] = ???
```

First class function: higher order

```scala
def map(xs: List[Int])(f: Int => Int): List[Int] = ???
```

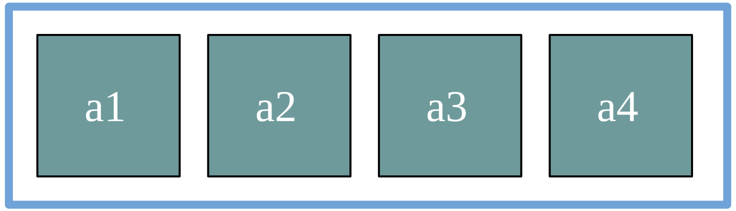
```scala
scala> List(1,2,3).map(inc)
res2: List[Int] = List(2, 3, 4)
```

```scala
scala> List("hello", "world", "!").takeWhile(_.length > 2)
res3: List[String] = List(hello, world)
```

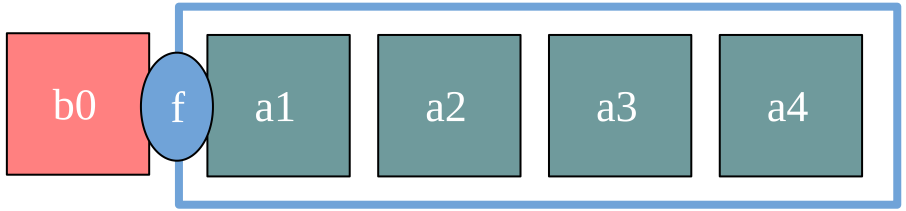
Exercises 1, 2 and 3a-c

`exercises.function.FunctionExercises.scala`

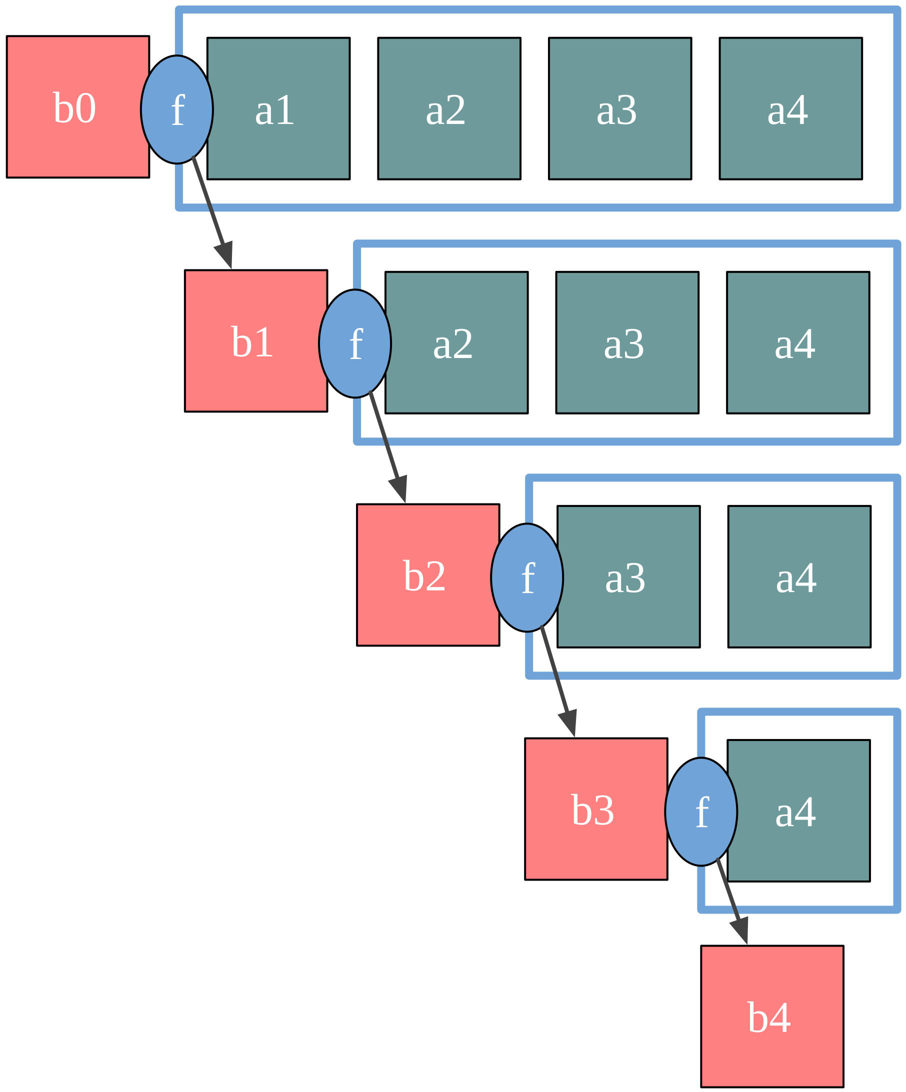
Folding



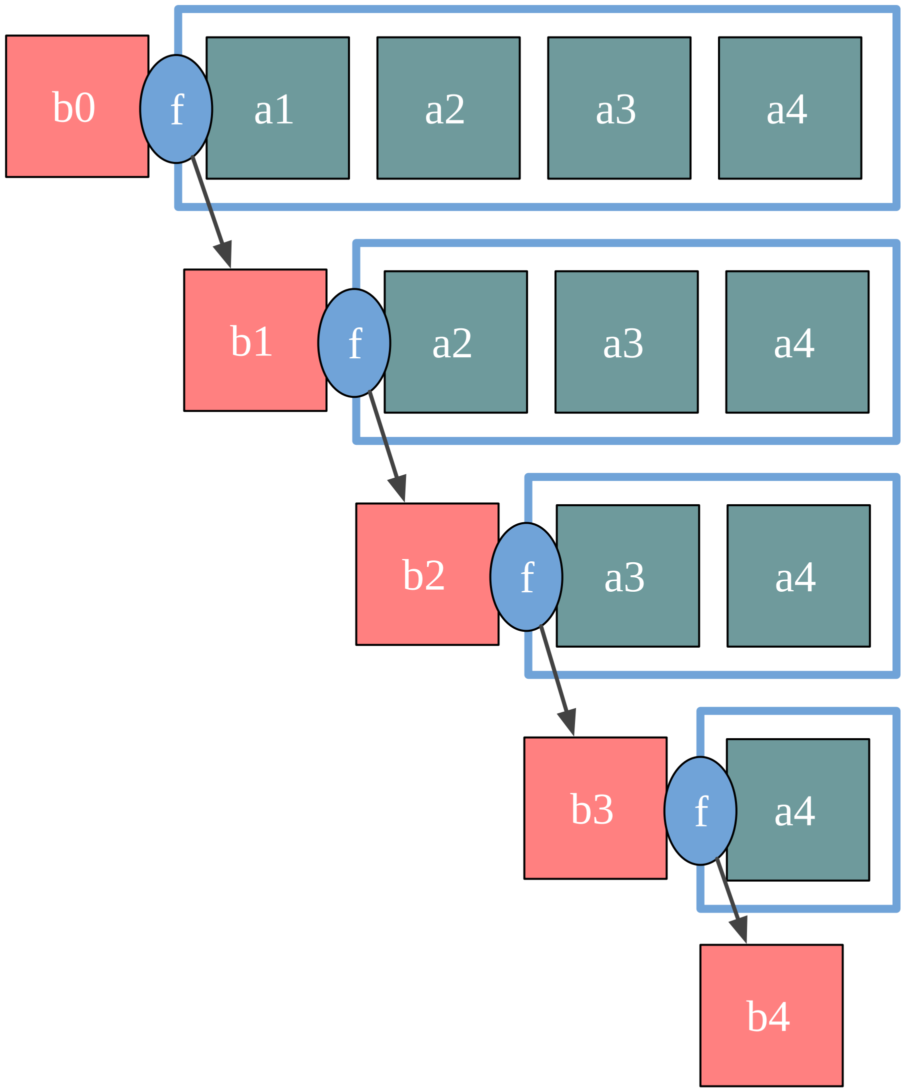
Fold Left



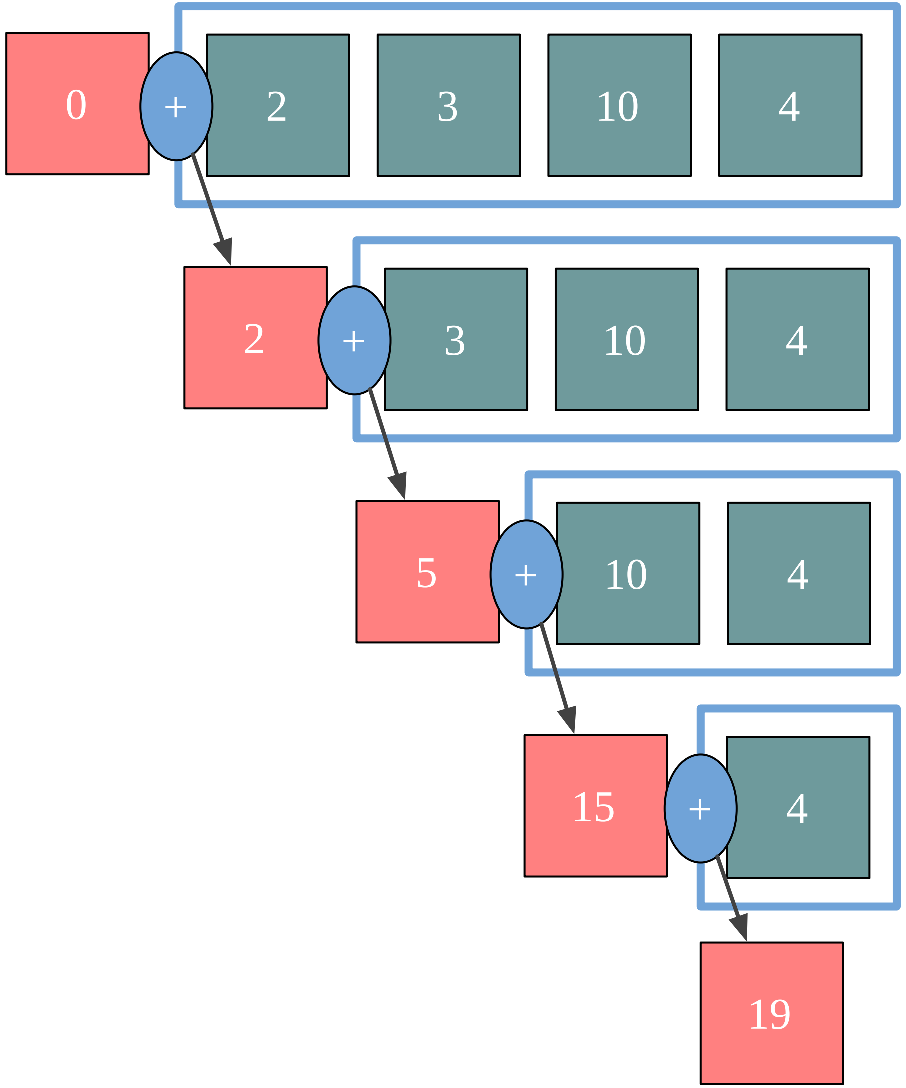
Fold Left



```scala
def foldLeft[A, B](fa: List[A], b: B)(f: (B, A) => B): B = {
  var acc = b
  val it = fa.iterator

  while(it.hasNext) {
    val current = it.next()
    acc = f(acc, current)
  }

  acc
}
```



FoldLeft



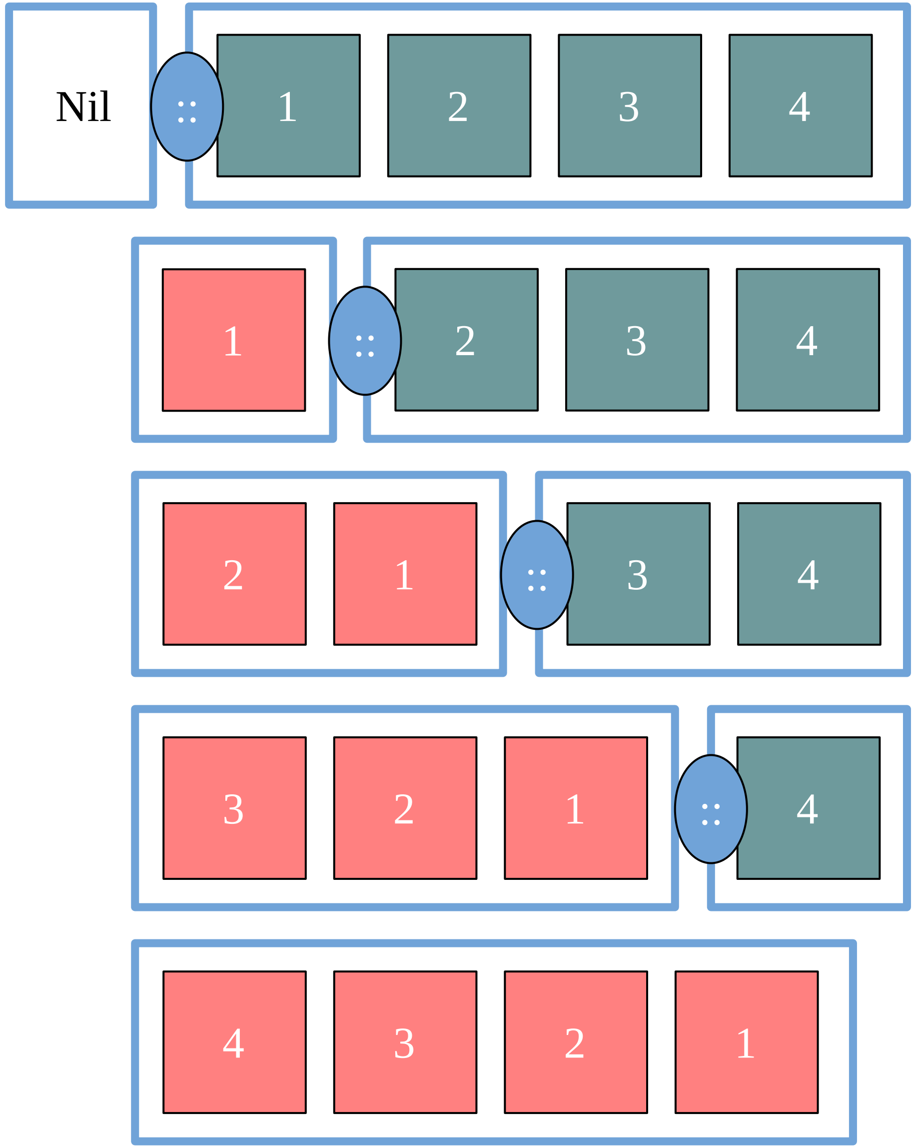

```scala
def sum(xs: List[Int]): Int =
  foldLeft(xs, 0)(_ + _)
```

```scala
scala> sum(List(2,3,10,4))
res4: Int = 19
```

FoldLeft

```scala
def reverse[A](xs: List[A]): List[A] =
  foldLeft(xs, List.empty[A])((acc, a) => a :: acc)
```

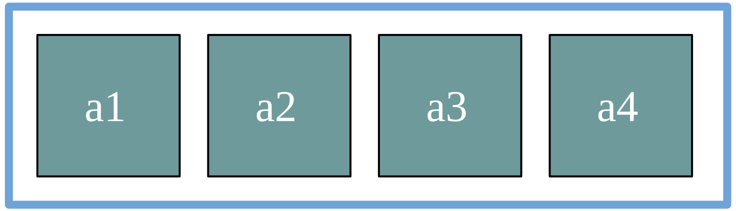
```scala
scala> reverse(List(1,2,3,4))
res5: List[Int] = List(4, 3, 2, 1)
```



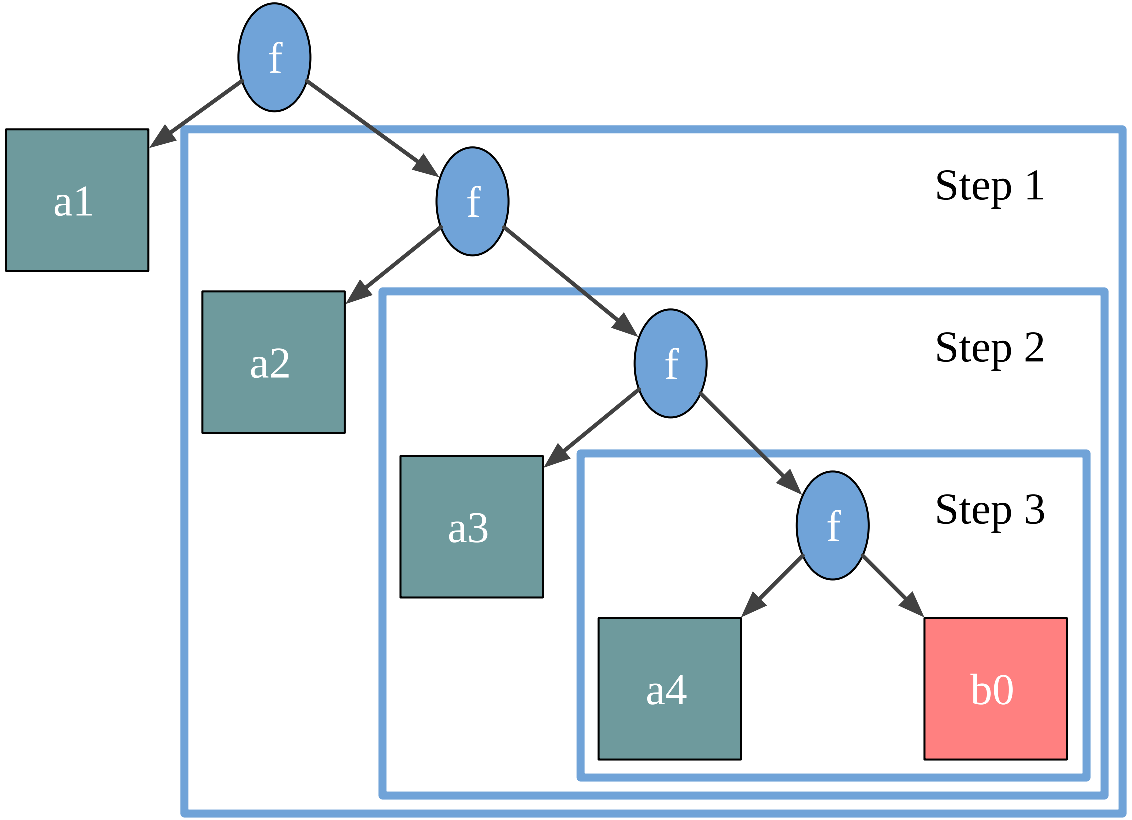
Finish Exercise 3

`exercises.function.FunctionExercises.scala`

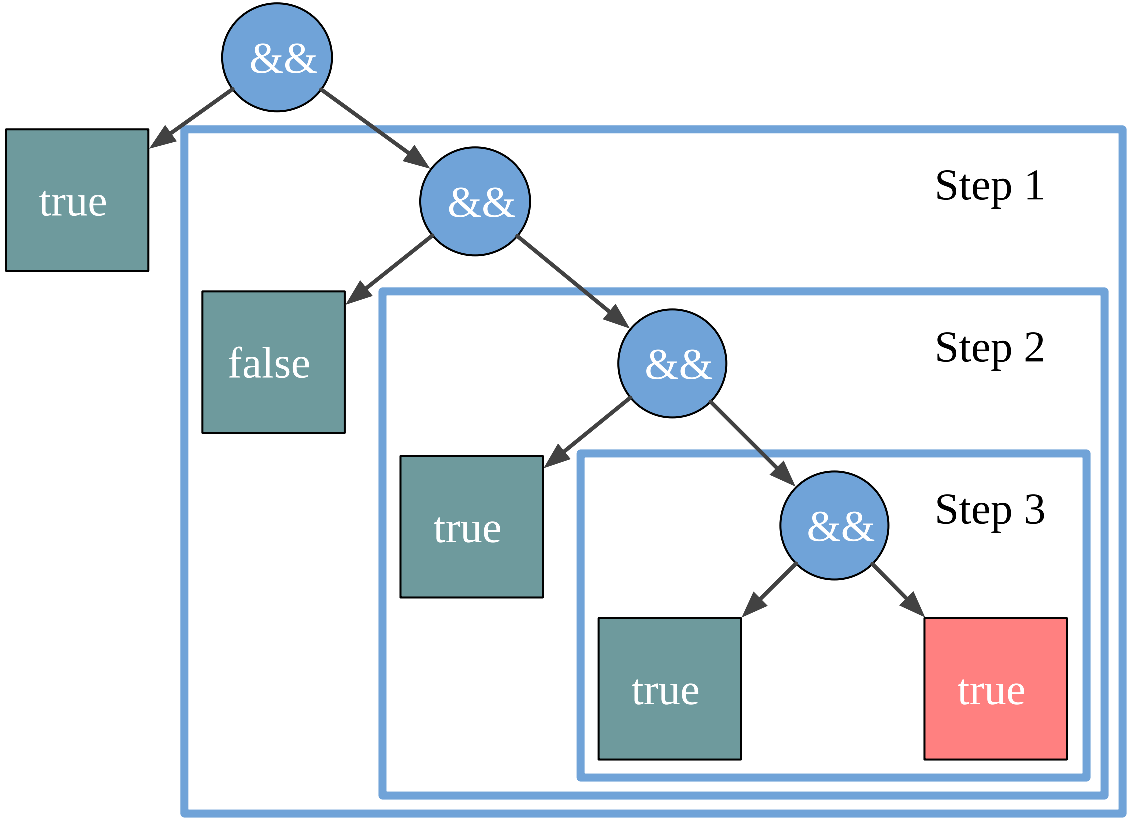
Folding



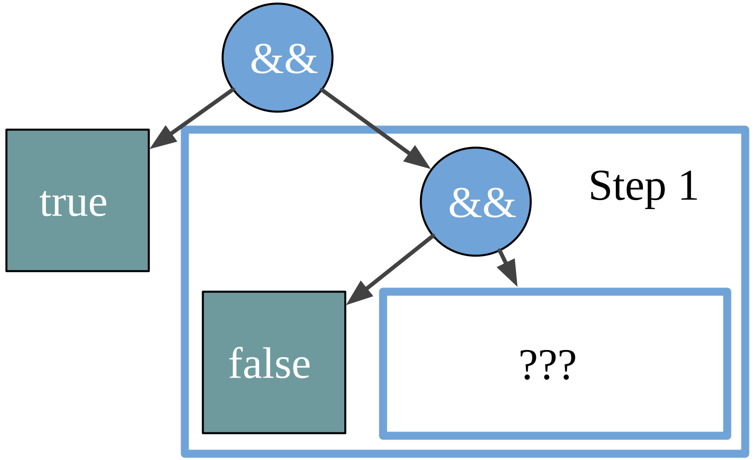
Fold Right



Fold Right

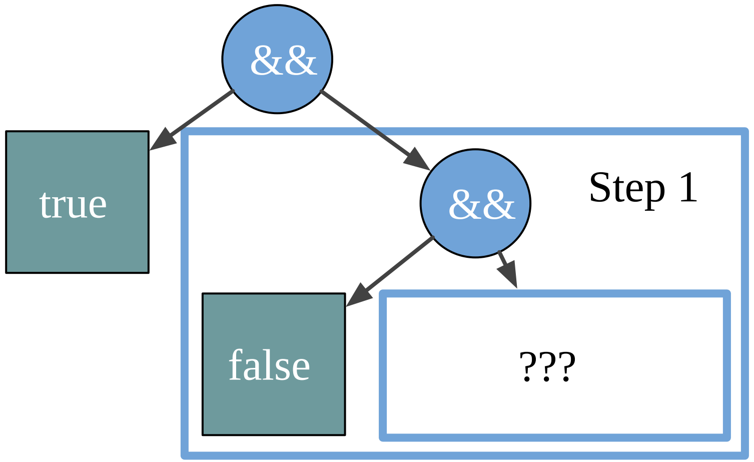


Fold Right is lazy

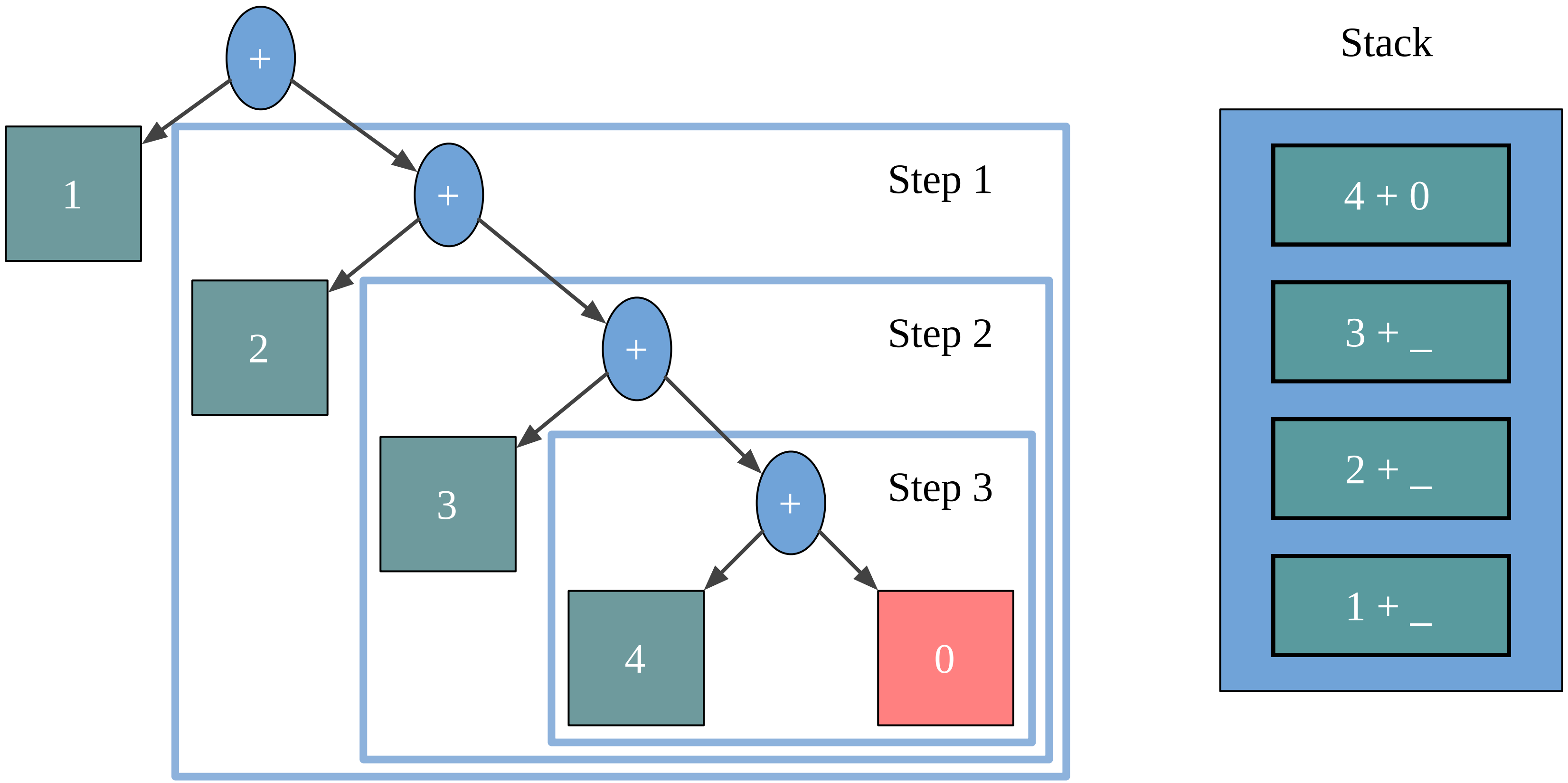


Fold Right is lazy

```scala
def foldRight[A, B](xs: List[A], z: B)(f: (A, => B) => B): B =
  xs match {
    case Nil    => z
    case h :: t => f(h, foldRight(t, z)(f))
  }
```



Fold Right is NOT always stack safe



Fold Right replaces constructors

```scala
sealed trait List[A]

case class Nil[A]() extends List[A]
case class Cons[A](head: A, tail: List[A]) extends List[A]
```

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

Fold Right replaces constructors

```
sealed trait List[A]

case class Nil[A]() extends List[A]
case class Cons[A](head: A, tail: List[A]) extends List[A]
```

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

```
def foldRight[A, B](list: List[A], z: B)(f: (A, => B) => B): B

foldRight(xs, z)(f) == foldRight(Cons(1, Cons(2, Cons(3, Nil()))), z)(f)
                    ==           f    (1, f    (2, f    (3, z    )))
```

Fold Right replaces constructors

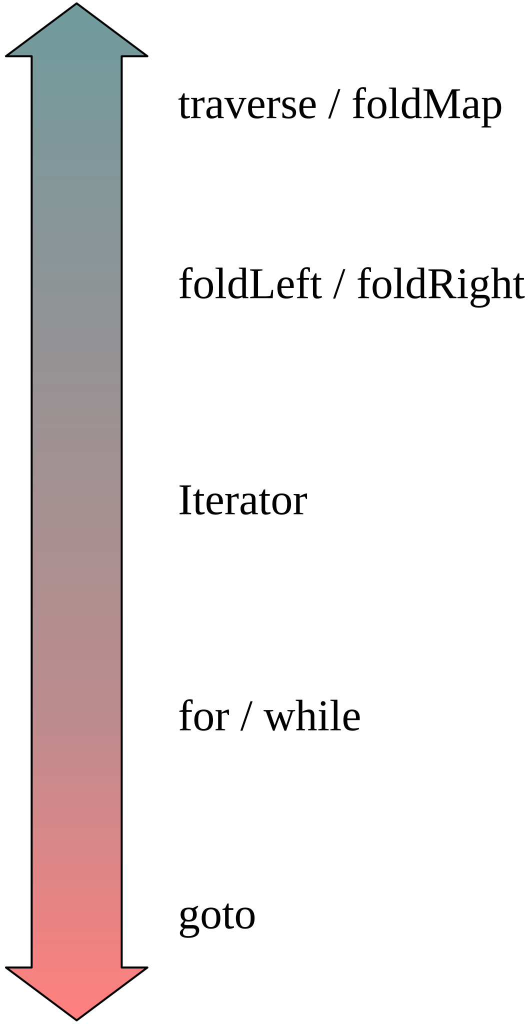
```
sealed trait List[A]

case class Nil[A]() extends List[A]
case class Cons[A](head: A, tail: List[A]) extends List[A]
```

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

```
def foldRight[A, B](list: List[A], z: B)(f: (A, => B) => B): B

foldRight(xs, z)(f) == foldRight(Cons(1, Cons(2, Cons(3, Nil()))), z)(f)
                    ==           f   (1, f   (2, f   (3, z    )))
```

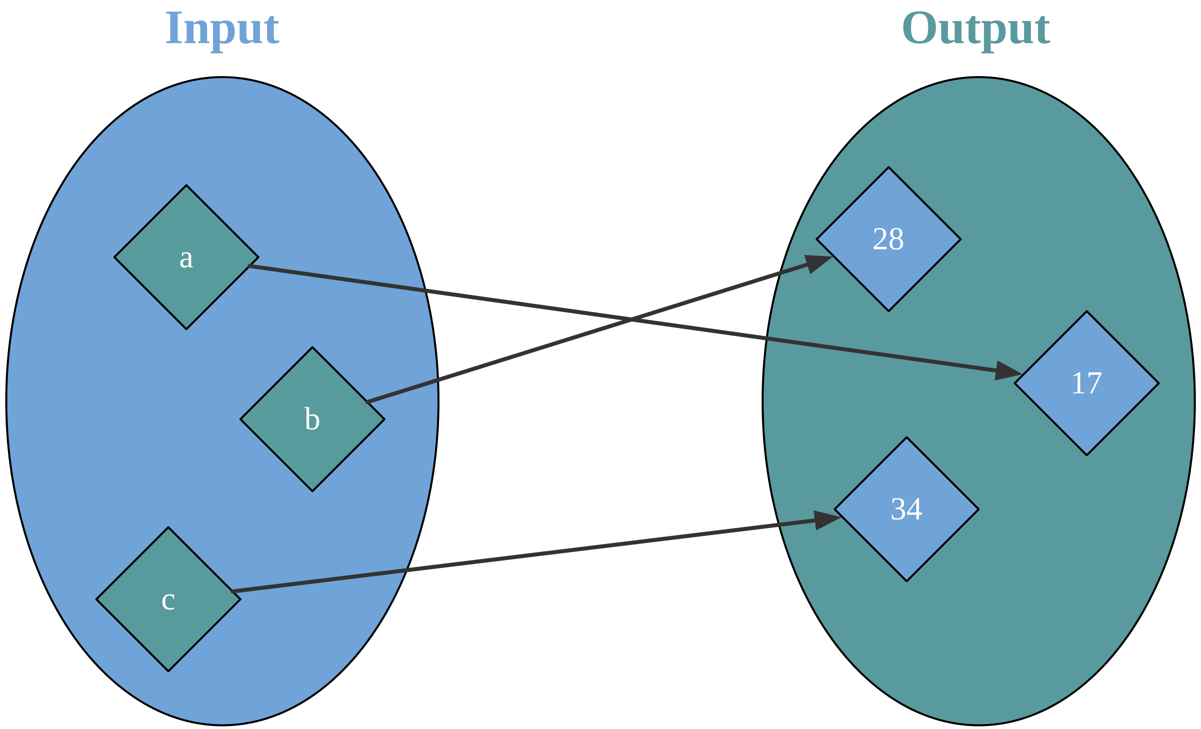
Exercise: How would you "replace constructors" for Option or Binary Tree?

Different level of abstractions

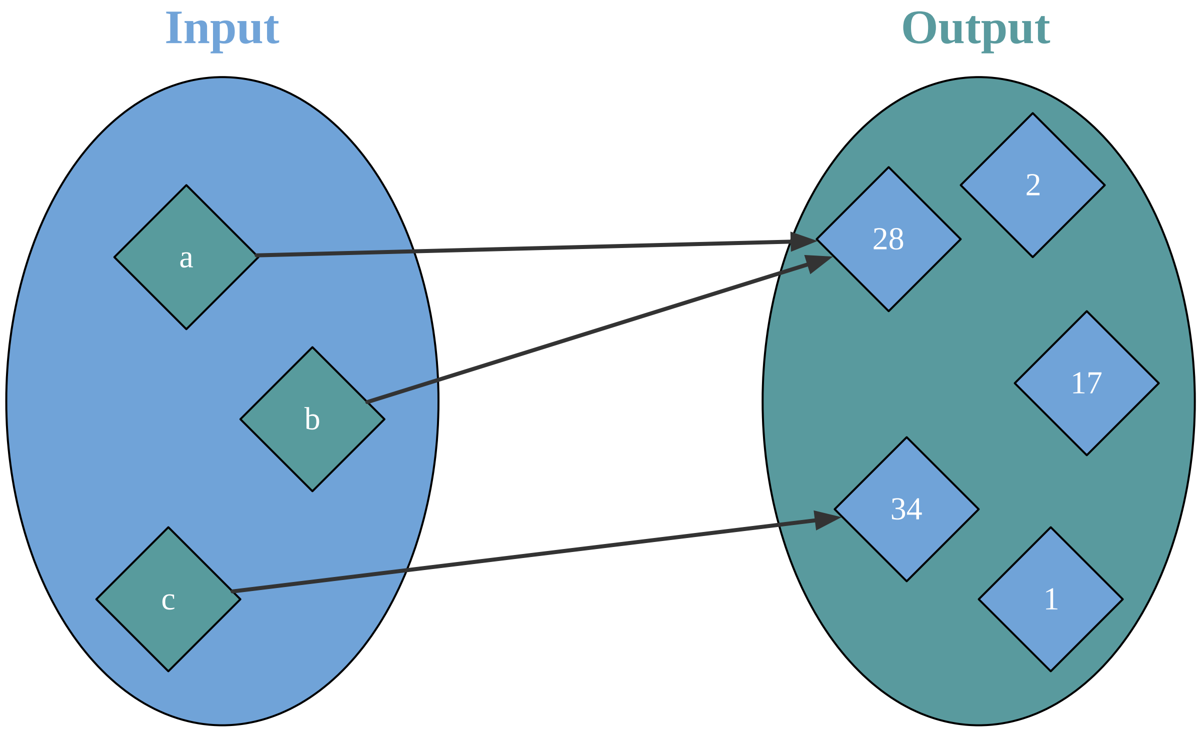


Pure function

Pure function is a mapping



Pure function is a mapping

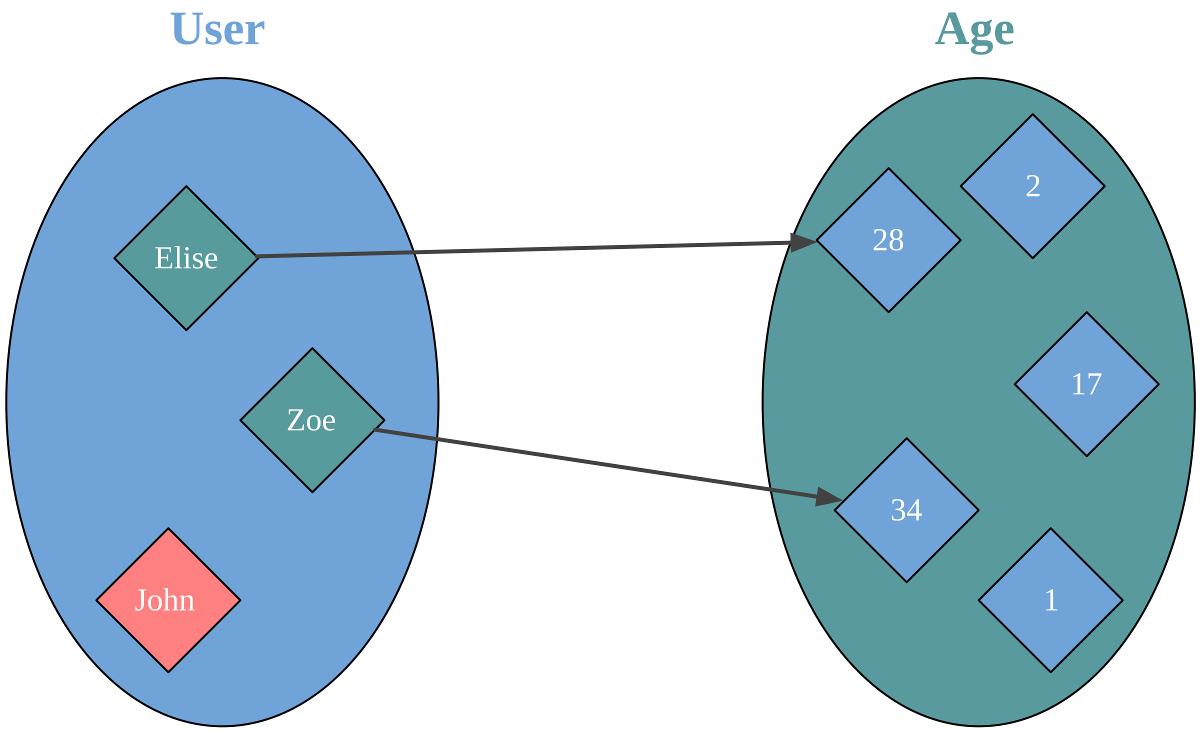


Programming function

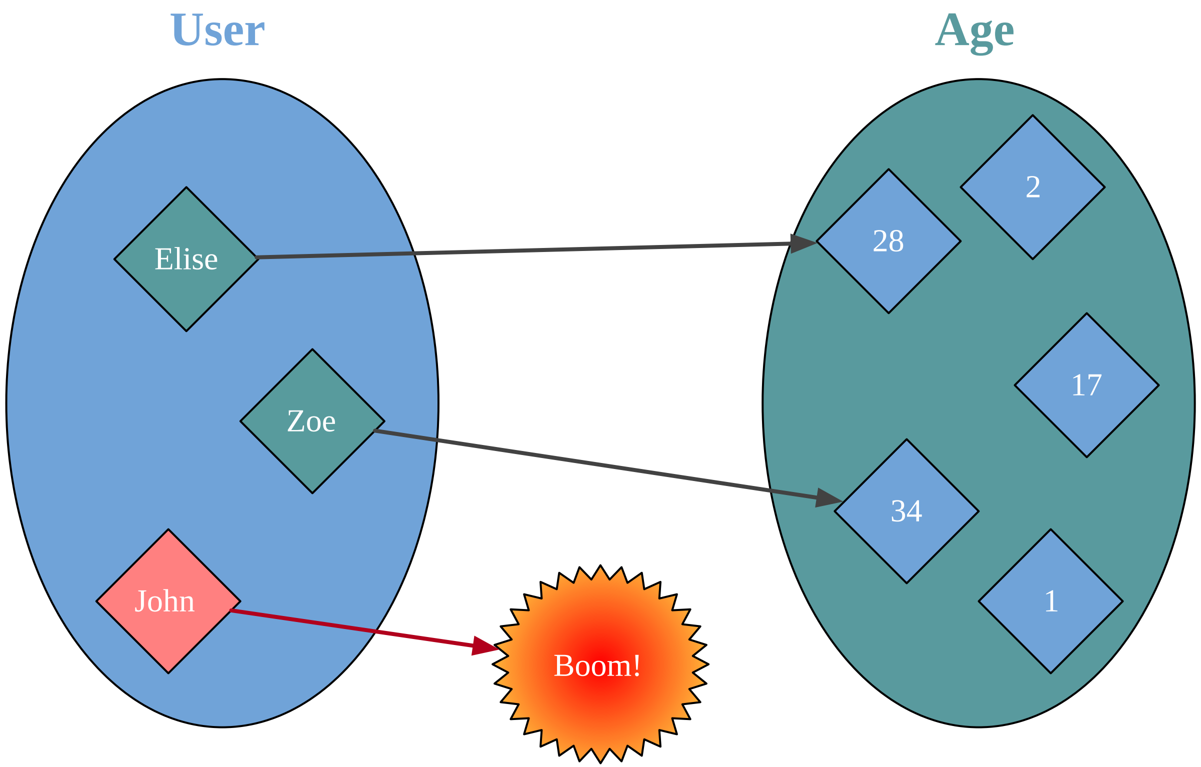
!=

Pure function

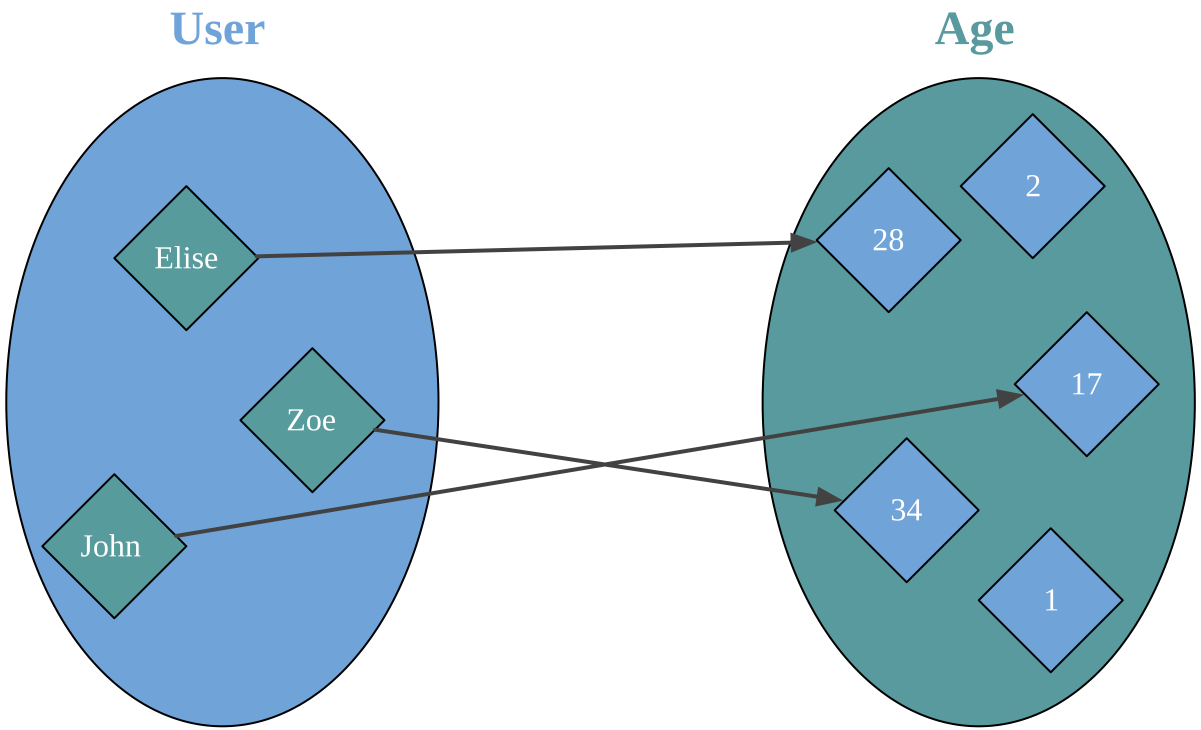
Partial function



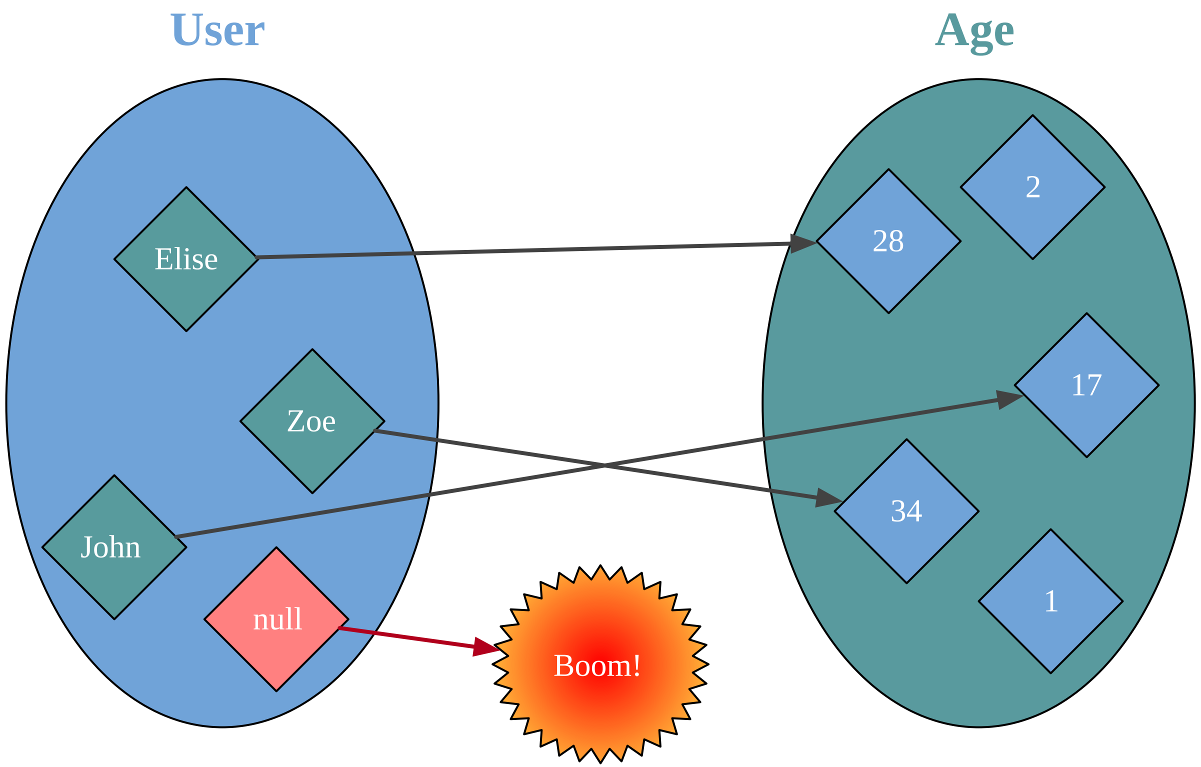
Partial function



Null



Null



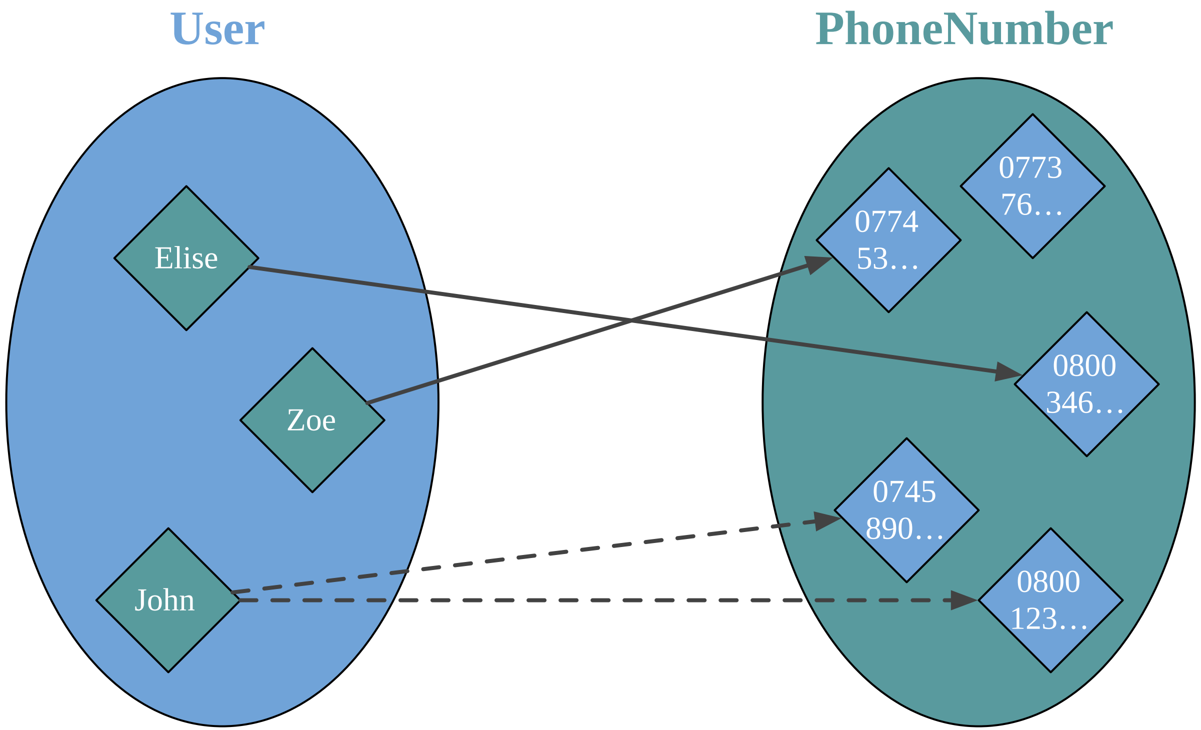
Null

We cannot remove `null` from the language (maybe in 3.0)

We cannot handle it for all functions

So we ignore null: don't return it, don't handle it

Nondeterministic



Nondeterministic

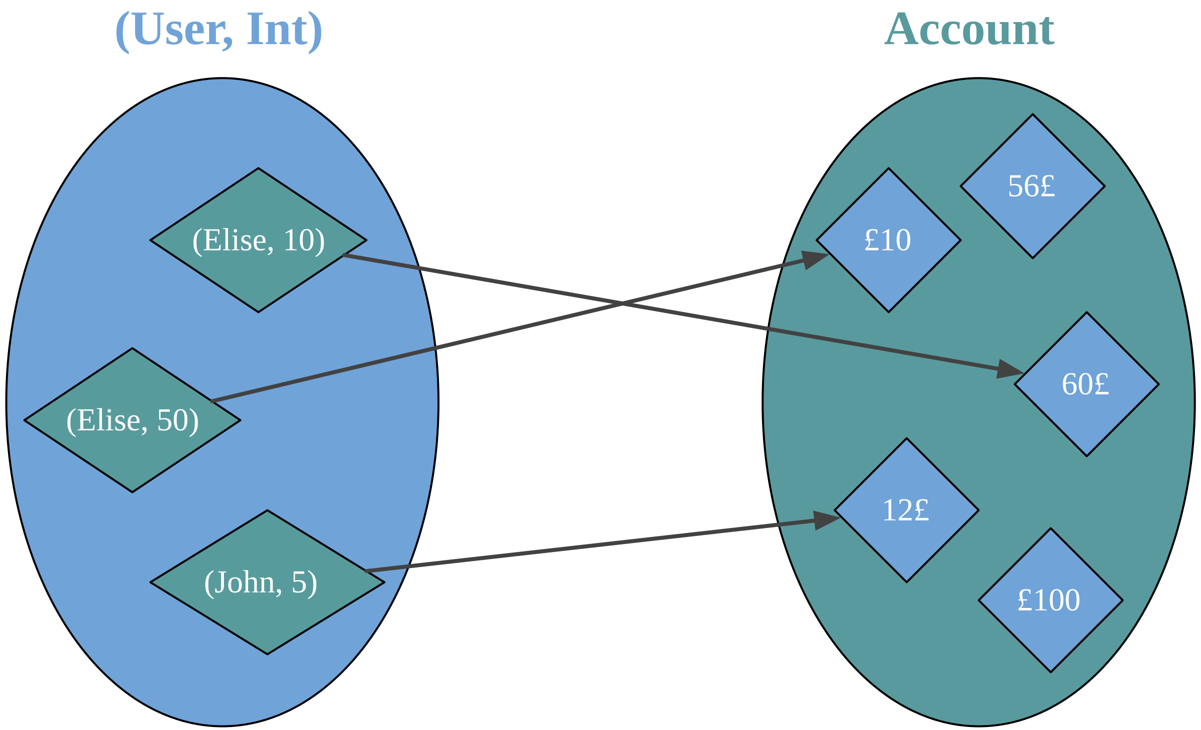
```scala
import scala.util.Random
```

```
scala> Random.nextInt(100)
res6: Int = 0

scala> Random.nextInt(100)
res7: Int = 36

scala> Random.nextInt(100)
res8: Int = 91
```

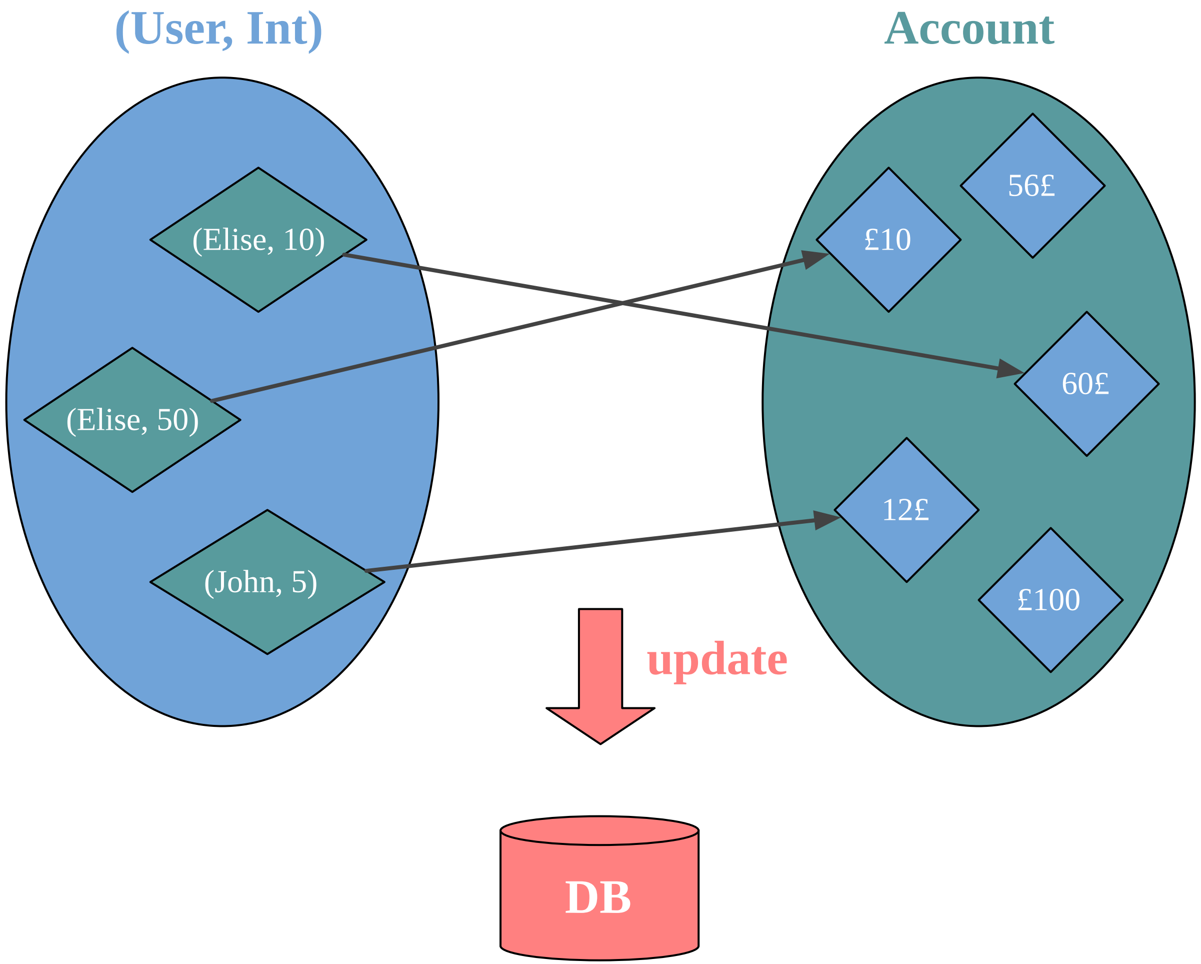
```scala
import java.time.Instant
```

```
scala> Instant.now()
res9: java.time.Instant = 2019-08-31T18:35:20.513666Z

scala> Instant.now()
res10: java.time.Instant = 2019-08-31T18:35:20.597555Z
```

Side effect



Side effect



(User, Int)
Account
(Elise, 10)
(Elise, 50)
(John, 5)
56£
£10
60£
12£
£100
update
DB

Side effect

```scala
def println(message: String): Unit = ...
```

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

Side effect

```
def println(message: String): Unit = ...
```

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

```
scala> scala.io.Source.fromURL("http://google.com")("ISO-8859-1").take(100).mkString
res11: String = <!doctype html><html itemscope="" itemtype="http://schema.org/WebPage" lang="en"><head><meta content
```

Side effect

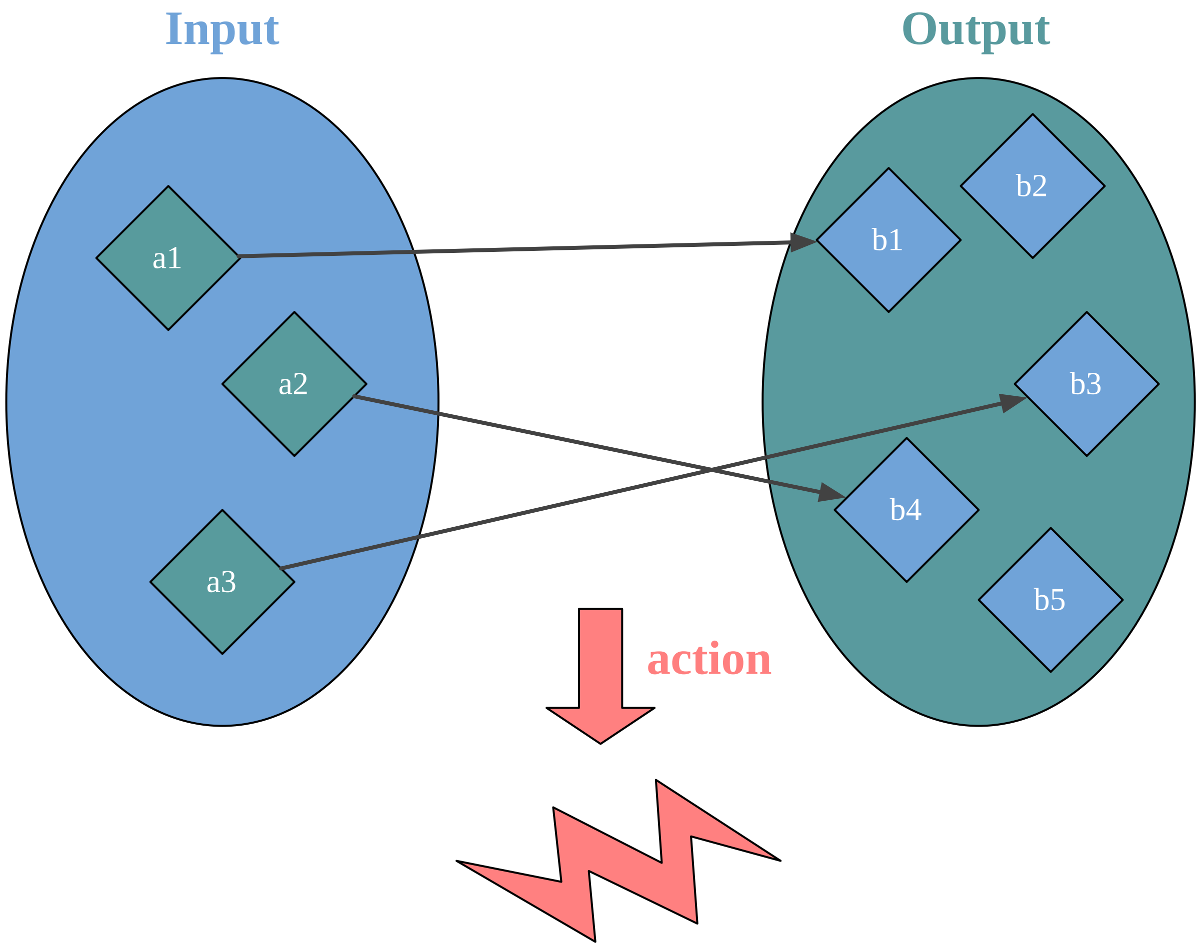
```scala
def println(message: String): Unit = ...
```

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

```scala
scala> scala.io.Source.fromURL("http://google.com")("ISO-8859-1").take(100).mkString
res11: String = <!doctype html><html itemscope="" itemtype="http://schema.org/WebPage" lang="en"><head><meta content
```

```scala
var x: Int = 0

def count(): Int = {
  x = x + 1
  x
}
```

Side effect



Reflection

```scala
def foo[A](a: A): A = a match {
  case x: Int    => (x + 1).asInstanceOf[A]
  case x: String => x.reverse.asInstanceOf[A]
  case _         => a
}
```

```
scala> foo(5)
res12: Int = 6

scala> foo("Hello")
res13: String = olleH

scala> foo(true)
res14: Boolean = true
```

Reflection is not reliable

```scala
def foo[A](a: A): Int = a match {
  case _: List[Int]    => 0
  case _: List[String] => 1
  case _               => 2
}
```

```
scala> foo(List(1,2,3))
res15: Int = 2

scala> foo(List("abc"))
res16: Int = 2
```

Reflection renders signature documentation unreliable

```
def foo[A](a: A): A = ???
```

Reflection renders signature documentation unreliable

```
def foo[A](a: A): A = ???
```

Without Reflection

```
def foo[A](a: A): A = a
```

(and without infinite recursion)

Also apply to `Any` and non sealed trait

```
def foo(a: Any): Int = ???
```

Also apply to `Any` and non sealed trait

```
def foo(a: Any): Int = ???
```

Without Reflection

```
def foo[A](a: Any): Int = 5
```

Pure Function (aka Scalazzi subset)

- deterministic
- total (not partial)
- no mutation
- no exception
- no null
- no side effect
- no reflection

Exercise 4

`exercises.function.FunctionExercises.scala`

Why pure function?

1. Refactoring

Refactoring

```
def hello_1(foo: Foo, bar: Bar) = {
  val x = f(foo)
  val y = g(bar)
  h(y)
  y
}
```

Refactoring: remove unused code

```
def hello_1(foo: Foo, bar: Bar) = {
  val x = f(foo)
  val y = g(bar)
  h(y)
  y
}
```

Refactoring: remove unused code

```scala
def hello_1(foo: Foo, bar: Bar) = {
  val x = f(foo)
  val y = g(bar)
  h(y)
  y
}
```

should be equivalent to

```scala
def hello_2(foo: Foo, bar: Bar): Int =
  g(bar)
```

Refactoring: remove unused code

```
def hello_1(foo: Foo, bar: Bar) = {
  val x = f(foo)
  val y = g(bar)
  h(y)
  y
}
```

should be equivalent to

```
def hello_2(foo: Foo, bar: Bar): Int =
  g(bar)
```

Counter example

```
def f(foo: Foo): Unit = upsertToDb(foo)

def h(id: Int): Unit = globalVar += 1
```

Refactoring: reorder variables

```scala
def hello_1(foo: Foo, bar: Bar) = {
  val x = f(foo)
  val y = g(bar)
  h(x, y)
}
```

```scala
def hello_2(foo: Foo, bar: Bar): Int = {
  val y = g(bar)
  val x = f(foo)
  h(x, y)
}
```

Refactoring: reorder variables

```scala
def hello_1(foo: Foo, bar: Bar) = {
  val x = f(foo)
  val y = g(bar)
  h(x, y)
}
```

```scala
def hello_2(foo: Foo, bar: Bar): Int = {
  val y = g(bar)
  val x = f(foo)
  h(x, y)
}
```

Counter example

```scala
def f(foo: Foo): Unit = print("foo")
def g(bar: Bar): Unit = print("bar")

hello_1(foo, bar) // print foobar
hello_2(foo, bar) // print barfoo
```

Refactoring: extract - inline

```scala
def hello_extract(foo: Foo, bar: Bar) = {
  val x = f(foo)
  val y = g(bar)
  h(x, y)
}
```

```scala
def hello_inline(foo: Foo, bar: Bar) = {
  h(f(foo), g(bar))
}
```

Refactoring: extract - inline

```scala
def hello_extract(foo: Foo, bar: Bar) = {
  val x = f(foo)
  val y = g(bar)
  h(x, y)
}
```

```scala
def hello_inline(foo: Foo, bar: Bar) = {
  h(f(foo), g(bar))
}
```

Counter example

```scala
def f(foo: Foo): Boolean = false

def g(bar: Bar): Boolean = throw new Exception("Boom!")

def h(b1: Boolean, b2: => Boolean): Boolean = b1 && b2

hello_inline (foo, bar) // false
hello_extract(foo, bar) // throw Exception
```

Refactoring: extract - inline

```scala
import scala.concurrent.Future
import scala.concurrent.ExecutionContext.Implicits.global

def doSomethingExpensive(x: Int): Future[Int] =
  Future { ??? }

for {
  x <- doSomethingExpensive(5)
  y <- doSomethingExpensive(8) // sequential, only starts when first Future is complete
} yield x + y
```

```scala
val fx = doSomethingExpensive(5)
val fy = doSomethingExpensive(8) // in parallel

for {
  x <- fx
  y <- fy
} yield x + y
```

Refactoring: de-duplicate

```scala
def hello_duplicate(foo: Foo) = {
  val x = f(foo)
  val y = f(foo)
  h(x, y)
}
```

```scala
def hello_simplified(foo: Foo) = {
  val x = f(foo)
  h(x, x)
}
```

Refactoring: de-duplicate

```scala
def hello_duplicate(foo: Foo) = {
  val x = f(foo)
  val y = f(foo)
  h(x, y)
}
```

```scala
def hello_simplified(foo: Foo) = {
  val x = f(foo)
  h(x, x)
}
```

Counter example

```scala
def f(foo: Foo): Unit = print("foo")

hello_duplicate(foo)  // print foofoo
hello_simplified(foo) // print foo
```

Pure function

means

fearless refactoring

2. Local reasoning

Local reasoning

```
def hello(foo: Foo, bar: Bar): Int = {

  ??? // only depends on foo, bar
}
```

Local reasoning

```
class HelloWorld(fizz: Fizz) {

  val const = 12.3

  def hello(foo: Foo, bar: Bar): Int = {

    ??? // only depends on foo, bar, const and fizz
  }

}
```

Local reasoning

```scala
class HelloWorld(fizz: Fizz) {

  var secret = null // □

  def hello(foo: Foo, bar: Bar): Int = {
    FarAwayObject.mutableMap += "foo" -> foo // □
    publishMessage(Hello(foo, bar)) // □
    ???
  }

}

object FarAwayObject {
  val mutableMap = ??? // □
}
```

3. Easier testing

4. Better documentation

Better documentation

```scala
def getAge(user: User): Int = ???

def getOrElse[A](fa: Option[A])(orElse: => A): A = ???

def parseJson(x: String): Either[ParsingError, Json] = ???

def void[A](fa: Option[A]): Option[Unit] = ???

def forever[A](fa: IO[A]): IO[Nothing] = ???
```

5. Potential compiler optimisations

See Exercise 5

`exercises.function.FunctionExercises.scala`

What's the catch?

With pure function, you cannot **DO** anything

Resources and further study

- Explain List Folds to Yourself
- Constraints Liberate, Liberties Constrain

Module 2: Side Effect