Functional Programming

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What do we have for you today?

Functional Programming

- What is a function?
- Referential Transparency
- Laziness
- Purity

Functional Programming

Scala

- `trait`, `class`, `object` and `type`
- Mixins
- Self-Type annotations
- `val`, `def`, `lazy` and type inference
- Generics
- Invariant, Covariant and Contravariant
- `case class`, `sealed trait` and co-products
- `Option`, `Vector` and `Future`
- Pattern Matching
- Total and partial functions
- Generic - Polymorphic - functions
- Higher-Order functions
- Currying, Multiple parameter lists and Partially applied functions
- Composing functions
- Implicit values and parameters

Functional Programming

Scala

Not Enough Functions

- `map` as a member method
- Generalizing `map` in a base trait
- Externalizing `map`
- `Functor`, type constructors and higher-kinded types
- `Functor` is a type-class
- `Functor` instances
- `pure`
- `flatMap`
- Implementing `map` in terms of `pure` and `flatMap`
- `Monad` is a type-class
- `for` comprehension

Functional Programming

Scala

Not Enough Functions

Domain Modeling, Services and Effects

- Everything is in the function (signature)
- The Tale of One City
    - Value Types
    - Entities
    - Aggregates
- IO, Kleisli, Future
    - Database actions
    - Security actions
    - Composing actions

Functional Programming

Scala

Not Enough Functions

Domain Modeling, Services and Effects

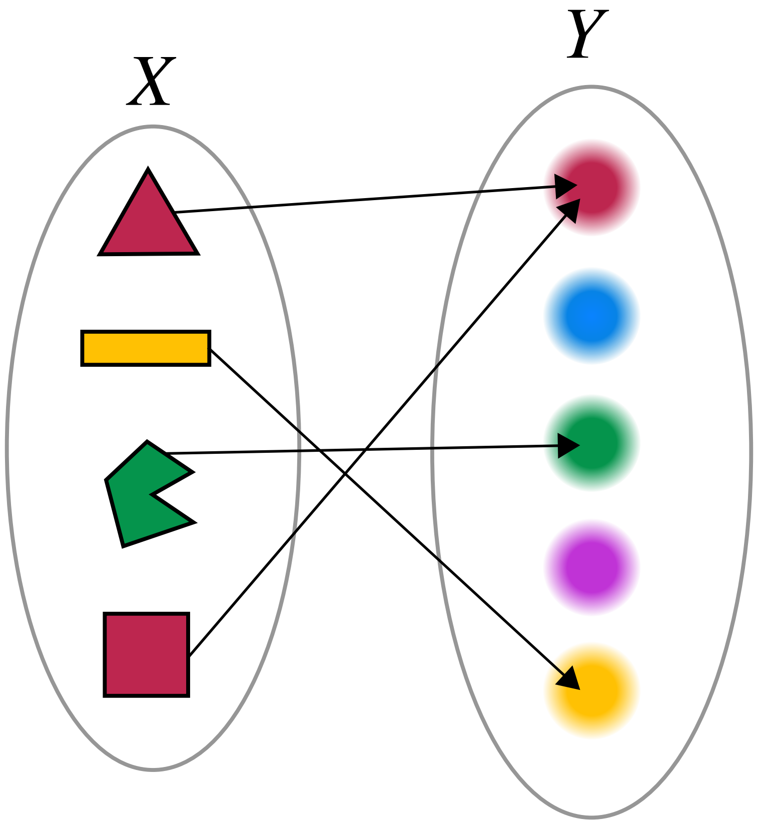
Streaming

- Unix Pipes
- Source - Flow - Sink
- Simple file processing, map-reduce flow
- From a database source to the browser and back again - a bi-directional streaming use case using Akka Streams and Akka HTTP WebSockets

Let's get started

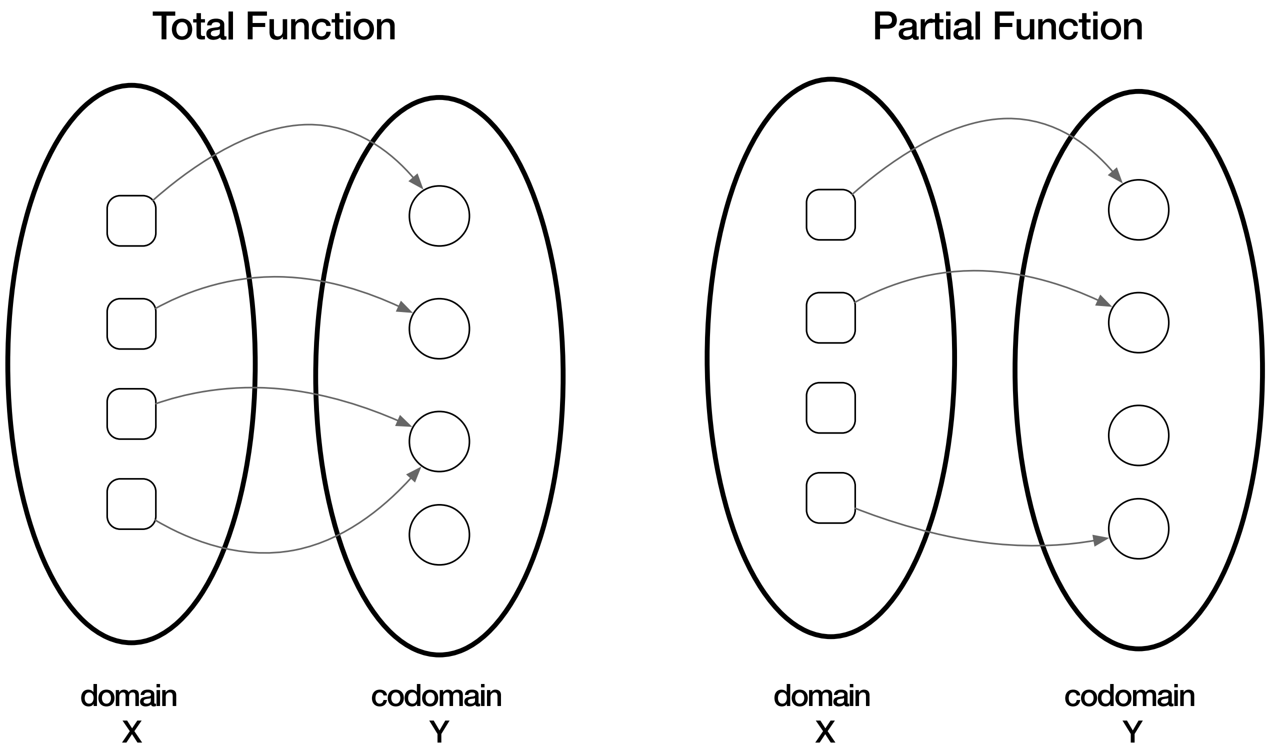
What is a function?

$$f\colon X \mapsto Y$$



What is a function?

$$f: X \mapsto Y$$



Referential Transparency

Compare those 2 programs:

```
int i = iterator.next();
int j = i;
```

```
int i = iterator.next();
int j = iterator.next();
```

- `iterator.next()` has a **Side-Effect**
- Each time we call `next()` on an `iterator` we might get a different value

Referential Transparency

Compare those 2 programs:

```
float a = MathLib.avg(2,3,4);
float b = a;
```

```
float a = MathLib.avg(2,3,4);
float b = MathLib.avg(2,3,4);
```

- `MathLib.avg(...)` has **No Side-Effect**
- Each time we call `avg()` with a particular set of arguments, we get the same result

Scala Programming Language

Scala

trait, class, object and type

```scala
trait Organization
class Company extends Organization
class University extends Organization
object IBM extends Company
object AUC extends University
object TypeAlias {
  type Name = String
  type Money = Double
}
```

Scala

Mixins

```scala
trait Organization

trait Entity

class Company extends Organization with Entity

class University extends Organization with Entity

object IBM extends Company

object AUC extends University
```

Scala

Self-Type Annotation

```
trait DatabaseAccess

trait Networking

trait Service {
  self: DatabaseAccess with Networking =>
}

trait PostgresDatabaseAccess extends DatabaseAccess

trait TcpNetworking extends Networking

object MyService
  extends Service
  with PostgresDatabaseAccess
  with TcpNetworking
```

Scala

`val`, `def` and `lazy`

```scala
// name and birthDate are immutable
class Person(
  val name: String,
  val birthDate: LocalDate)

val p01: Person = new Person("p01", LocalDate.of(1970, 4, 15))
val p02         = new Person("p02", LocalDate.of(1988, 10, 4))
```

```scala
def show(person: Person): String =
  s"The person's name is ${person.name}"
```

```scala
lazy val localDateOnFirstCall: LocalDate = LocalDate.now()
```

Scala

Generics

```scala
object Generics {

  trait Combiner[A] {
    def combine(left: A, right: A): A
  }

  object StringCombiner extends Combiner[String] {
    def combine(left: String, right: String): String =
      s"$left and $right"
  }

  object IntegerCombiner extends Combiner[Int] {
    def combine(left: Int, right: Int): Int =
      left + right
  }

}
```

Scala

Generics

```scala
import Generics._

@tailrec
def combineAll[A](first: A, rest: A*)(combiner: Combiner[A]): A =
  if (rest.isEmpty)
    first
  else
    combineAll(
      combiner.combine(first, rest.head),
      rest.tail:_*
    )(combiner)


def main(args: Array[String]): Unit = {

  println(combineAll(1, 2, 3, 4)(IntegerCombiner))

  println(combineAll("1", "2", "3", "4")(StringCombiner))

}
```

Scala

Generics

```
class Invariant[A]

class Covariant[+A]

class Contravariant[-A]
```

```
trait LivingBeing

trait Animal extends LivingBeing

class Cat extends Animal
```

Scala

Generics

```
class Invariant[A]

class Covariant[+A]

class Contravariant[-A]
```

```
trait LivingBeing

trait Animal extends LivingBeing

class Cat extends Animal
```

And Given:

```
def invariant(instance: Invariant[Animal]): Unit
```

Then:

```
//invariant(new Invariant[LivingBeing]) // will not compile
invariant(new Invariant[Animal])        // compiles
//invariant(new Invariant[Cat])         // will not compile
```

Scala

Generics

```
class Invariant[A]

class Covariant[+A]

class Contravariant[-A]
```

```
trait LivingBeing

trait Animal extends LivingBeing

class Cat extends Animal
```

And Given:

```
def covariant(instance: Covariant[Animal]): Unit
```

Then:

```
//covariant(new Covariant[LivingBeing])  // will not compile
covariant(new Covariant[Animal])         // compiles
covariant(new Covariant[Cat])            // compiles
```

Scala

Generics

```scala
class Invariant[A]

class Covariant[+A]

class Contravariant[-A]
```

```scala
trait LivingBeing

trait Animal extends LivingBeing

class Cat extends Animal
```

And Given:

```scala
def contravariant(instance: Contravariant[Animal]): Unit
```

Then:

```scala
contravariant(new Contravariant[LivingBeing]) // compiles
contravariant(new Contravariant[Animal])      // compiles
//contravariant(new Contravariant[Cat])       // will not compile
```

Scala

case class

```scala
case class Name(value: String)
case class Person(name: Name, birthData: LocalDate)
```

Scala

case class

```
case class Name(value: String)
case class Person(name: Name, birthData: LocalDate)
```

```
val p01 = Person(Name("p01"), LocalDate.of(1980, 11, 12))
val p02 = Person(Name("p02"), LocalDate.of(1980, 11, 12))
```

Scala

case class

```scala
case class Name(value: String)
case class Person(name: Name, birthData: LocalDate)
```

```scala
val p01 = Person(Name("p01"), LocalDate.of(1980, 11, 12))
val p02 = Person(Name("p02"), LocalDate.of(1980, 11, 12))
```

```scala
p01.copy(name = Name("p02")) == p02 // true
```

```scala
p01.productIterator.mkString(", ") // Name(p01), 1980-11-12
```

Scala

Pattern Matching

```
case class Name(value: String)

trait LivingBeing {
  def name: Name // notice Scala uniform access
}

case class Person(name: Name, birthData: LocalDate) extends LivingBeing
case class Animal(name: Name) extends LivingBeing
```

```
def classify(being: LivingBeing): String = being match {
  case Person(n, bd) => s"a person called: ${n.value} born ${bd.toString}"
  case Animal(n)     => s"an animal called: ${n.value}"
  case _             => s"a living being called: ${being.name.value}"
}
```

Scala

Higher-Order Functions

Remember this one?

```scala
trait Combiner[A] {
  def combine(left: A, right: A): A
}

object StringCombiner extends Combiner[String] {
  def combine(left: String, right: String): String = s"$left and $right"
}

object IntegerCombiner extends Combiner[Int] {
  def combine(left: Int, right: Int): Int = left + right
}

def combineAll[A](first: A, rest: A*)(combiner: Combiner[A]): A =
  if (rest.isEmpty)
    first
  else
    combineAll(
      combiner.combine(first, rest.head),
      rest.tail:_*
    )(combiner)
```

Scala

Higher-Order Functions

Tadaaaaaaaaaaaaaaaaaaaaaaaaaaa

```scala
def combineAll[A](first: A, rest: A*)(combine: (A, A) => A): A =
  rest.foldLeft(first)(combine)
```

What is `foldLeft`?

```scala
def foldLeft[B](z: B)(op: (B, A) => B): B
```

Scala

Higher-Order Functions

What is `foldLeft`?

```
def foldLeft[B](z: B)(op: (B, A) => B): B
```

Example:

```
val schedule = List("had breakfast", "went to RiseUp")

val folded =
  schedule
    .foldLeft("woke up early")( (accumulator, next) => s"$accumulator then $next")
```

Then `folded` value is:

```
"woke up early then had breakfast then went to RiseUp"
```

Scala

Companion Objects

```scala
// Company trait
trait Company {
  def name: String
}

// Company companion object
object Company {

  def apply(companyName: String): Company = new Company {
    def name: String = companyName
  }

}

val c01 = Company.apply("c01") // invoke `apply` explicitly
val c02 = Company("c02")       // invoke `apply` also, syntactic sugar
```

Scala

Let's build a Binary Search Tree

A `Tree` in Haskell:

```haskell
data Tree a = Empty | Leaf a | Node (Tree a) a (Tree a)
```

Yeah, that's it! But,

A `Tree` in Scala:

```scala
sealed trait Tree[+A]

case class Node[+A](data: A, left: Tree[A], right: Tree[A]) extends Tree[A]

case class Leaf[+A](data: A) extends Tree[A]

case object Empty extends Tree[Nothing]
```

Scala

Let's build a Binary Search Tree

The `insert` function:

```scala
def insert[A](tree: Tree[A], data: A)
             (ordering: Ordering[A]): Tree[A] = tree match {

  case Empty         =>
    Leaf(data)

  case Leaf(a)       =>
    if (ordering.compare(data, a) < 0)
      Node(a, Leaf(data), Empty)
    else
      Node(a, Empty, Leaf(data))

  case Node(a, l, r) =>
    if (ordering.compare(data, a) < 0)
      Node(a, insert(l, data)(ordering), r)
    else
      Node(a, l, insert(r, data)(ordering))

}
```

Scala

Let's build a Binary Search Tree

Walk the `Tree` `inOrder`, sorting the `Tree`:

```scala
def inOrder[A](tree: Tree[A]): List[A] = tree match {
  case Empty          => List.empty[A]
  case Leaf(a)        => List(a)
  case Node(a, l, r) => inOrder(l) ++ List(a) ++ inOrder(r)
}
```

Scala

Let's build a Binary Search Tree

The `insert` function *REVISITED*. Can you spot the changes?

```scala
def insert[A](tree: Tree[A], data: A)
             (implicit ordering: Ordering[A]): Tree[A] = tree match {

  case Empty         =>
    Leaf(data)

  case Leaf(a)       =>
    if (ordering.compare(data, a) < 0)
      Node(a, Leaf(data), Empty)
    else
      Node(a, Empty, Leaf(data))

  case Node(a, l, r) =>
    if (ordering.compare(data, a) < 0)
      Node(a, insert(l, data), r)
    else
      Node(a, l, insert(r, data))

}
```

Not Enough Functions!

`map` Trial 01 | What's wrong with this?

```scala
trait Container[A] {
  def map[B](f: A => B): Container[B]
}

trait Bag[A] {
  def map[B](f: A => B): Bag[B]
}
```

```scala
def container: Container[Int] = ???
def bag: Bag[String] = ???
```

Having:

```scala
def change[A, B](instance: Container[A])(f: A => B): Container[B] =
  instance.map(f)
def change[A, B](instance: Bag[A])(f: A => B): Bag[B] =
  instance.map(f)
```

Then:

```scala
change(container)(_ + 1)
change(bag)(string => s"here is your $string")
```

`map` Trial 02 | What's wrong with this?

```scala
trait Mapped[A] {
  def map[B](f: A => B): Mapped[B]
}

trait Container[A] extends Mapped[A]

trait Bag[A] extends Mapped[A]
```

Then:

```scala
change(container)(_ + 1)
change(bag)(string => s"here is your $string")
```

`map` Trial 03 | What's wrong with this?

```scala
trait Functor[F[_]] {
  def map[A, B](fa: F[A])(f: A => B): F[B]
}

trait Container[A]

trait Bag[A]

def change[F[_], A, B]
  (instance: F[A])(f: A => B)
  (functor: Functor[F]): F[B] = functor.map(instance)(f)
```

And:

```scala
def containerFunctor: Functor[Container] = ???
def bagFunctor: Functor[Bag] = ???
```

Then:

```scala
change(container)(_ + 1)(containerFunctor)
change(bag)(string => s"here is your $string")(bagFunctor)
```

`map` Trial 04 | What's wrong with this?

```
trait Functor[F[_]] {
  def map[A, B](fa: F[A])(f: A => B): F[B]
}

trait Container[A]

trait Bag[A]

def change[F[_], A, B]
  (instance: F[A])(f: A => B)
  (implicit functor: Functor[F]): F[B] = functor.map(instance)(f)
```

And:

```
implicit def containerFunctor: Functor[Container] = ???
implicit def bagFunctor: Functor[Bag] = ???
```

Then:

```
change(container)(_ + 1)
change(bag)(string => s"here is your $string")
```

What about `flatMap`?

```scala
def flatMap[B](f: A => Option[B]): Option[B]
```

Example:

```scala
Some(1).flatMap(i => Some(i + 1))               // Some(2)

Option.empty[Int].flatMap(i => Some(i + 1))     // None
```

What about `flatMap`?

```
def flatMap[B](f: A => List[B]): List[B]  // simplified
```

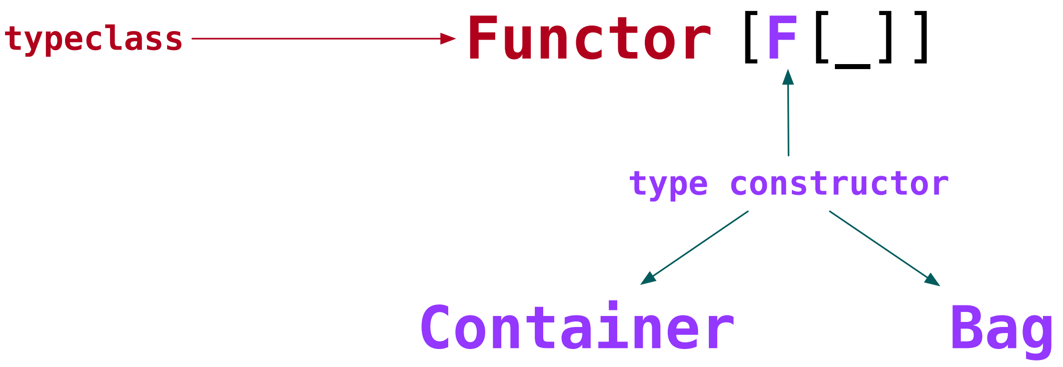
Example:

```
List(1,2,3).flatMap(i => List(s"number $i", s"número $i", s"nombre $i"))
// List(
//      number 1, número 1, nombre 1,
//      number 2, número 2, nombre 2,
//      number 3, número 3, nombre 3)

List.empty[Int].flatMap(i => List(s"number $i", s"número $i", s"nombre $i"))
// List()
```

Getting Serious

Functor



typeclass

Functor [F[_]]

type constructor

Container

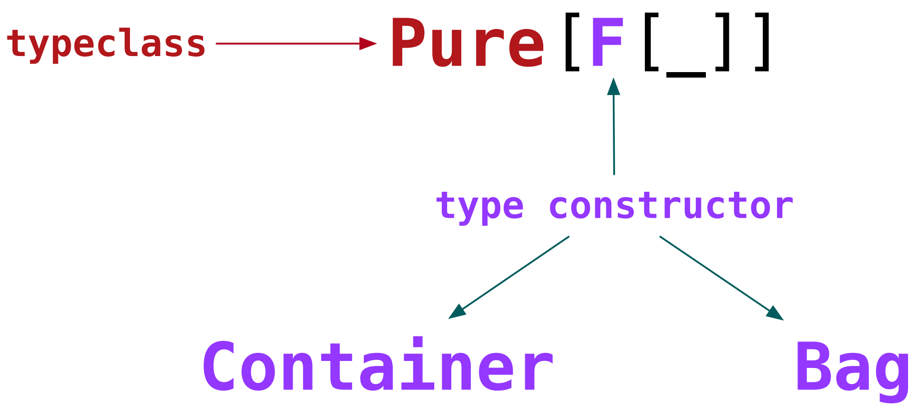
Bag

```
def map[A, B](fa: F[A])(f: A => B): F[B]

def map[A, B](fa: Container[A])(f: A => B): Container[B]

def map[A, B](fa: Bag[A])(f: A => B): Bag[B]
```

Pure



typeclass

Pure[F[_]]

type constructor

Container

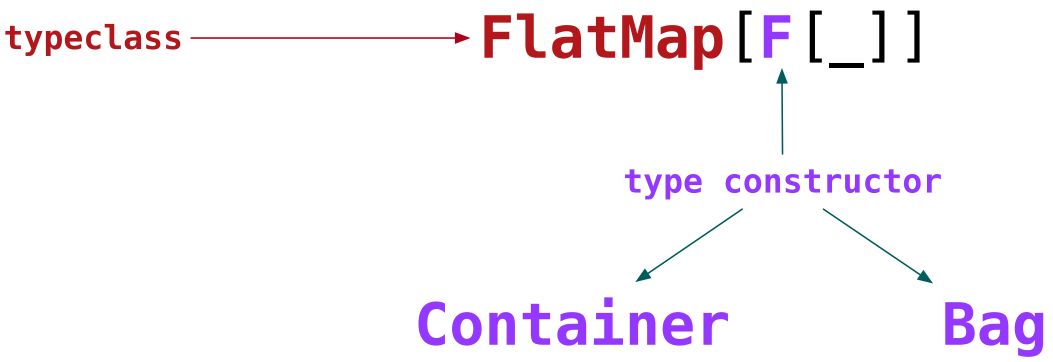
Bag

```
def pure[A](x: A): F[A]

def pure[A](x: A): Container[A]

def pure[A](x: A): Bag[A]
```

FlatMap



typeclass

FlatMap[F[_]]

type constructor

Container

Bag

```
def flatMap[A, B](fa: F[A])(f: A => F[B]): F[B]

def flatMap[A, B](fa: Container[A])(f: A => Container[B]): Container[B]

def flatMap[A, B](fa: Bag[A])(f: A => Bag[B]): Bag[B]
```

Functional Data Access

Getting Ready for the Real World

Data Access

IO

```scala
lazy val db: Database = Database.forConfig("db.elmenus", configuration)

// create an action to be performed on the database
// we are not running the action here
val io: DBIO[Vector[Int]] = sql"select 1".as[Int]

// run the action, i.e. perform IO
val f: Future[Vector[Int]] = db.run(io)

// register a callback when the IO is done
f.onComplete {
  case Success(v) => println(v)
  case Failure(e) => e.printStackTrace()
}

// block until we get the result back
// do not do this in your code
Await.result(f, Duration.Inf)

// clean up
db.close()
```

Data Access

Callback Hell

```
val createAccountTable: DBIO[Int] =
  sqlu"create table if not exists account(id bigint, email varchar(255))"

def insertAccount(account: Account): DBIO[Int] =
  sqlu"insert into account values (${account.id}, ${account.email})"

val findAllAccounts: DBIO[Vector[Account]] =
  sql"select id, email from account".as[Account]

val dropAccountTable: DBIO[Int] =
  sqlu"drop table account"
```

We need to:

- create the `Account` table
- insert an `Account`
- get all `Accounts`
- drop the table

Data Access

Callback Hell

```
createAccountTable.flatMap { _ =>
    insertAccount(account)
      .flatMap { _ =>
          findAllAccounts
            .flatMap { accounts =>
                dropAccountTable
                  .map { _ =>
                      accounts
                  }
            }
      }
}
```

We need to:

- create the `Account` table
- insert an `Account`
- get all `Accounts`
- drop the table

Data Access

`for` Comprehension

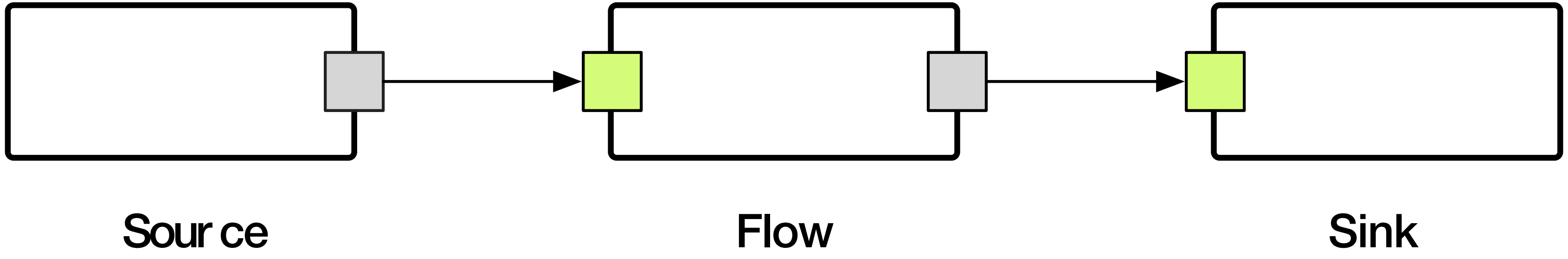
```
for {
  _        <- createAccountTable
  _        <- insertAccount(account)
  accounts <- findAllAccounts
  _        <- dropAccountTable
} yield accounts
```

We need to:

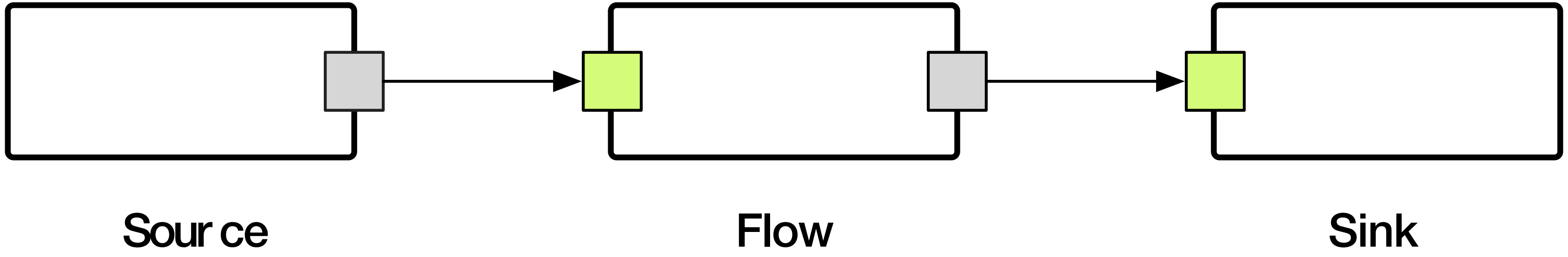
- create the `Account` table
- insert an `Account`
- get all `Accounts`
- drop the table

Streaming Data

Source - Flow - Sink



Source - Flow - Sink



Source

```
val citySource =
  Source
    .fromPublisher(
      postgres.stream(sql"select * from city limit 100".as[City]))
```

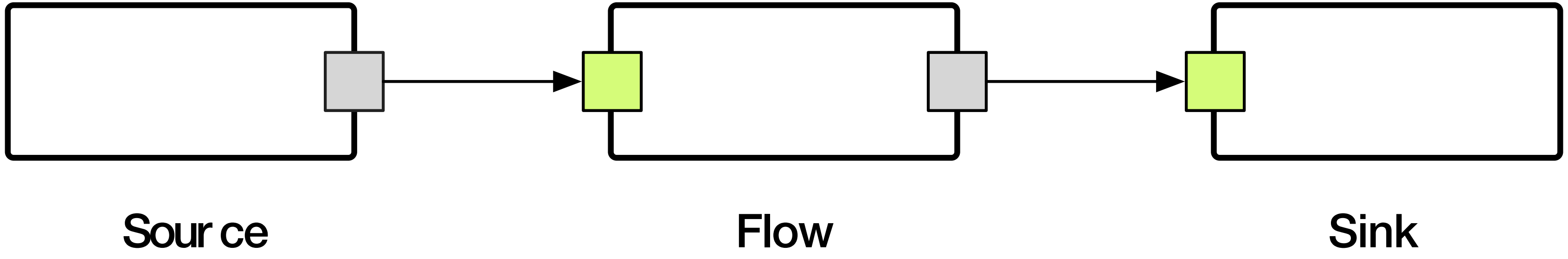
Flow

```
val cityFlow = Flow[City].map(_.asJson.noSpaces)
```

Sink

```
val citySink = Sink.foreach[String](println)
```

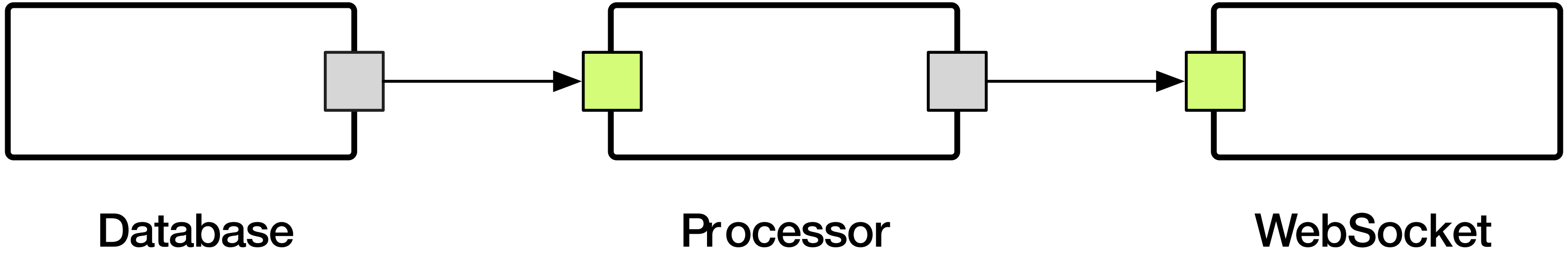
Source - Flow - Sink



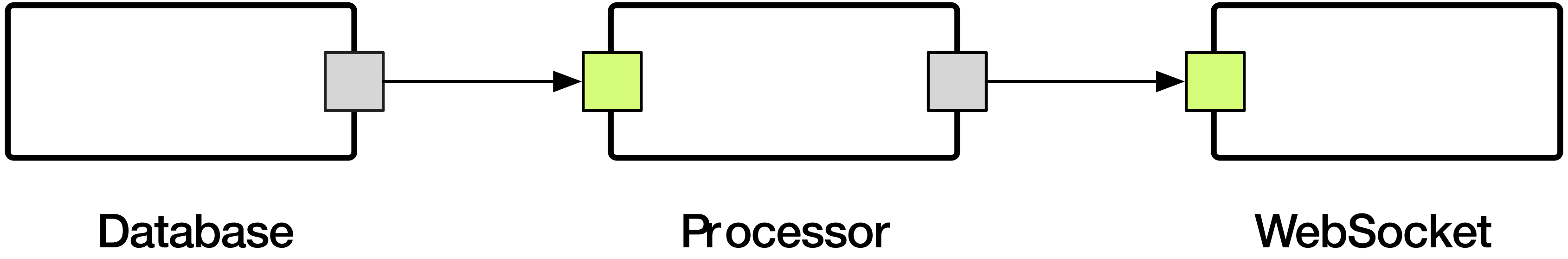
Wire it together

```
val graph = citySource.via(cityFlow).to(citySink)
```

Example - Streaming WebSocket



Example - Streaming WebSocket



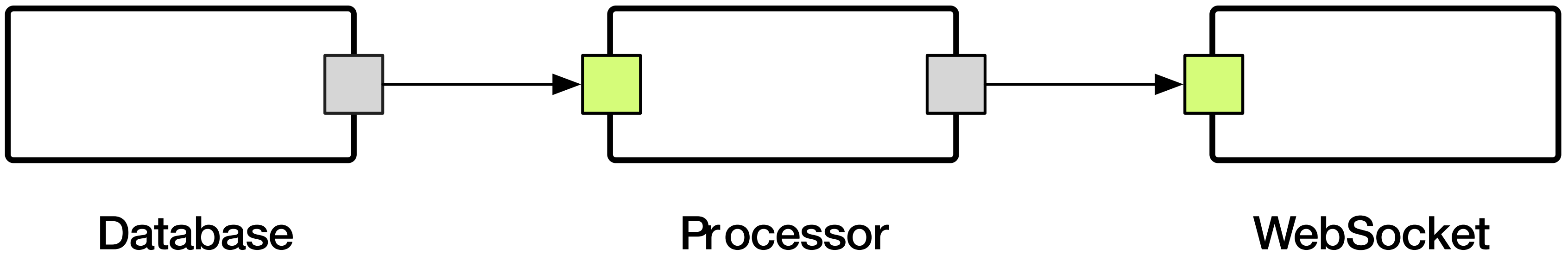
Source

```
// data source, populated from DB
val city: Source[City, Any] =
  Source
    .fromPublisher(
      postgres.stream(
        sql"select id, name, countrycode, district, population from city"
          .as[City]))

// map City into WebSocket TextMessage
def map(city: City): Message =
  TextMessage(city.asJson.noSpaces)

// construct the websocket source
def source: Source[Message, Any] =
  city
    .map(map)
    .delay(1.second, DelayOverflowStrategy.backpressure)
```

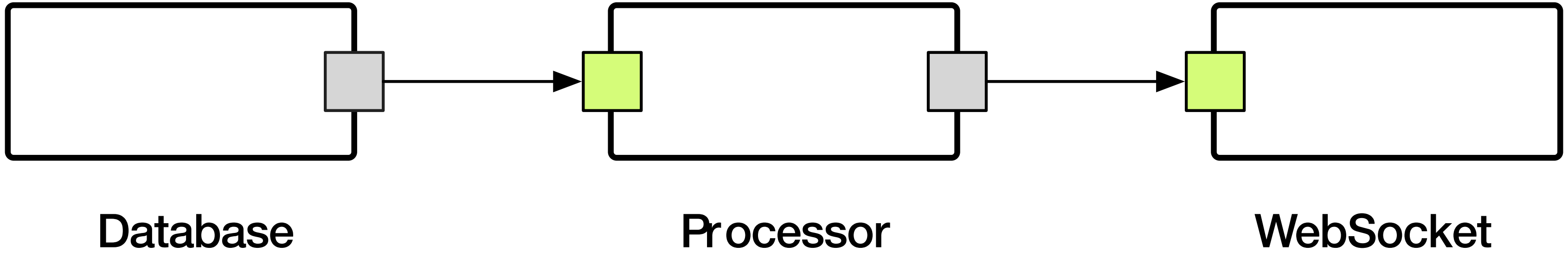
Example - Streaming WebSocket



Flow

```
// construct the WebSocket flow
val cityWebSocketFlow: Flow[Message, Message, Any] =
  Flow[Message]
    .flatMapConcat(_ => source)
```

Example - Streaming WebSocket

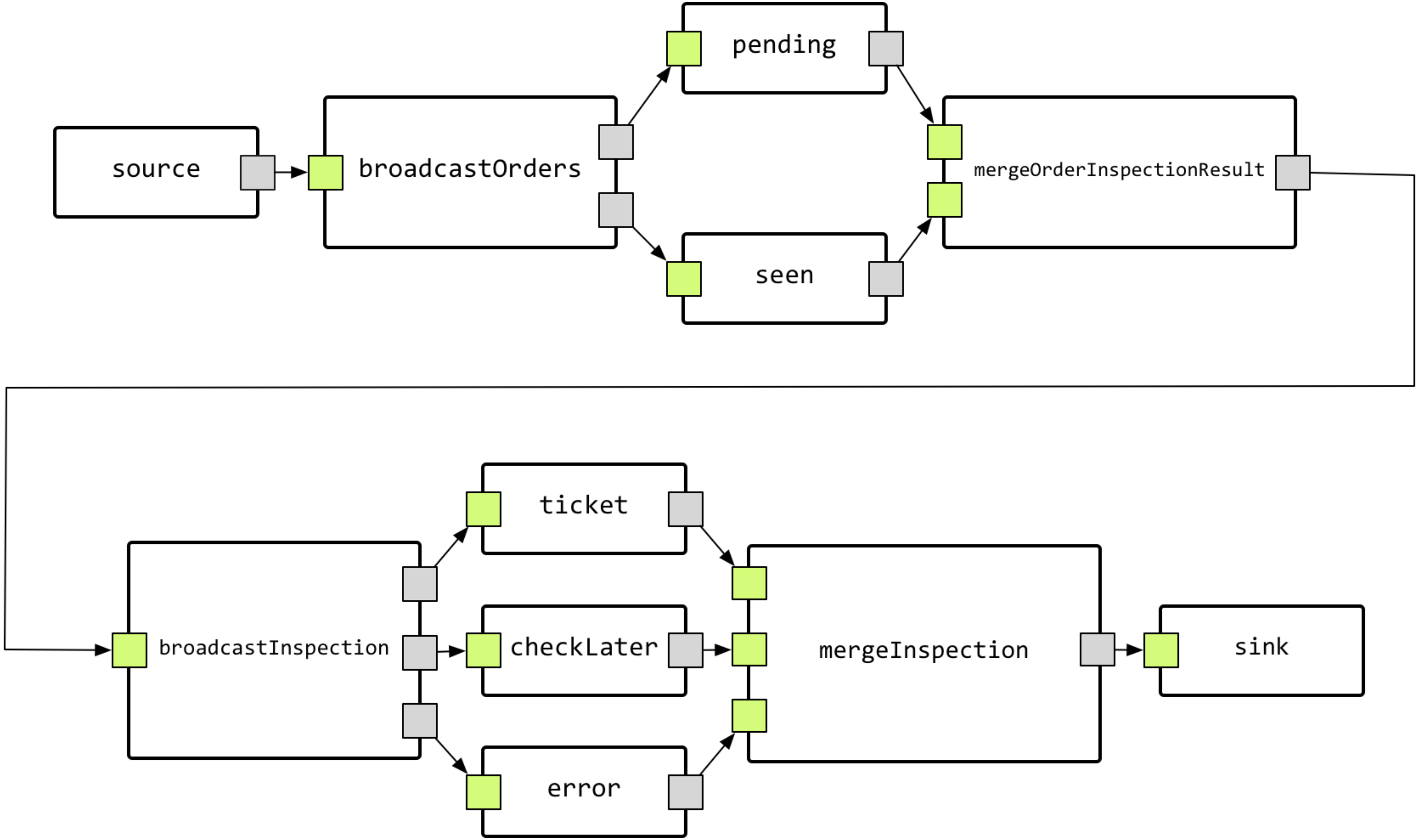


Sink

```
val route =
  pathPrefix("city") {
    pathEndOrSingleSlash {
      handleWebSocketMessages(cityWebSocketFlow)
    }
  }

val bindingFuture = Http().bindAndHandle(route, ip, port)
```

Real-World Stream - Order Monitor



```
def activityMonitor: KillSwitch = {

  val switch: SharedKillSwitch = KillSwitches.shared("ActivityMonitorProcessorKillSwitch")

  val graph =
    RunnableGraph.fromGraph(GraphDSL.create() { implicit b =>
      import GraphDSL.Implicits._

      val broadcastOrders            = b.add(Broadcast[StreamMessage](2))
      val mergeOrderInspectionResult = b.add(Merge[InspectionResult](2))
      val broadcastInspection        = b.add(Broadcast[InspectionResult](3))
      val mergeInspection            = b.add(Merge[Record](3))
      val source                     = b.add(streamSource)
      val pending                    = b.add(pendingFlow(switch))
      val seen                       = b.add(seenFlow(switch))
      val checkLater                 = b.add(checkLaterFlow(switch))
      val ticket                     = b.add(ticketFlow(switch))
      val error                      = b.add(errorFlow(switch))
      val sink                       = b.add(Producer.plainSink(producerSettings))

      source ~> broadcastOrders.in

      broadcastOrders.out(0) ~> pending ~> mergeOrderInspectionResult
      broadcastOrders.out(1) ~> seen ~> mergeOrderInspectionResult

      mergeOrderInspectionResult ~> broadcastInspection.in

      broadcastInspection.out(0) ~> ticket ~> mergeInspection
      broadcastInspection.out(1) ~> checkLater ~> mergeInspection
      broadcastInspection.out(2) ~> error ~> mergeInspection

      mergeInspection ~> sink

      ClosedShape
    })

  graph.run()

  switch
}
```

Bonus - Kleisli

```scala
case class Kleisli[F[_], A, B](run: A => F[B])
```

```scala
// Given an AuthenticatedUser, compose a DBIO[A]
type SecureAction[A] = Kleisli[DBIO, AuthenticatedUser, A]

// check the required permission, then, given the user, compose a DBIO[A]
def authorized[A](required: Permission)
                 (f: AuthenticatedUser => DBIO[A]): SecureAction[A]
```

```scala
def findValidRestaurantAggregate(uuid: RestaurantUUID):
  SecureAction[RestaurantAggregate] =
    authorized(Permissions.Guest) { guest =>
      // elmenus.com secrets ...
    }
```

```scala
get {
  onSuccess(
    db.run(
      service
        .findValidRestaurantAggregate(restaurantUUID).run(user))) { restaurant =>
          complete((StatusCodes.OK, restaurant))
      }
    }
```

Talk to us

That's all folks! Thank You

Code, Slides and Goodies @ https://github.com/hkarim/riseup-summit-2017