FUTURES & PROMISES

in Scala 2.10

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Typesafe

EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Agenda

FUTURES/PROMISES

EXECUTION CTXS

FUTURES IN PLAY

scala.concurrent.

FUTURE & PROMISE

FIRST, SOME *Motivation*

1

Several important libraries have their own future/promise implementation

1

Several important libraries have their own Future/Promise implementation

java.util.concurrent.Future
scala.actors.Future
com.twitter.util.Future

akka.dispatch.Future
scalaz.concurrent.Promise
net.liftweb.actor.LAFuture

This makes it clear that…

THIS MAKES IT CLEAR THAT...

FUTURES ARE AN IMPORTANT, POWERFUL ABSTRACTION

THIS MAKES IT CLEAR THAT...

→ FUTURES ARE AN IMPORTANT, POWERFUL ABSTRACTION

→ THERE'S FRAGMENTATION IN THE SCALA ECOSYSTEM

no hope of interop!

Furthermore…

Furthermore...

2 Java futures neither efficient nor composable

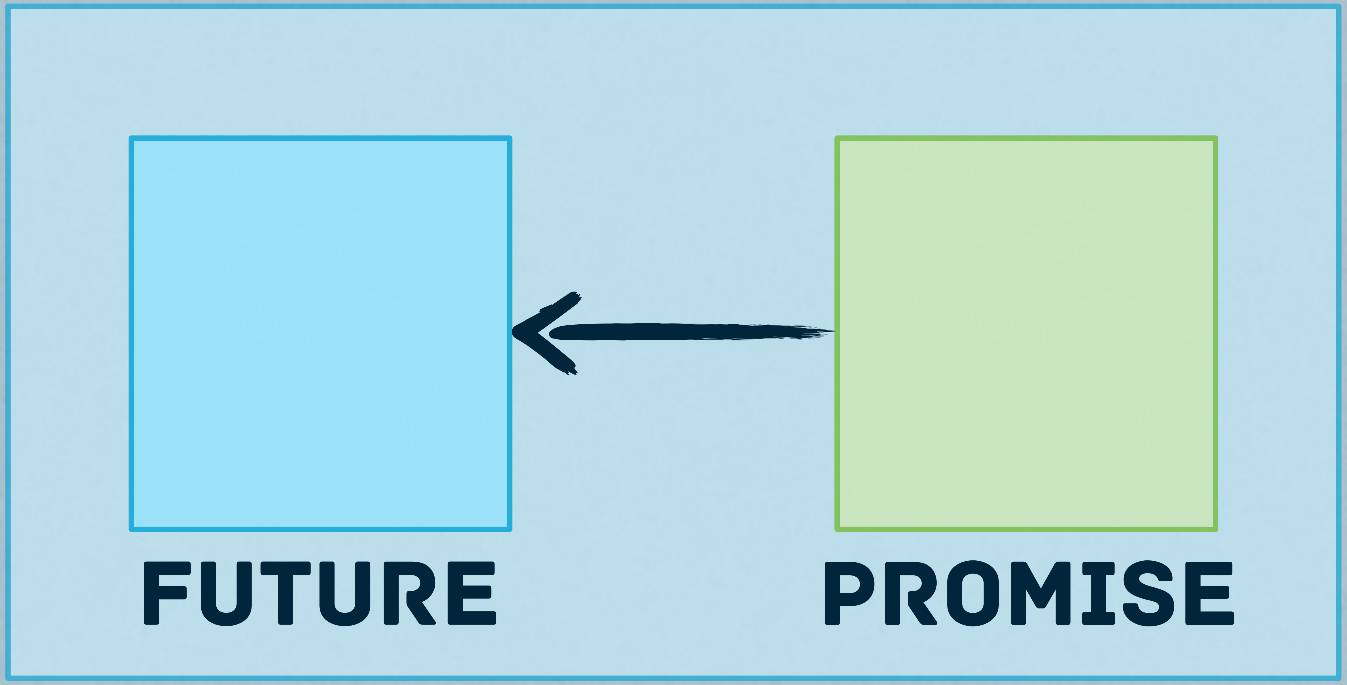
Furthermore...

2. Java futures neither efficient nor composable

3. We could make futures more powerful, by taking advantage of Scala's features

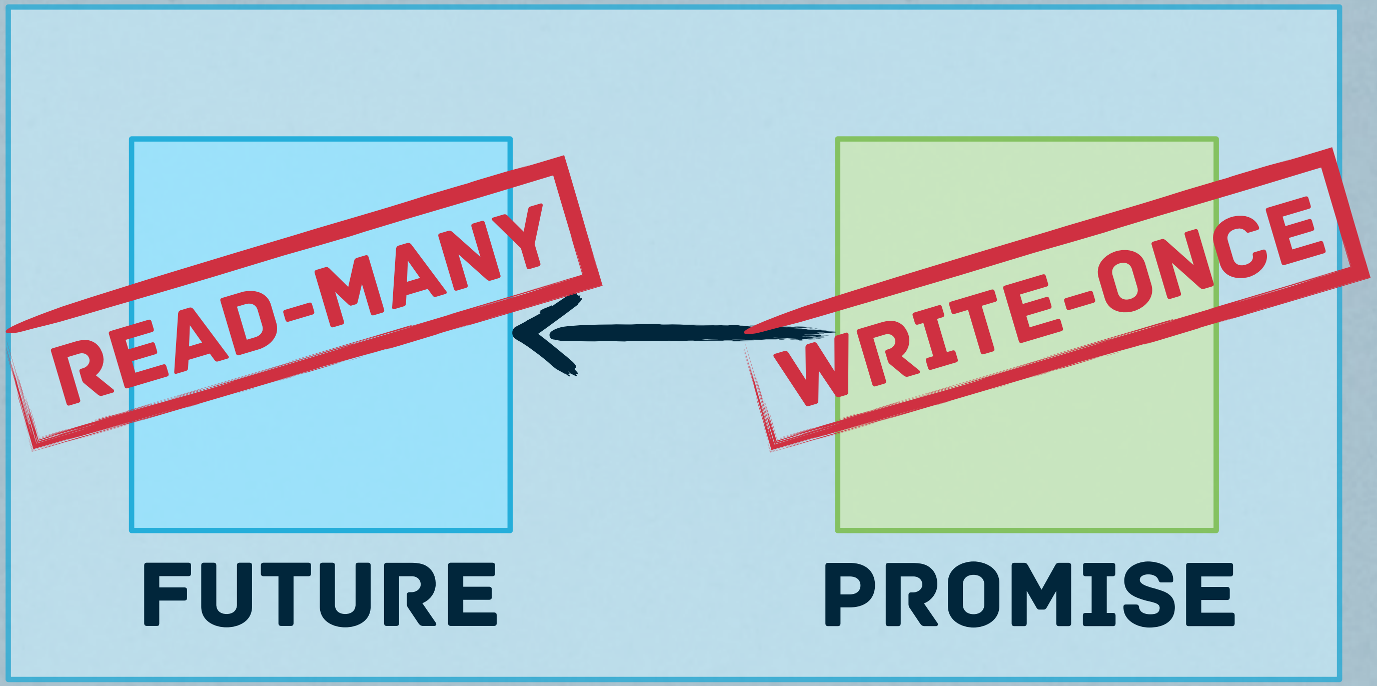
Futures&Promises

Can be thought of as a combined concurrency abstraction



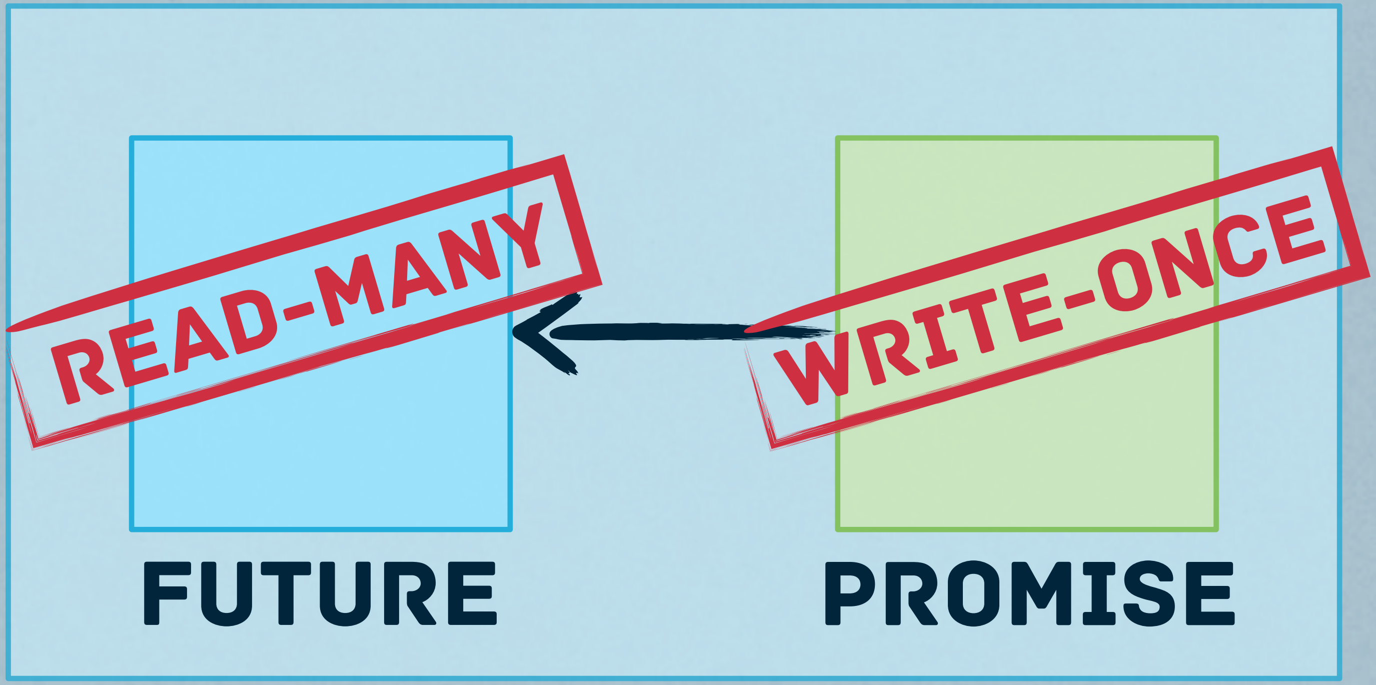
Futures&Promises

can be thought of as a combined concurrency abstraction



Futures&Promises

Can be thought of as a combined concurrency abstraction



Important Ops

- ✓ Start async computation
- ✓ Wait for result
- ✓ Assign result value
- ✓ Obtain associated future object

Success& Failure

A PROMISE `p` **OF TYPE** `Promise[T]` **CAN BE COMPLETED IN TWO WAYS...**

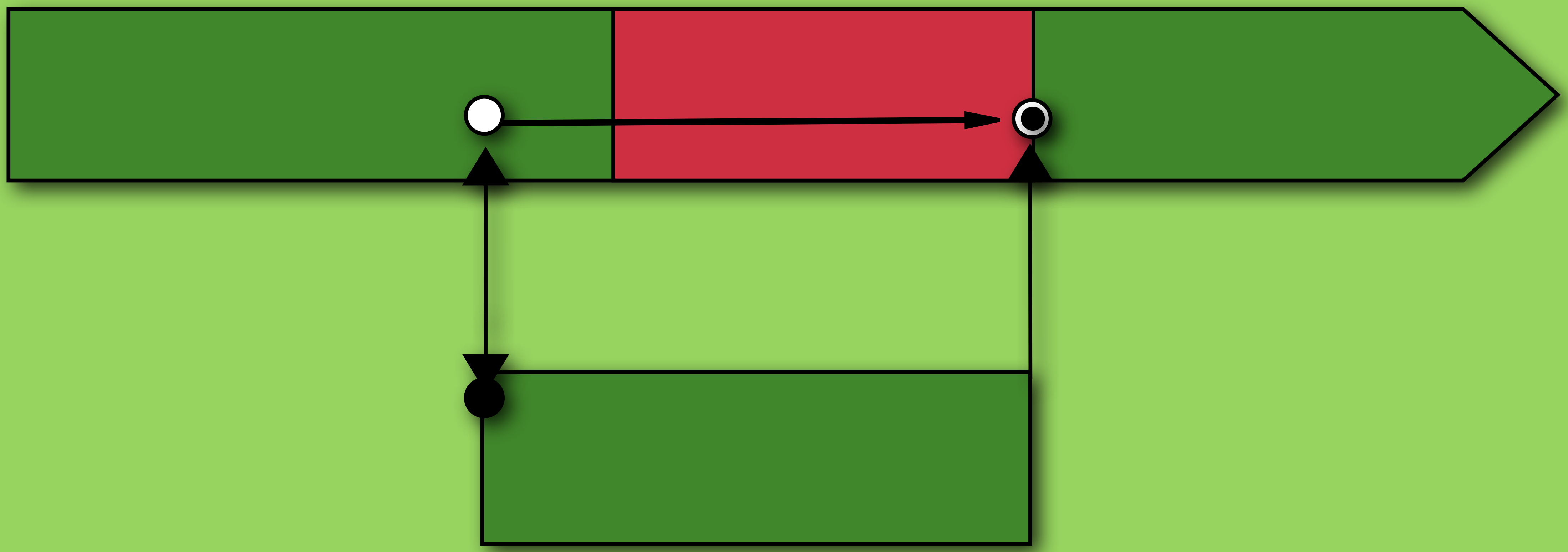
Success

```
val result: T = ...
p.success(result)
```

Failure

```
val exc = new Exception(“something went wrong”)
p.failure(exc)
```

java.util.concurrent.FUTURE

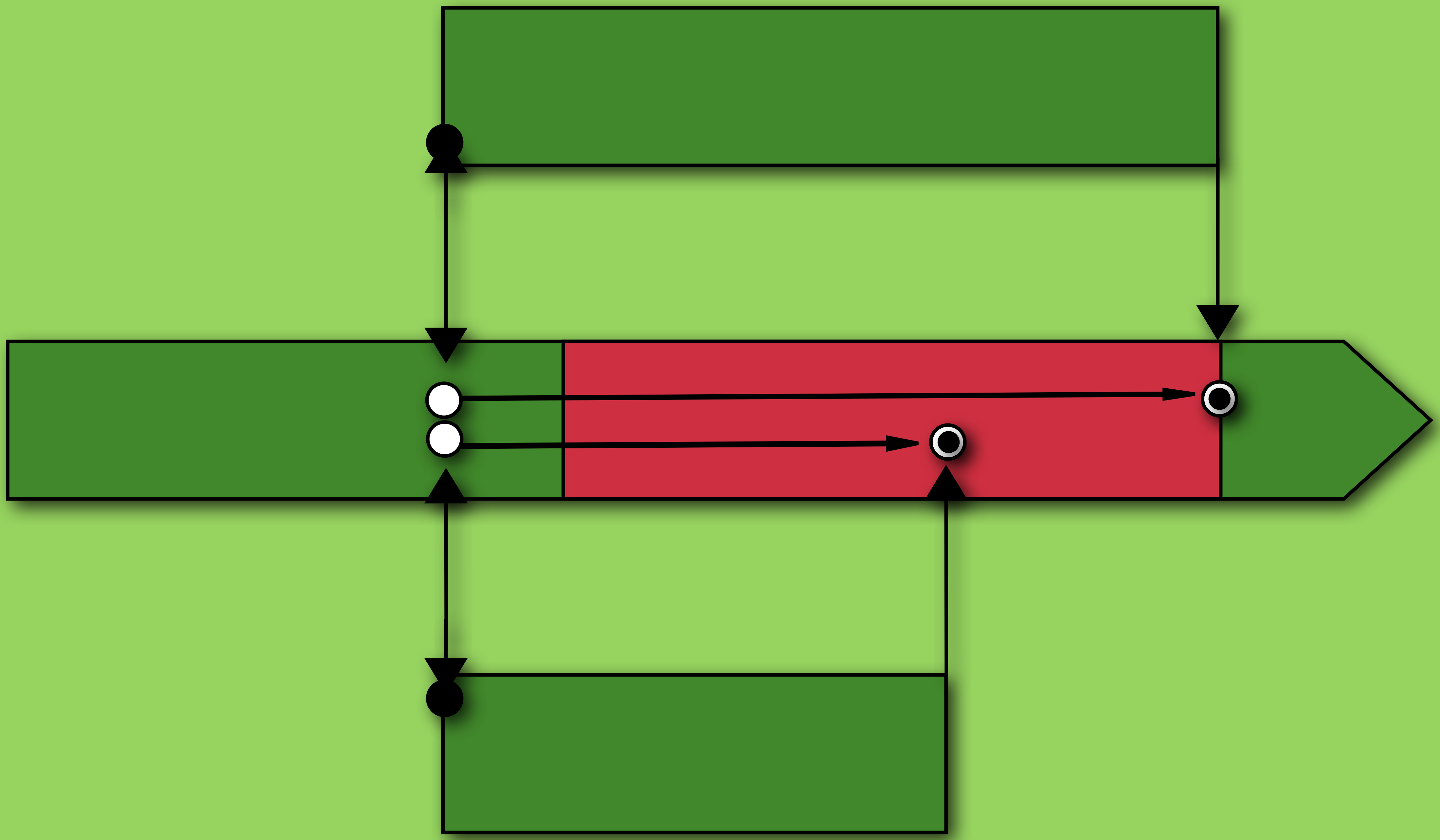


- ○ FUTURE
- ● PROMISE
- ◉ FUTURE WITH VALUE

Green meaningful work

Red thread waiting on the result of another thread

java.util.concurrent.FUTURE

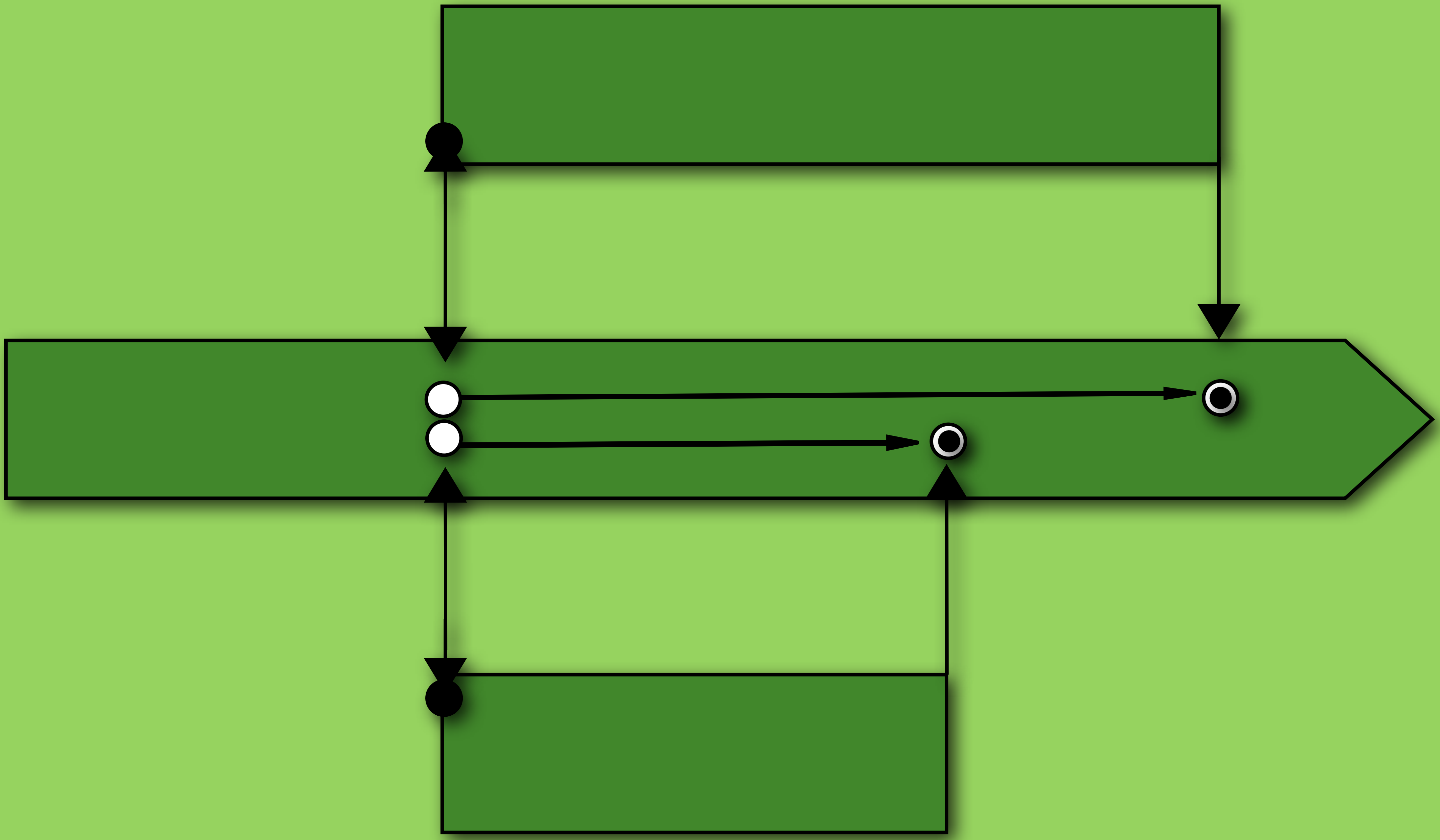


- ○ FUTURE
- ● PROMISE
- ◉ FUTURE WITH VALUE

Green meaningful work

Red thread waiting on the result of another thread

what we'd like to do instead



- ○ FUTURE
- ● PROMISE
- ◉ FUTURE WITH VALUE

Green meaningful work

Red thread waiting on the result of another thread

Async&NonBlocking

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GOAL: Do not block current thread while waiting for result of future

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GOAL: *Do not block current thread while waiting for result of future*

Callbacks

- **REGISTER CALLBACK** *which is invoked (asynchronously) when future is completed*
- **ASYNC COMPUTATIONS NEVER BLOCK** *(except for managed blocking)*

Async&NonBlocking

GOAL: *Do not block current thread while waiting for result of future*

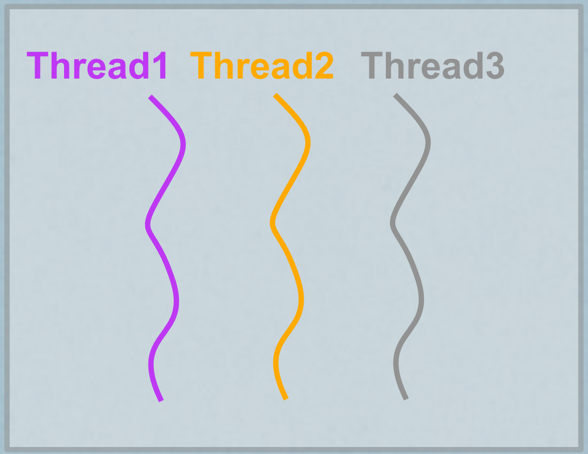
Callbacks

- **REGISTER CALLBACK** *which is invoked (asynchronously) when future is completed*
- **ASYNC COMPUTATIONS NEVER BLOCK** *(except for managed blocking)*

USER DOESN'T HAVE TO EXPLICITLY MANAGE CALLBACKS. HIGHER-ORDER FUNCTIONS INSTEAD!

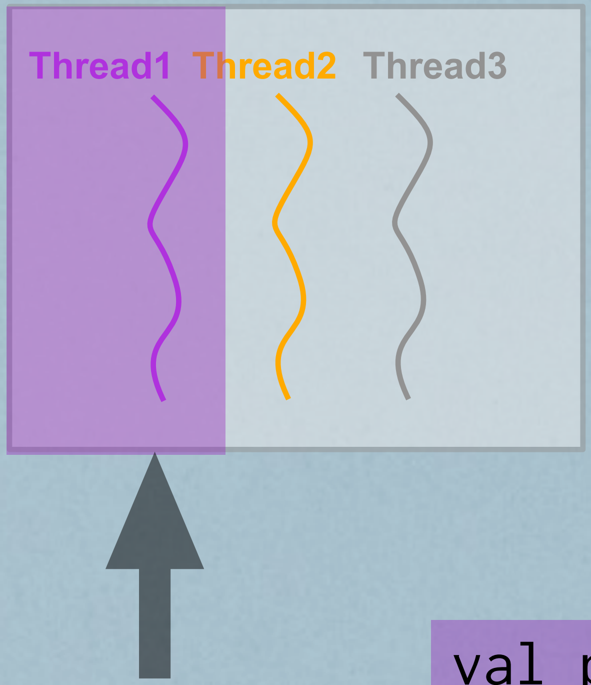
Futures&Promises

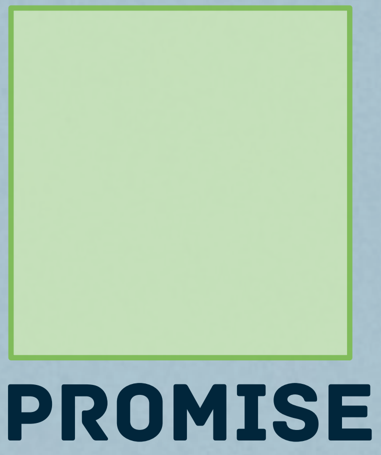
EXAMPLE



Futures&Promises

EXAMPLE



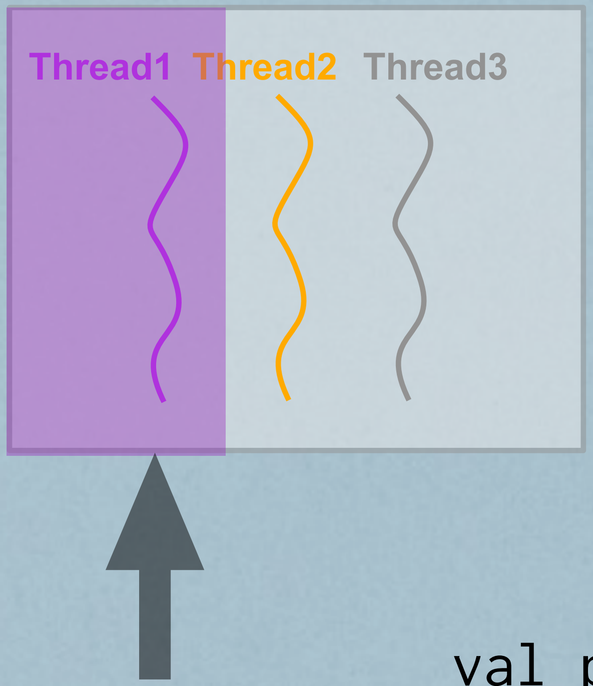


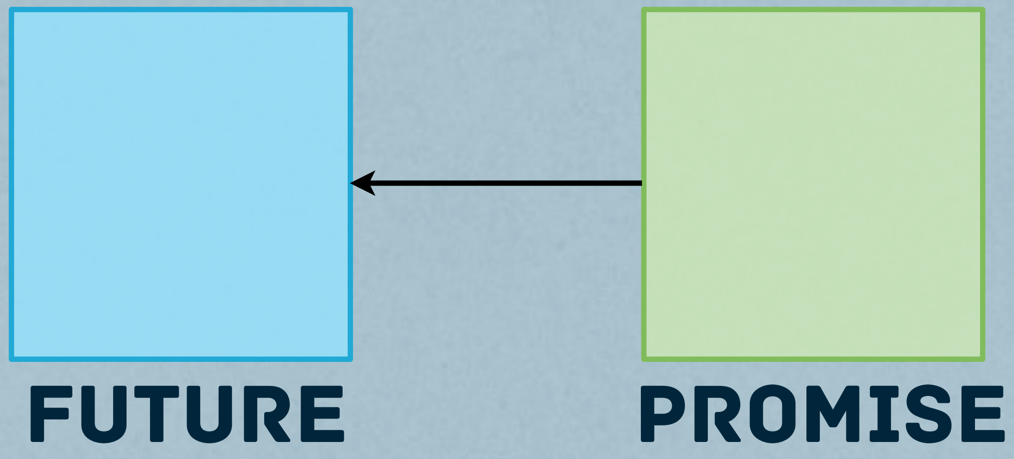
```
val p = Promise[Int]() // Thread 1
```

(CREATE PROMISE)

Futures&Promises

EXAMPLE




FUTURE

PROMISE

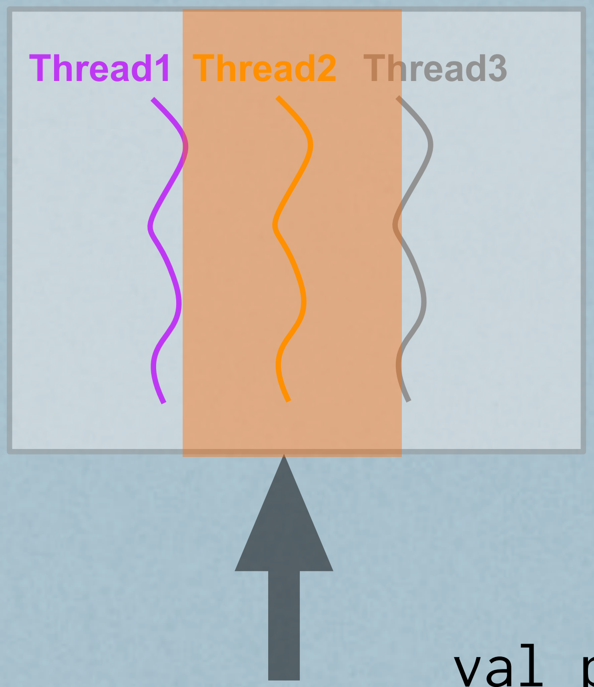
```
val p = Promise[Int]() // Thread 1
val f = p.future       // Thread 1
```

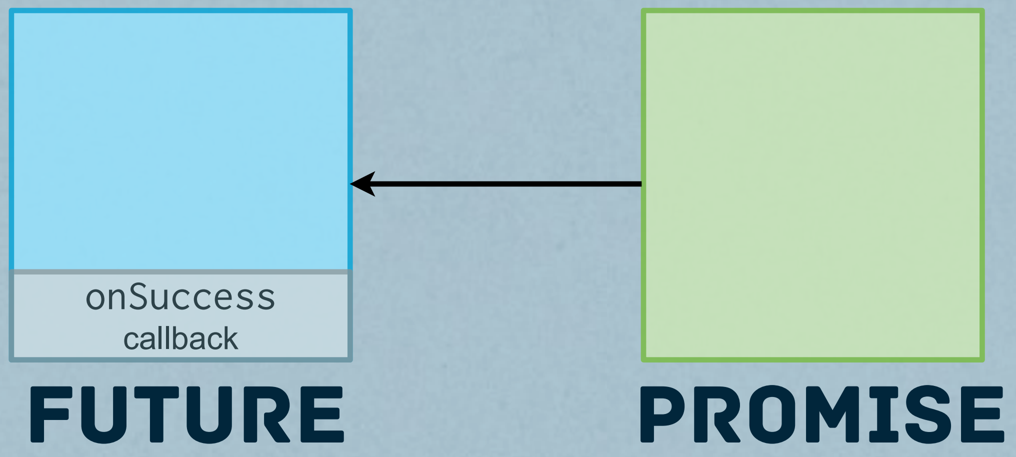
(CREATE PROMISE)

(GET REFERENCE TO FUTURE)

Futures&Promises

EXAMPLE




onSuccess
callback

FUTURE

PROMISE

```
val p = Promise[Int]() // Thread 1
val f = p.future       // Thread 1
f onSuccess {           // Thread 2
  case x: Int => println(“Successful!”)
}
```

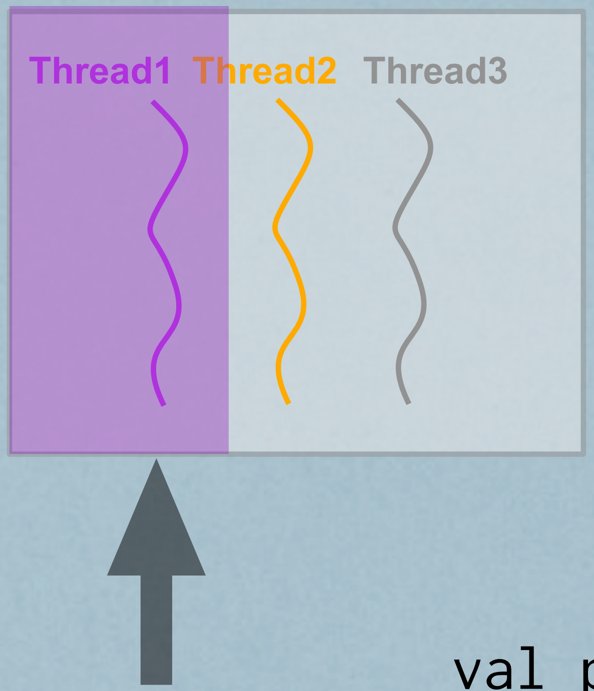
(CREATE PROMISE)

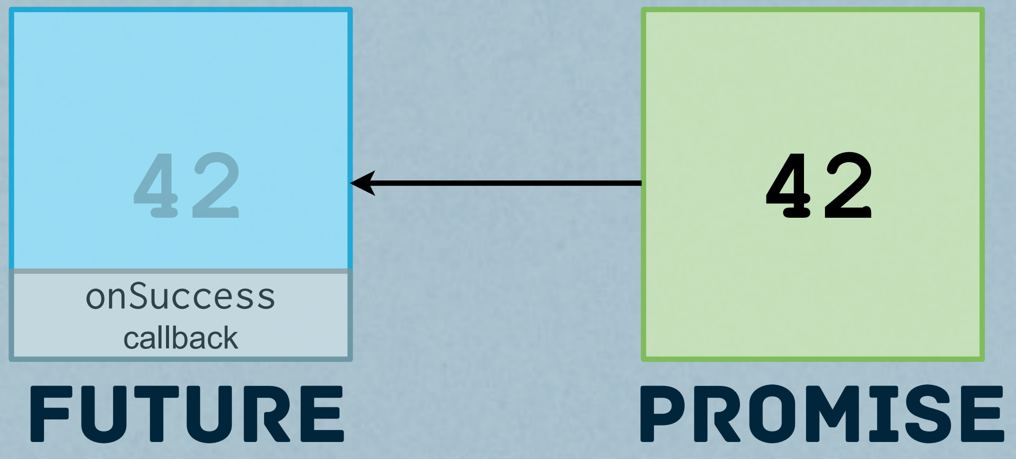
(GET REFERENCE TO FUTURE)

(REGISTER CALLBACK)

Futures&Promises

EXAMPLE





```
val p = Promise[Int]() // Thread 1
val f = p.future       // Thread 1
f onSuccess {           // Thread 2
  case x: Int => println(“Successful!”)
}
p.success(42)          // Thread 1
```

(CREATE PROMISE)

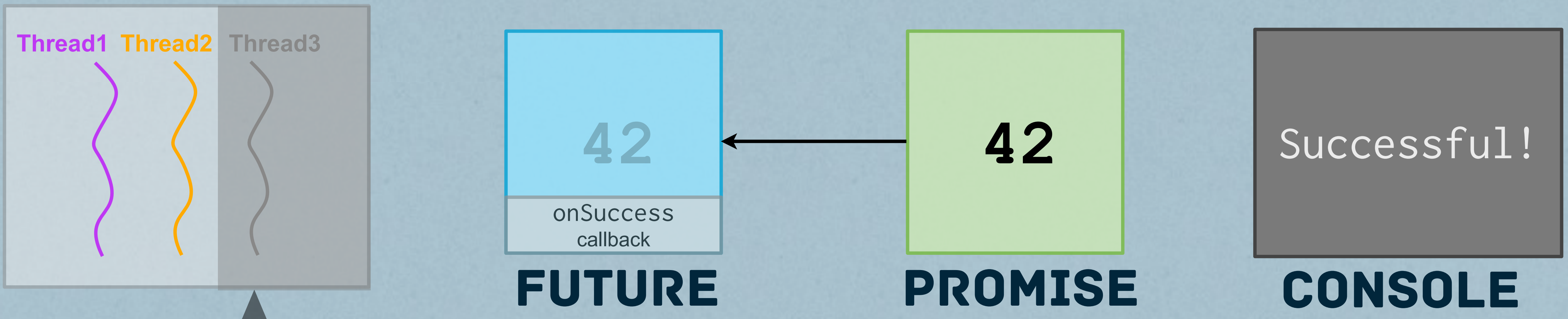
(GET REFERENCE TO FUTURE)

(REGISTER CALLBACK)

(WRITE TO PROMISE)

Futures&Promises

EXAMPLE



```
val p = Promise[Int]() // Thread 1
val f = p.future       // Thread 1
f onSuccess {           // Thread 2
  case x: Int => println("Successful!")
}                      // Thread
p.success(42)          // Thread 1
```

(CREATE PROMISE)

(GET REFERENCE TO FUTURE)

(REGISTER CALLBACK)

(EXECUTE CALLBACK)

(WRITE TO PROMISE)

NOTE: onSuccess **CALLBACK EXECUTED EVEN IF** f **HAS ALREADY BEEN COMPLETED AT TIME OF REGISTRATION**

Combinators

- Composability thru higher-order funcs
- Standard monadic combinators

```
def map[S](f: T => S): Future[S]
```

```
val purchase: Future[Int] = rateQuote map {
  quote => connection.buy(amount, quote)
}
```

```
def filter(pred: T => Boolean): Future[T]
```

```
val postBySmith: Future[Post] =
   post.filter(_.author == “Smith”)
```

Combinators

- COMPOSABILITY THRU HIGHER-ORDER FUNCS
- STANDARD MONADIC COMBINATORS

```
def map[S](f: T => S): Future[S]
```

```
val purchase: Future[Int] = rateQuote map {
  quote => connection.buy(amount, quote)
}
```

IF MAP FAILS: purchase is completed with unhandled exception

```
def filter(pred: T => Boolean): Future[T]
```

```
val postBySmith: Future[Post] =
   post.filter(_.author == “Smith”)
```

IF FILTER FAILS: postBySmith completed with NoSuchElementException

Combinators

ADDITIONAL FUTURE-SPECIFIC HIGHER-ORDER FUNCTIONS HAVE BEEN INTRODUCED

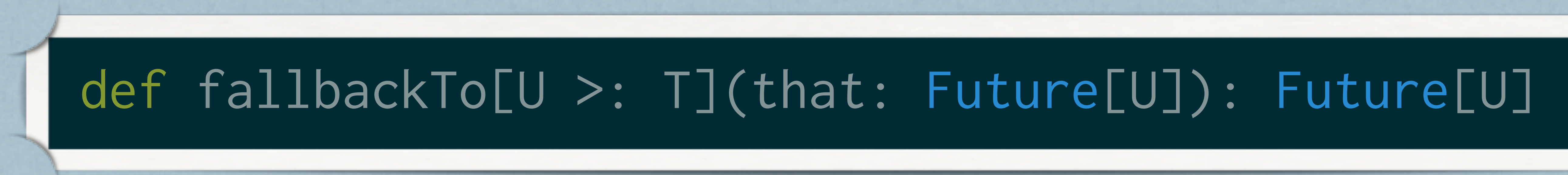
```scala
def fallbackTo[U >: T](that: Future[U]): Future[U]
```

```scala
val fut: Future[T] = Future.firstCompletedOf[T](futures)
```

```scala
def andThen(pf: PartialFunction[...]): Future[T]
```

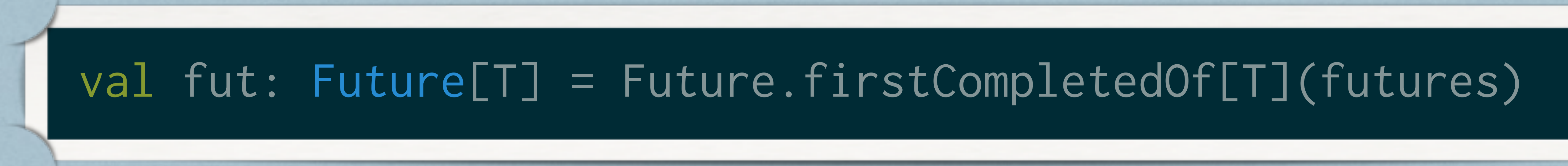
Combinators

ADDITIONAL FUTURE-SPECIFIC HIGHER-ORDER FUNCTIONS HAVE BEEN INTRODUCED



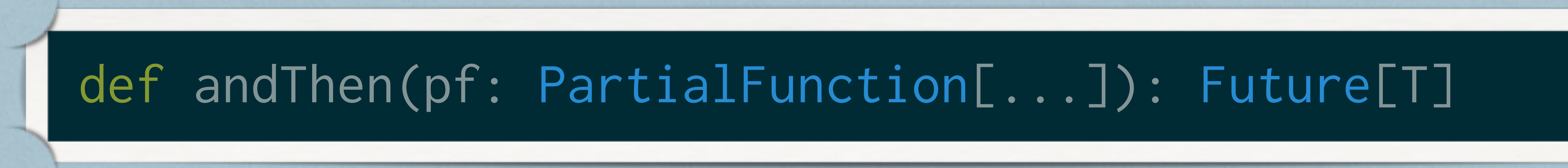
```
def fallbackTo[U >: T](that: Future[U]): Future[U]
```

"falls back" to `that` future in case of failure



```
val fut: Future[T] = Future.firstCompletedOf[T](futures)
```

returns a future completed with result of first completed future



```
def andThen(pf: PartialFunction[...]): Future[T]
```

allows one to define a sequential execution over a chain of futures

scala.concurrent. EXECUTION CONTEXT

Threadpools...

ARE NEEDED BY:

- **FUTURES** for executing callbacks and function arguments
- **ACTORS** for executing message handlers, scheduled tasks, etc.
- **PARALLEL COLLECTIONS** for executing data-parallel operations

Scala 2.10 introduces

EXECUTION CONTEXTS

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Goal

PROVIDE GLOBAL THREADPOOL AS PLATFORM SERVICE TO BE SHARED BY ALL PARALLEL FRAMEWORKS

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EXECUTION CONTEXTS

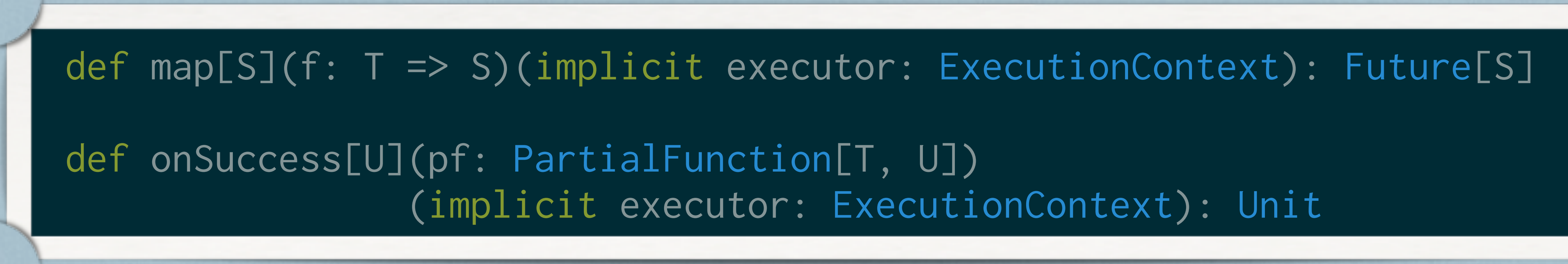
Goal

PROVIDE GLOBAL THREADPOOL AS PLATFORM SERVICE TO BE SHARED BY ALL PARALLEL FRAMEWORKS

- `scala.concurrent` *package provides global* `ExecutionContext`
- Default `ExecutionContext` backed by the most recent fork join pool (collaboration with Doug Lea, SUNY Oswego)

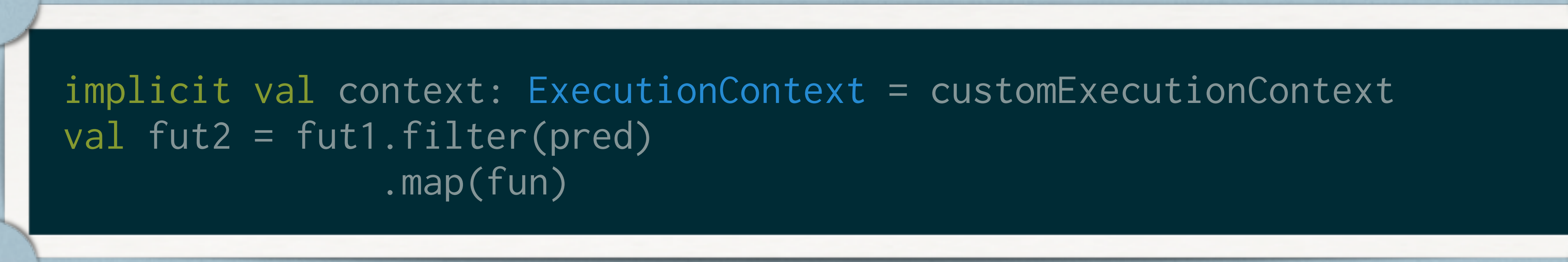
Implicit Execution Ctxs

Asynchronous computations are executed on an `ExecutionContext` which is provided implicitly.



```scala
def map[S](f: T => S)(implicit executor: ExecutionContext): Future[S]

def onSuccess[U](pf: PartialFunction[T, U])
                (implicit executor: ExecutionContext): Unit
```

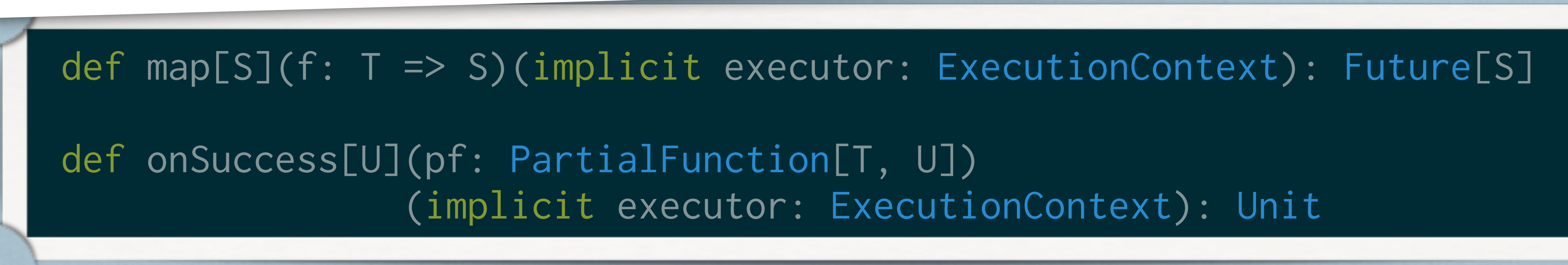
Implicit parameters enable fine-grained selection of the `ExecutionContext`:



```scala
implicit val context: ExecutionContext = customExecutionContext
val fut2 = fut1.filter(pred)
               .map(fun)
```

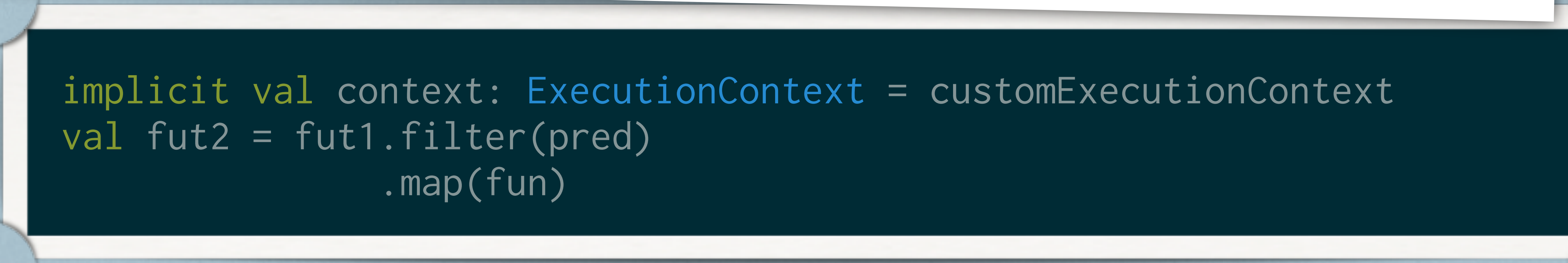
Implicit Execution Ctxs

IMPLICIT ExecutionContexts **ALLOW SHARING ECS BETWEEN FRAMEWORKS**



```
def map[S](f: T => S)(implicit executor: ExecutionContext): Future[S]

def onSuccess[U](pf: PartialFunction[T, U])
                (implicit executor: ExecutionContext): Unit
```

ENABLES FLEXIBLE SELECTION OF EXECUTION POLICY



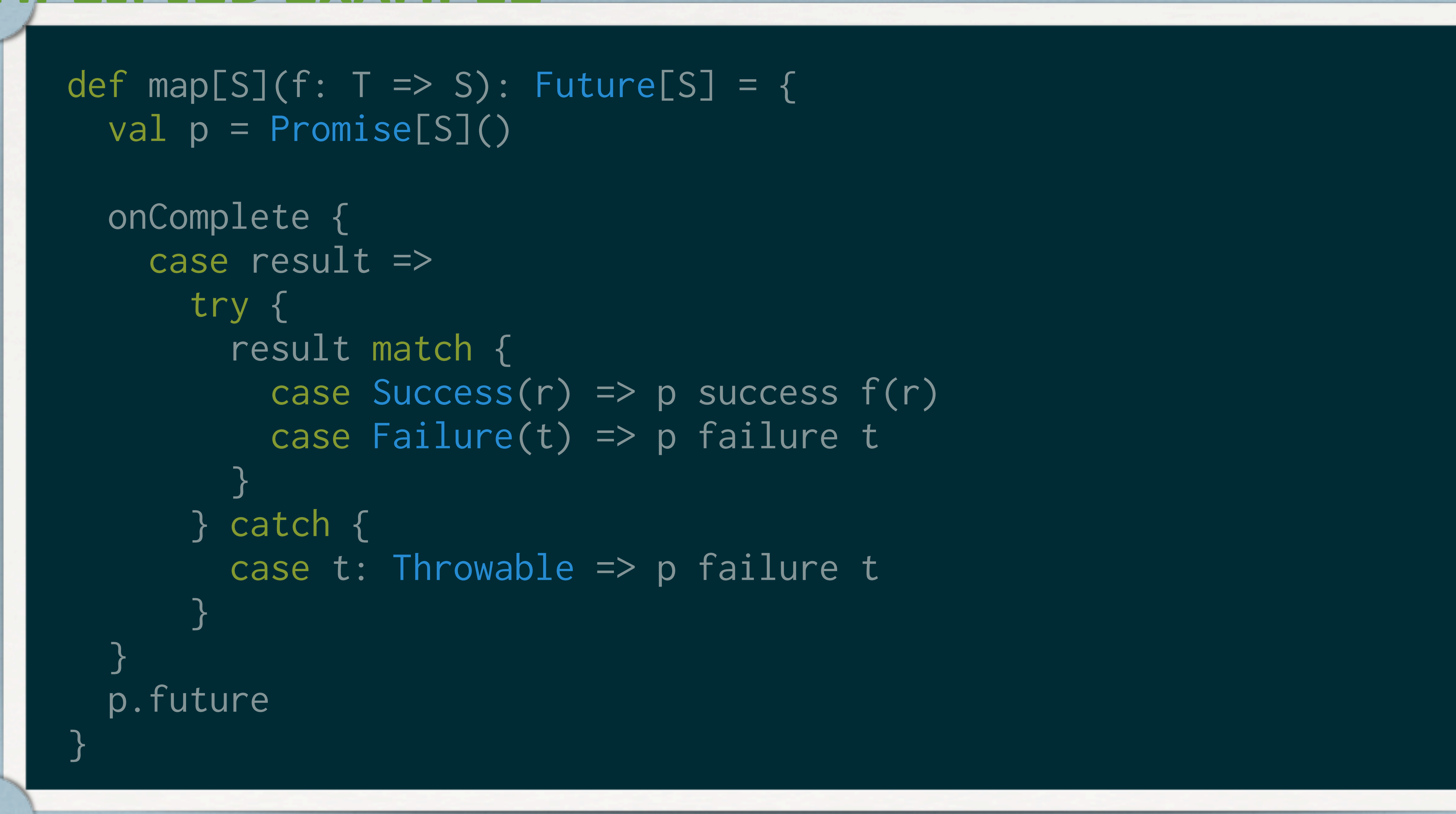
```
implicit val context: ExecutionContext = customExecutionContext
val fut2 = fut1.filter(pred)
               .map(fun)
```

Future

THE IMPLEMENTATION

Many operations implemented in terms of promises

SIMPLIFIED EXAMPLE

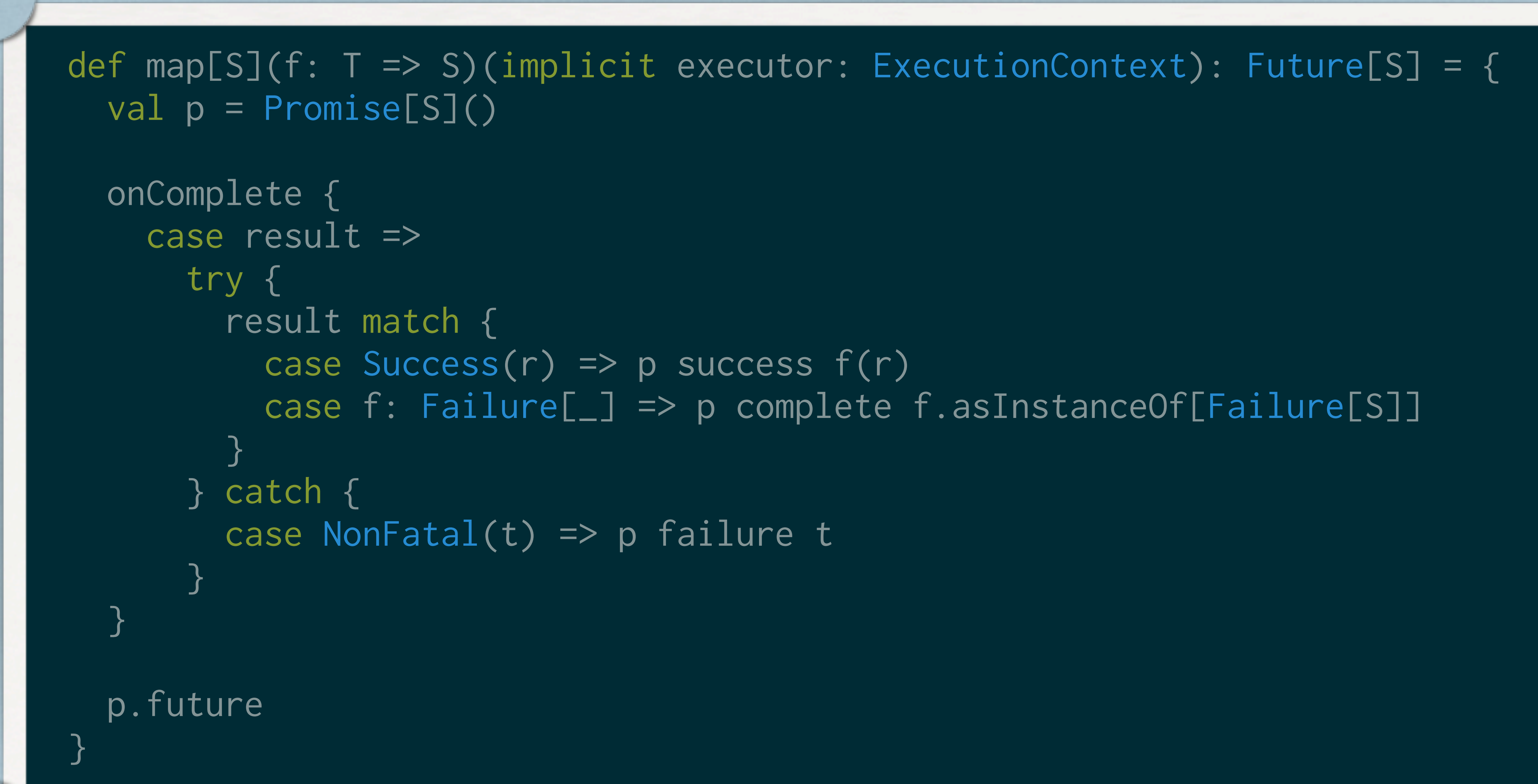


```scala
def map[S](f: T => S): Future[S] = {
  val p = Promise[S]()

  onComplete {
    case result =>
      try {
        result match {
          case Success(r) => p success f(r)
          case Failure(t) => p failure t
        }
      } catch {
        case t: Throwable => p failure t
      }
  }
  p.future
}
```

Future

THE REAL IMPLEMENTATION

The real implementation (a) adds an implicit ExecutionContext, (b) avoids extra object creations, and (c) catches only non-fatal exceptions:



```
def map[S](f: T => S)(implicit executor: ExecutionContext): Future[S] = {
  val p = Promise[S]()

  onComplete {
    case result =>
      try {
        result match {
          case Success(r) => p success f(r)
          case f: Failure[_] => p complete f.asInstanceOf[Failure[S]]
        }
      } catch {
        case NonFatal(t) => p failure t
      }
  }

  p.future
}
```

Promise
THE IMPLEMENTATION

Promise *is the work horse of the futures implementation.*

A Promise[T] *can be in one of two states:*

PENDING

No result has been written to the promise.
State represented using a list of callbacks (initially empty).

COMPLETED

The promise has been assigned a successful result or exception.
State represented using an instance of Try[T]

Invoking Promise.complete triggers a transition from state Pending to Completed

A PROMISE CAN BE COMPLETED AT MOST ONCE:

```scala
def complete(result: Try[T]): this.type =
  if (tryComplete(result)) this
  else throw new IllegalStateException("Promise already completed.")
```

Completing a Promise

```
def tryComplete(value: Try[T]): Boolean = {
  val resolved = resolveTry(value)
  (try {
    @tailrec
    def tryComplete(v: Try[T]): List[CallbackRunnable[T]] = {
      getState match {
        case raw: List[_] =>
          val cur = raw.asInstanceOf[List[CallbackRunnable[T]]]
          if (updateState(cur, v)) cur else tryComplete(v)
        case _ => null
      }
    }
    tryComplete(resolved)
  } finally {
    synchronized { notifyAll() } // Notify any blockers
  }) match {
    case null             => false
    case rs if rs.isEmpty => true
    case rs               =>
      rs.foreach(_.executeWithValue(resolved)); true
  }
}
```

THE AWKWARD SQUAD

```
abstract class AbstractPromise {
    private volatile Object _ref;
    final static long _refoffset;

    static {
        try {
            _refoffset =
                Unsafe.instance.objectFieldOffset(
                    AbstractPromise.class.getDeclaredField("_ref"));
        } catch (Throwable t) {
            throw new ExceptionInInitializerError(t);
        }
    }

    protected boolean updateState(Object oldState, Object newState) {
        return
            Unsafe.instance.compareAndSwapObject(this, _refoffset,
                                                 oldState, newState);
    }

    protected final Object getState() {
        return _ref;
    }
}
```

Integrating Futures & Actors

Futures are results of asynchronous message sends

When a response is expected

```
val response: Future[Any] = socialGraph ? getFriends(user)
```

Implementing synchronous send (untyped):

```
def syncSend(to: ActorRef, msg: Any, timeout: Duration): Any = {
  val fut = to ? msg
  Await.result(fut, timeout)
}
```

Fu
wr

Recovering types

```
val friendsFut: Future[Seq[Friend]] = response.mapTo[Seq[Friend]]
```

INTEGRATING Futures & Actors

Futures are results of asynchronous message sends

WHEN A RESPONSE IS EXPECTED

```scala
val response: Future[Any] = socialGraph ? getFriends(user)
```

`friendsFut` **IS EITHER COMPLETED WITH A SUCCESSFUL RESULT OR WITH A WRAPPED EXCEPTION IF RESPONSE TIMES OUT OR IS NOT OF TYPE** `Seq[Friend]`

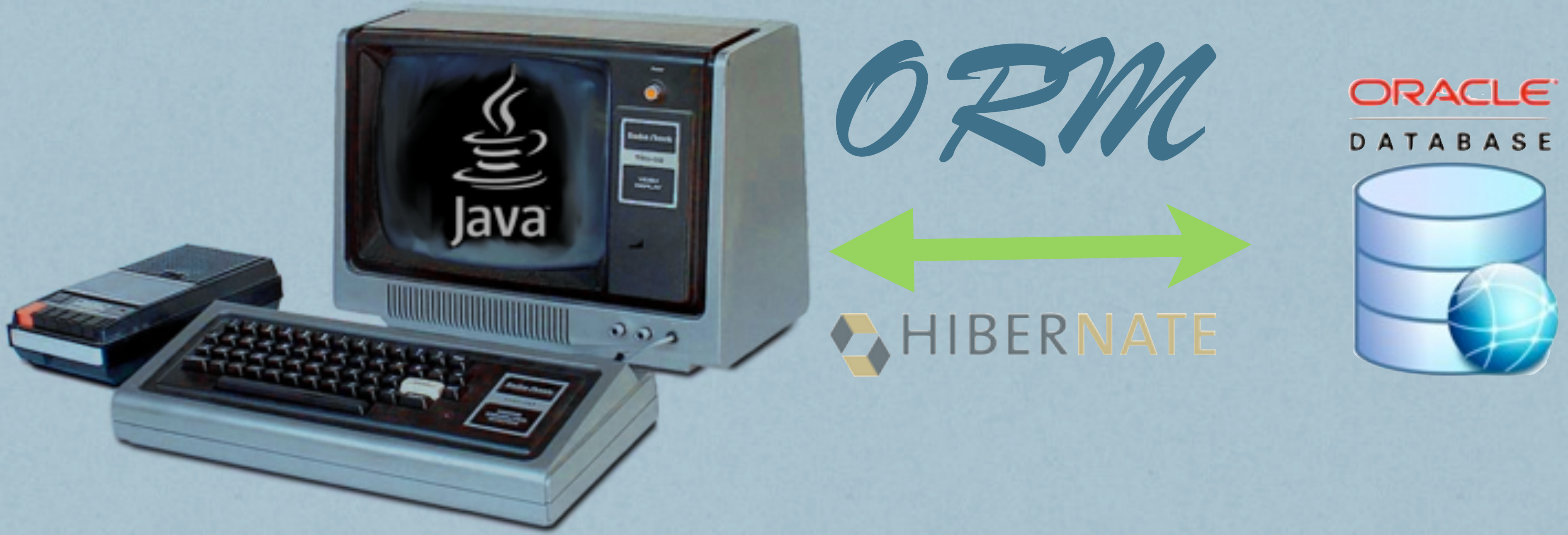
RECOVERING TYPES

```scala
val friendsFut: Future[Seq[Friend]] = response.mapTo[Seq[Friend]]
```

THE PLAY *Example*

Ye Olde Webapp

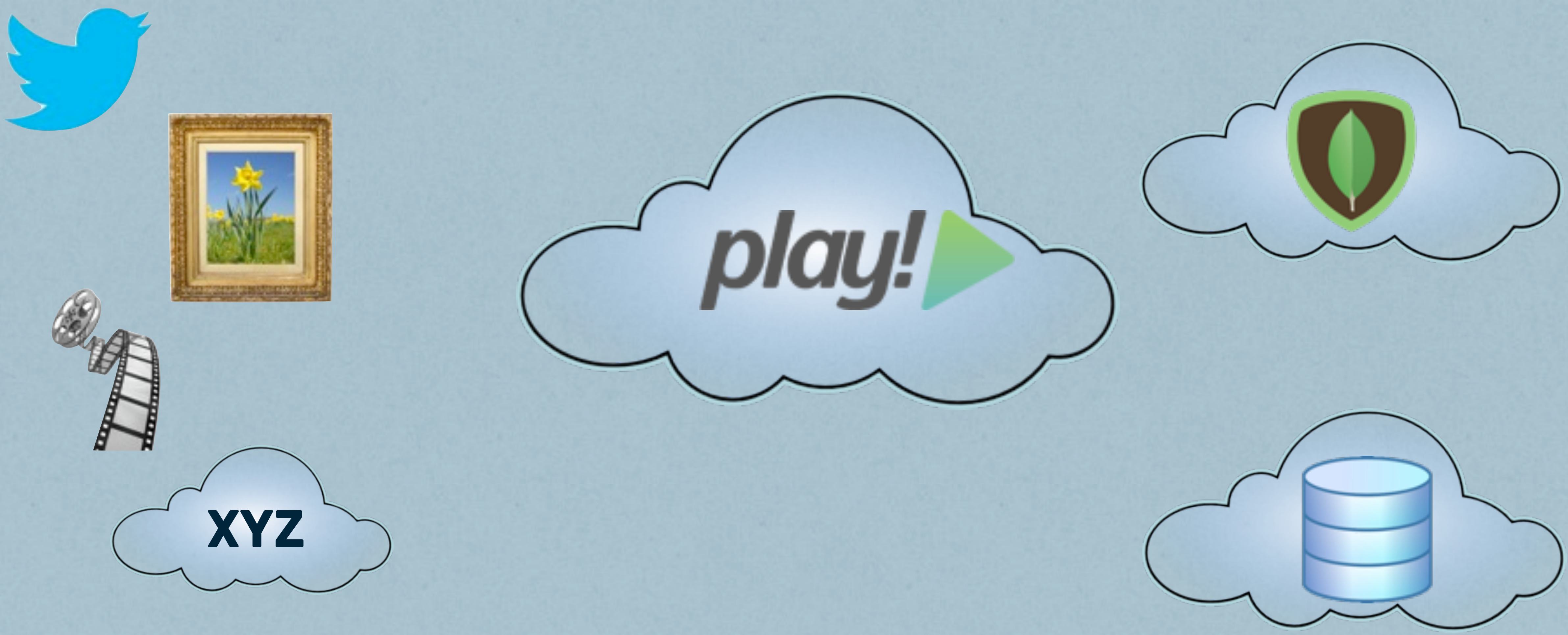
databases



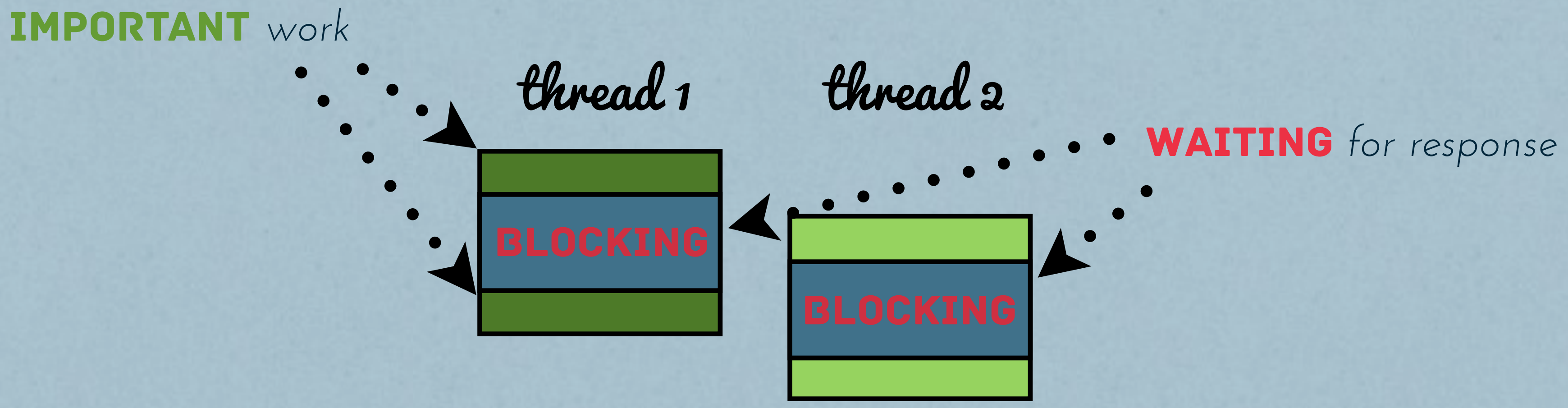
ORM

The Future of webapps is Now

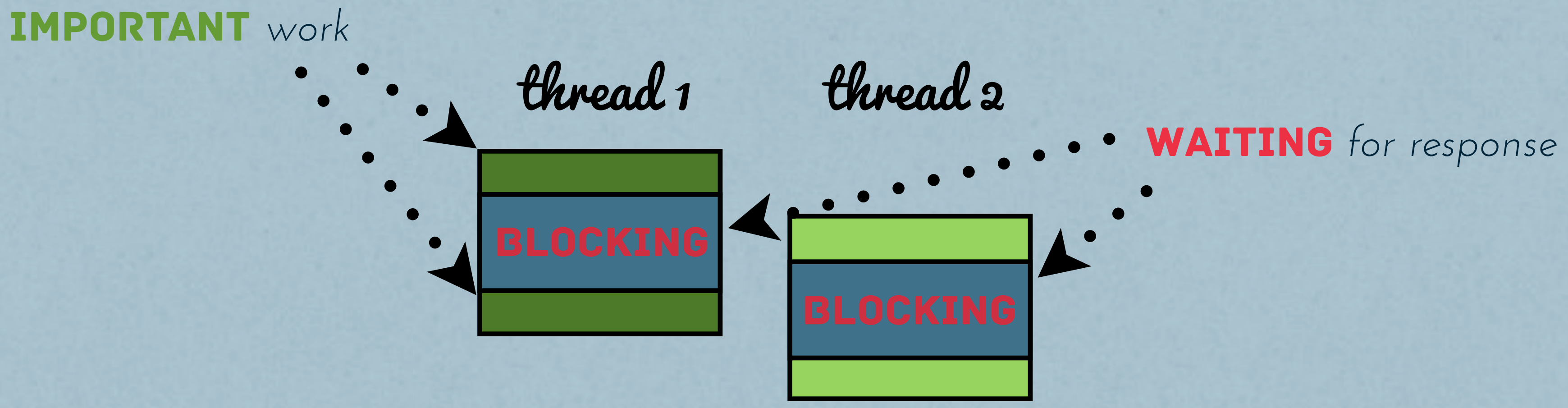
Services



Synchronous IO



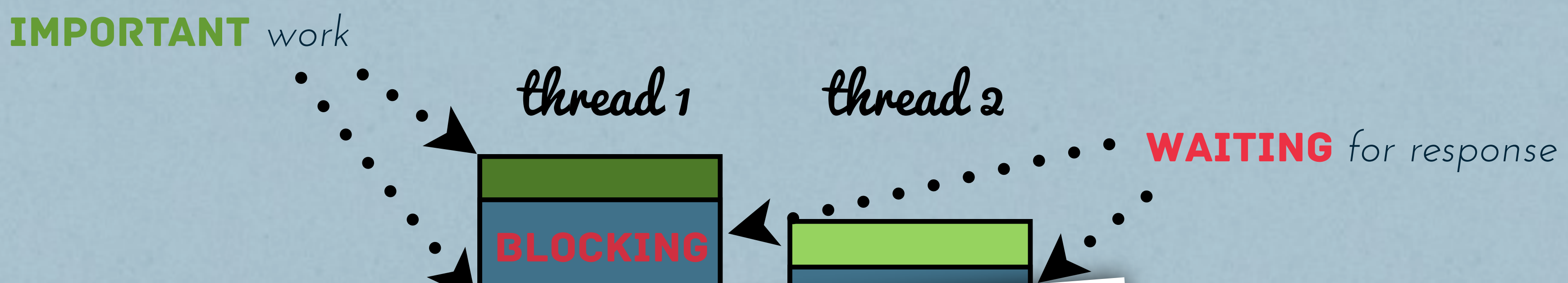
Synchronous IO



MEANS:

N requests == N threads

Synchronous IO



IMPORTANT work

thread 1

thread 2

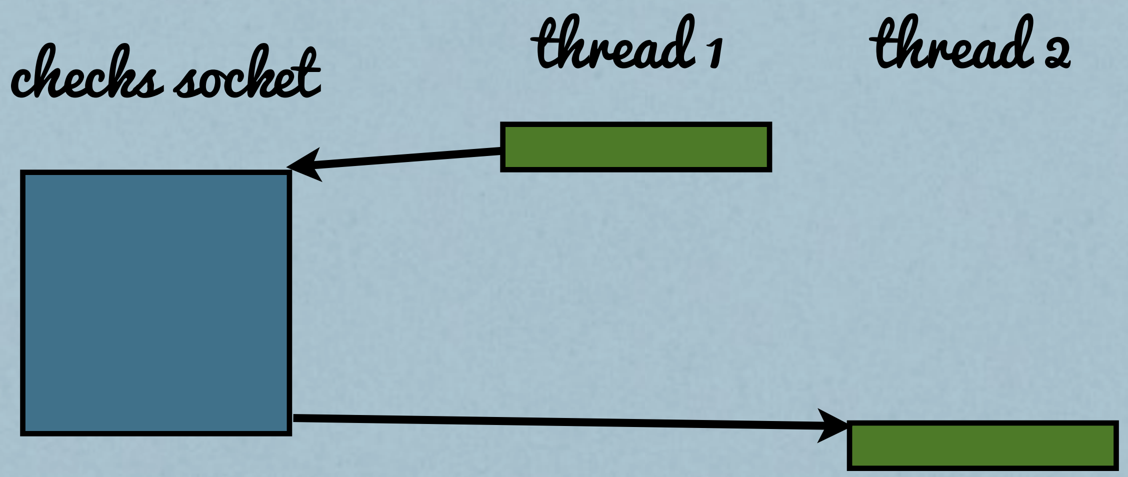
BLOCKING

WAITING for response

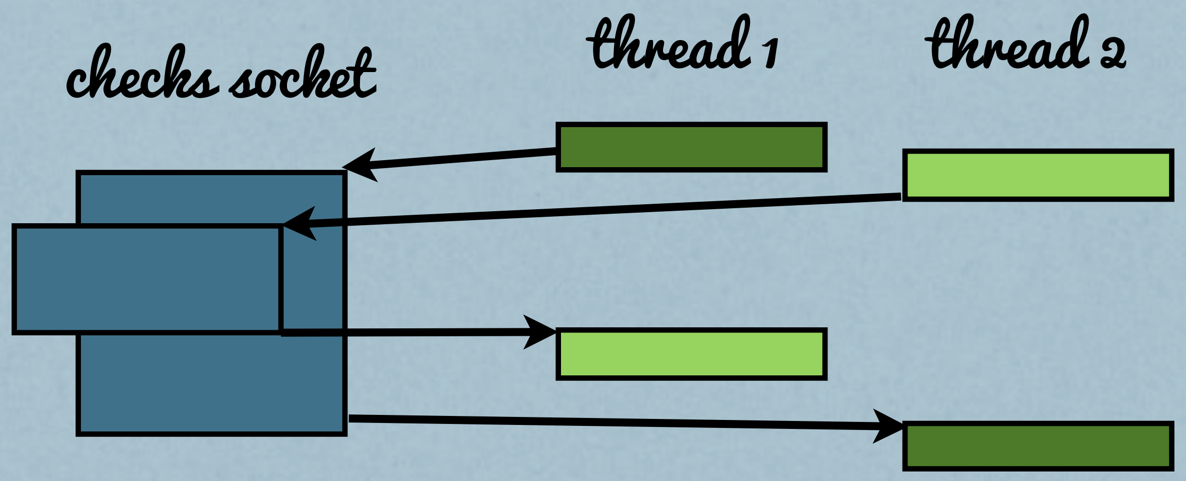
DOES
NOT
SCALE

MEANS: N requests == N threads

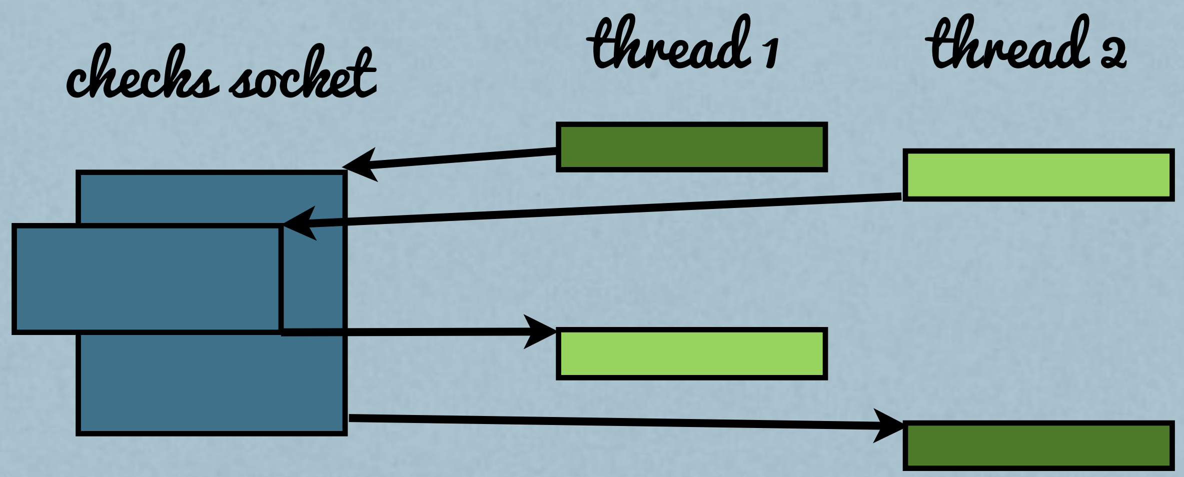
Asynchronous IO



Asynchronous IO



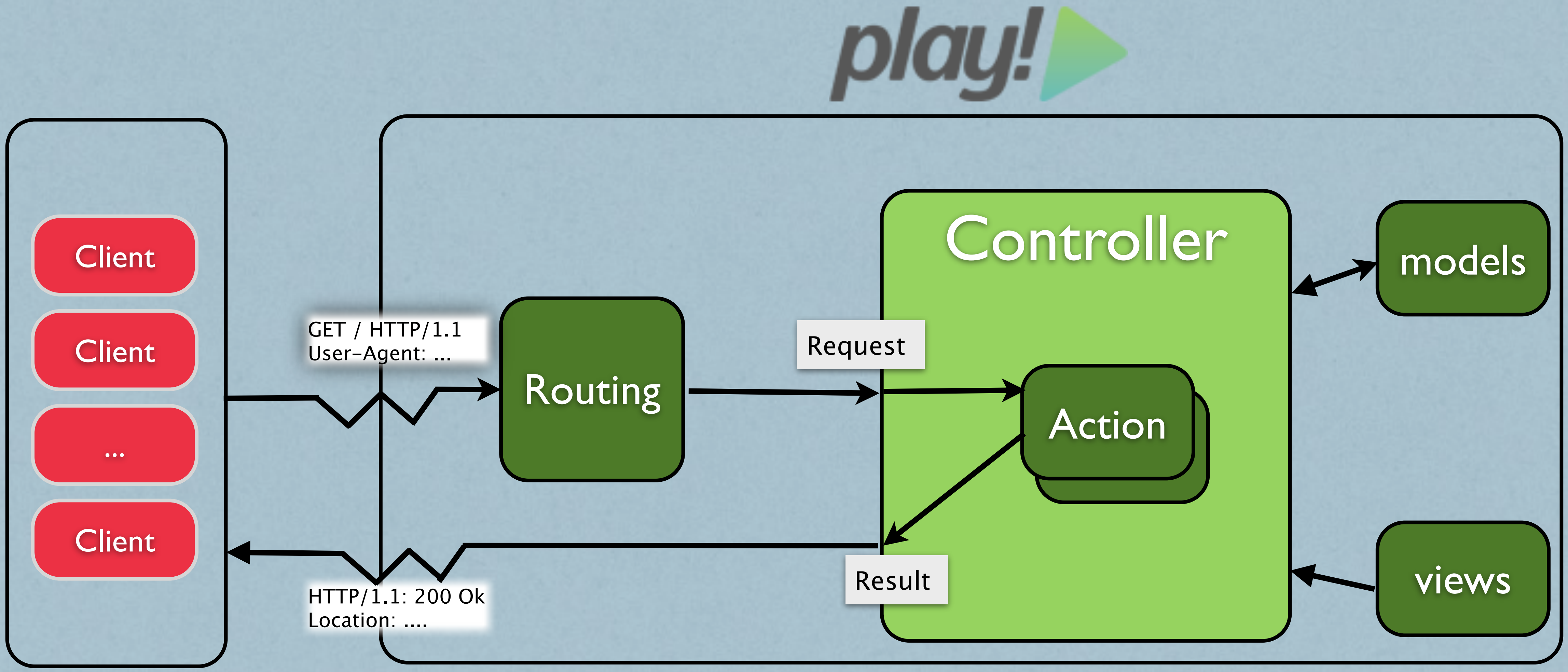
Asynchronous IO



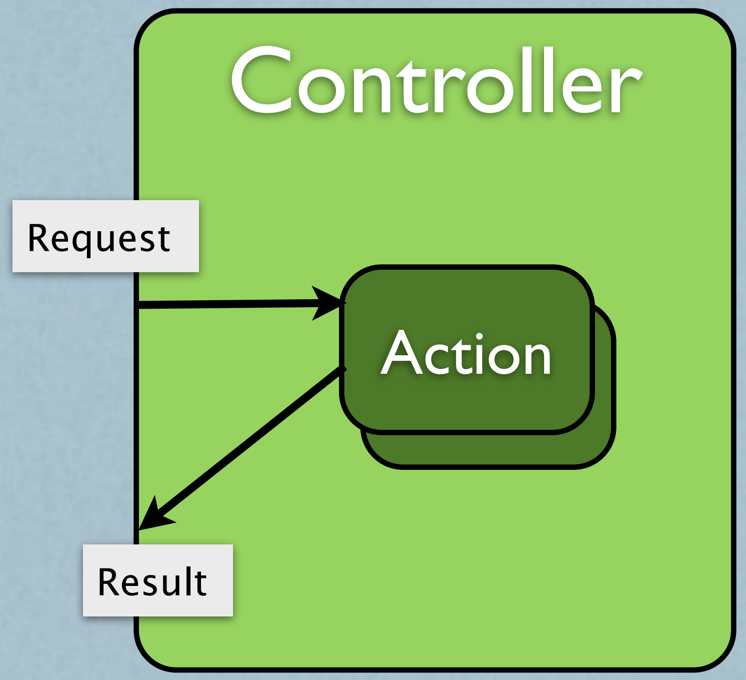
MEANS:

We now scale!

Play 101


play!
Client
Client
...
Client
GET / HTTP/1.1
User-Agent: ...
Routing
Request
Controller
Action
Result
HTTP/1.1: 200 Ok
Location: ....
models
views

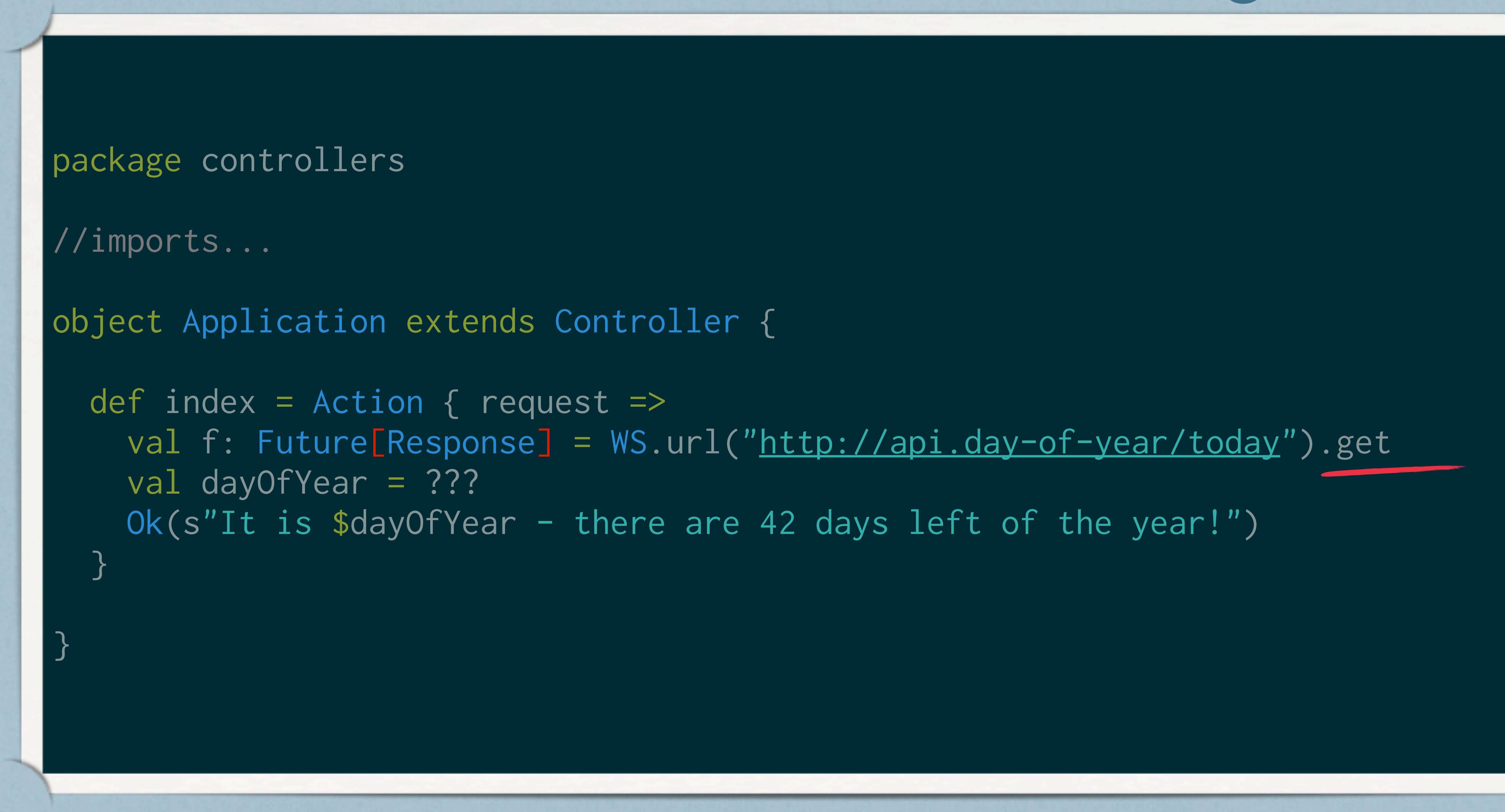
Play 101



ACTIONS IN Play

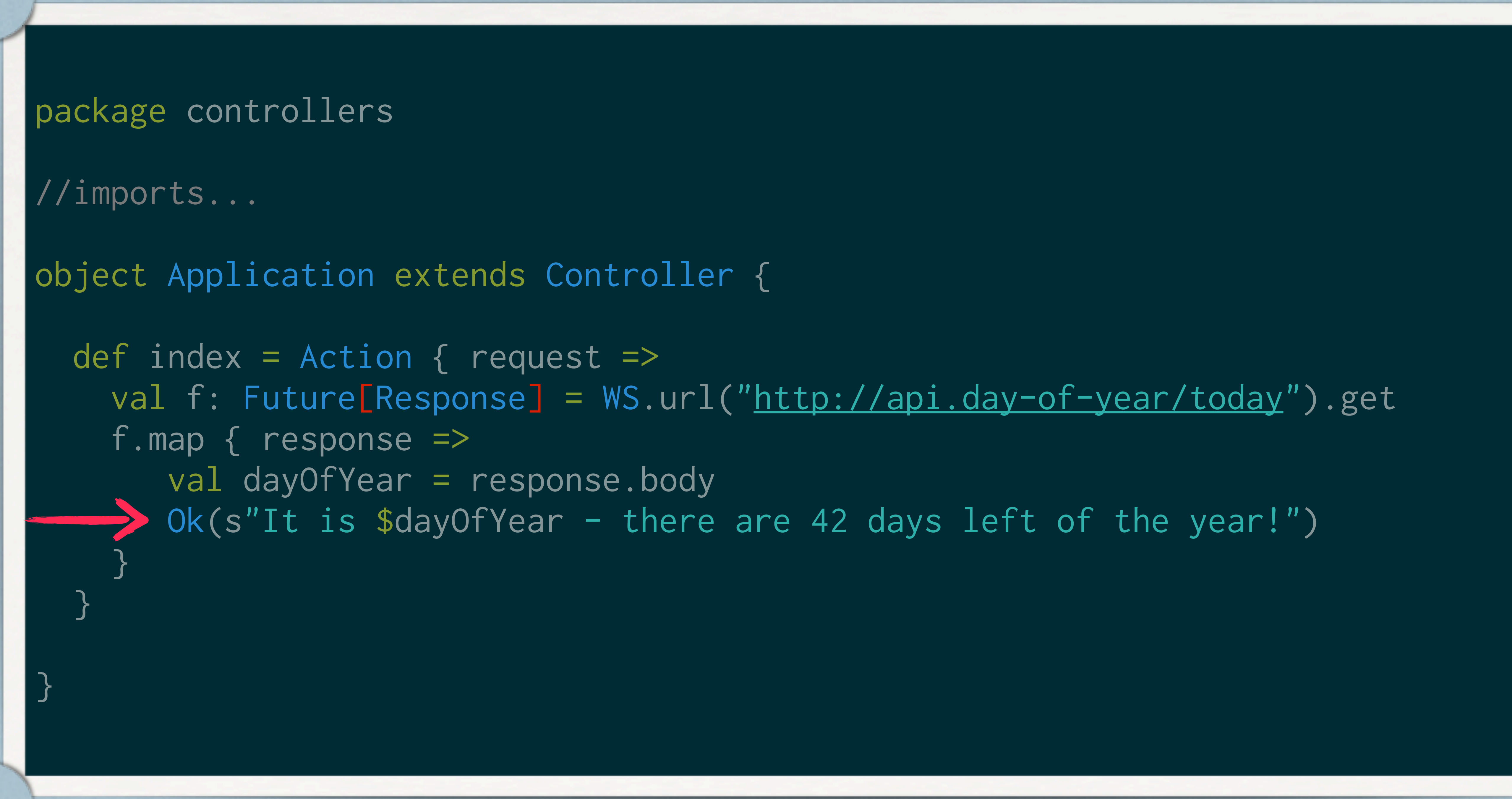
```scala
package controllers

//imports...

object Application extends Controller {

  def index = Action { request =>
    Ok("It is November 19th - there are 42 days left of the year!")
  }

}
```

Simple webservices in Play



```
package controllers

//imports...

object Application extends Controller {

  def index = Action { request =>
    val f: Future[Response] = WS.url("http://api.day-of-year/today").get
    val dayOfYear = ???
    Ok(s"It is $dayOfYear - there are 42 days left of the year!")
  }

}
```

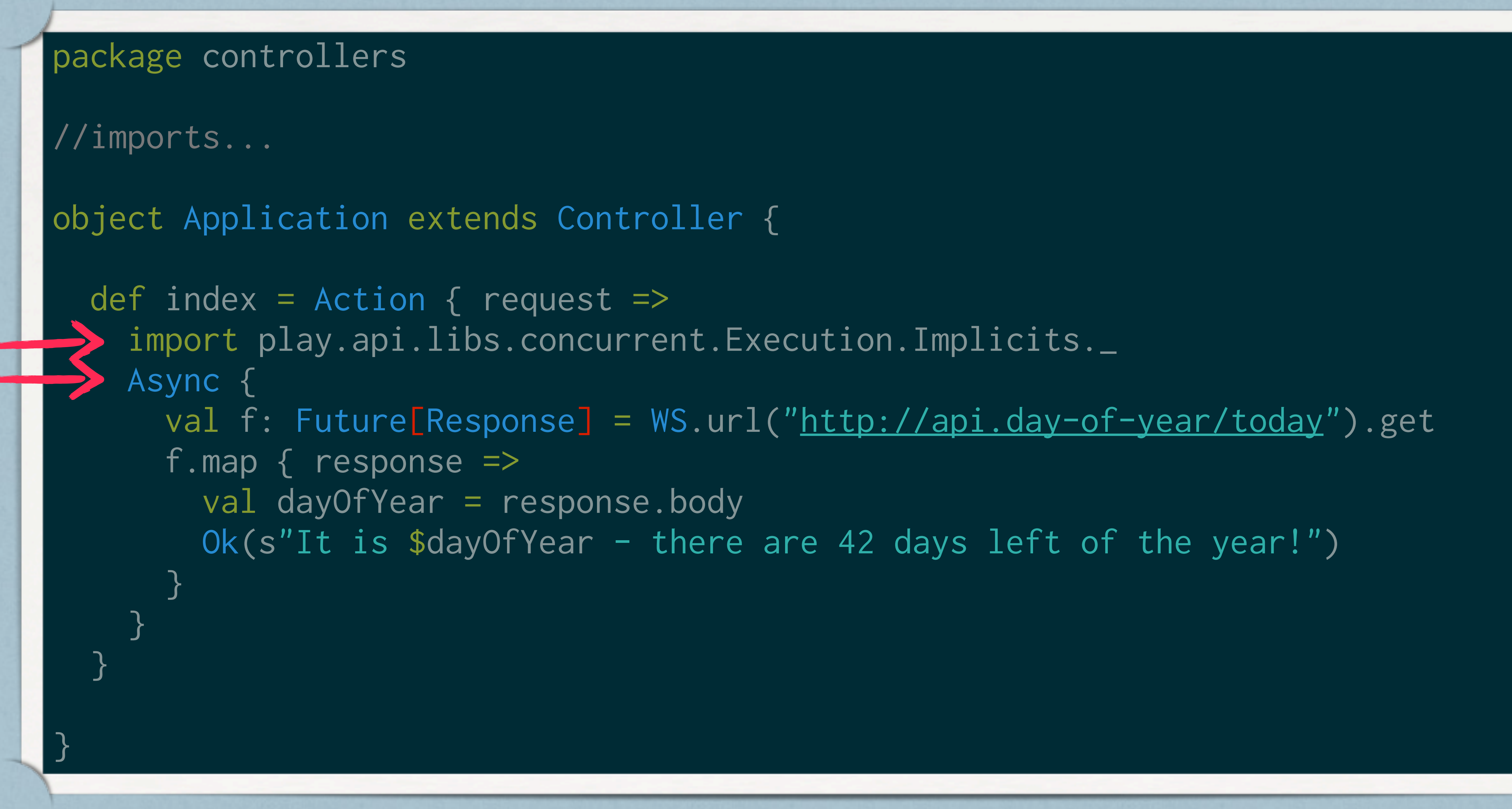
FUTURE IN Play



```
package controllers

//imports...

object Application extends Controller {

  def index = Action { request =>
    val f: Future[Response] = WS.url("http://api.day-of-year/today").get
    f.map { response =>
       val dayOfYear = response.body
       Ok(s"It is $dayOfYear - there are 42 days left of the year!")
    }
  }

}
```

FUTURE IN Play

EXECUTION CONTEXT & ASYNC

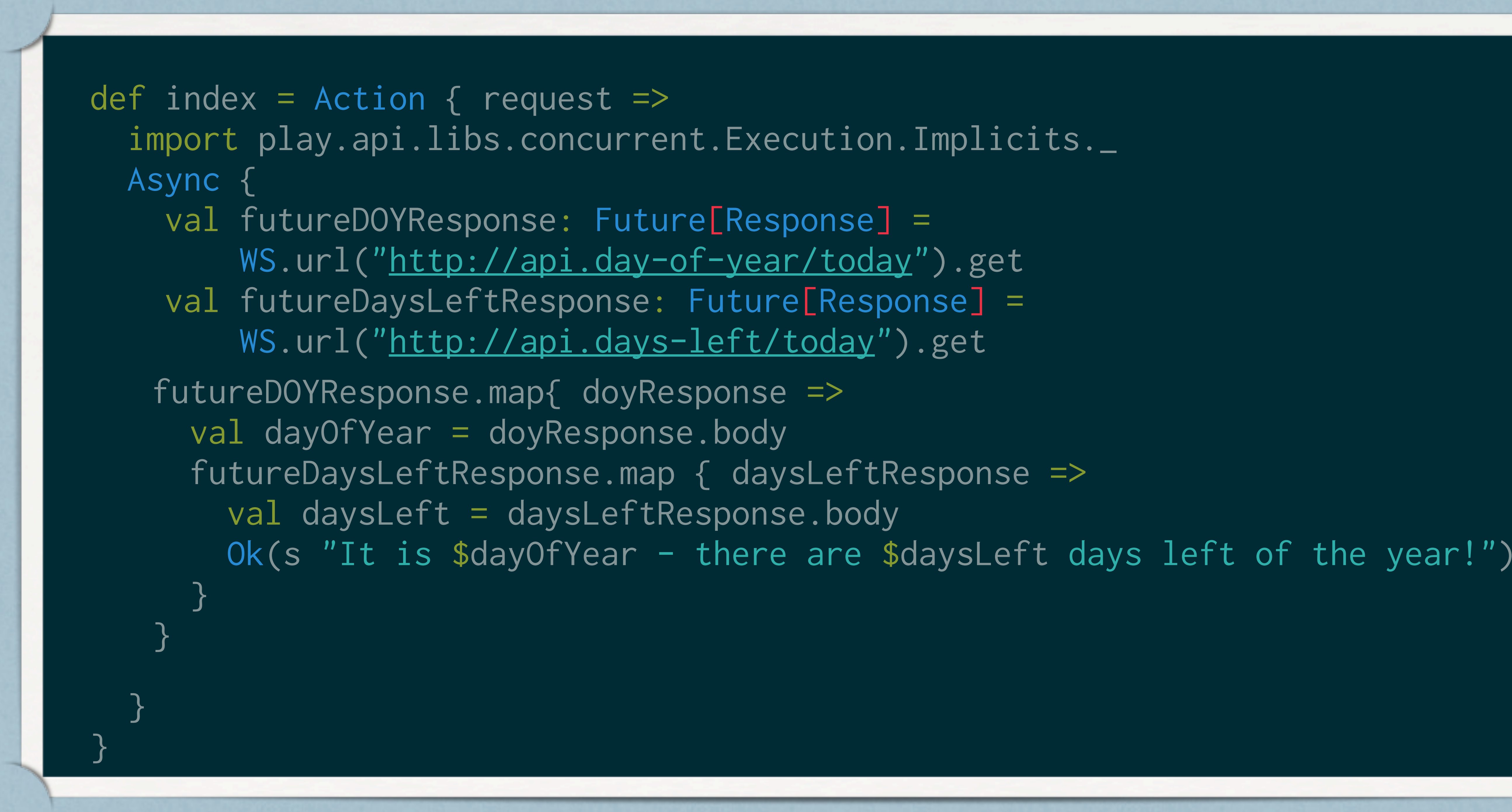


```
package controllers

//imports...

object Application extends Controller {

  def index = Action { request =>
    import play.api.libs.concurrent.Execution.Implicits._
    Async {
      val f: Future[Response] = WS.url("http://api.day-of-year/today").get
      f.map { response =>
        val dayOfYear = response.body
        Ok(s"It is $dayOfYear - there are 42 days left of the year!")
      }
    }
  }

}
```

Future composition in Play

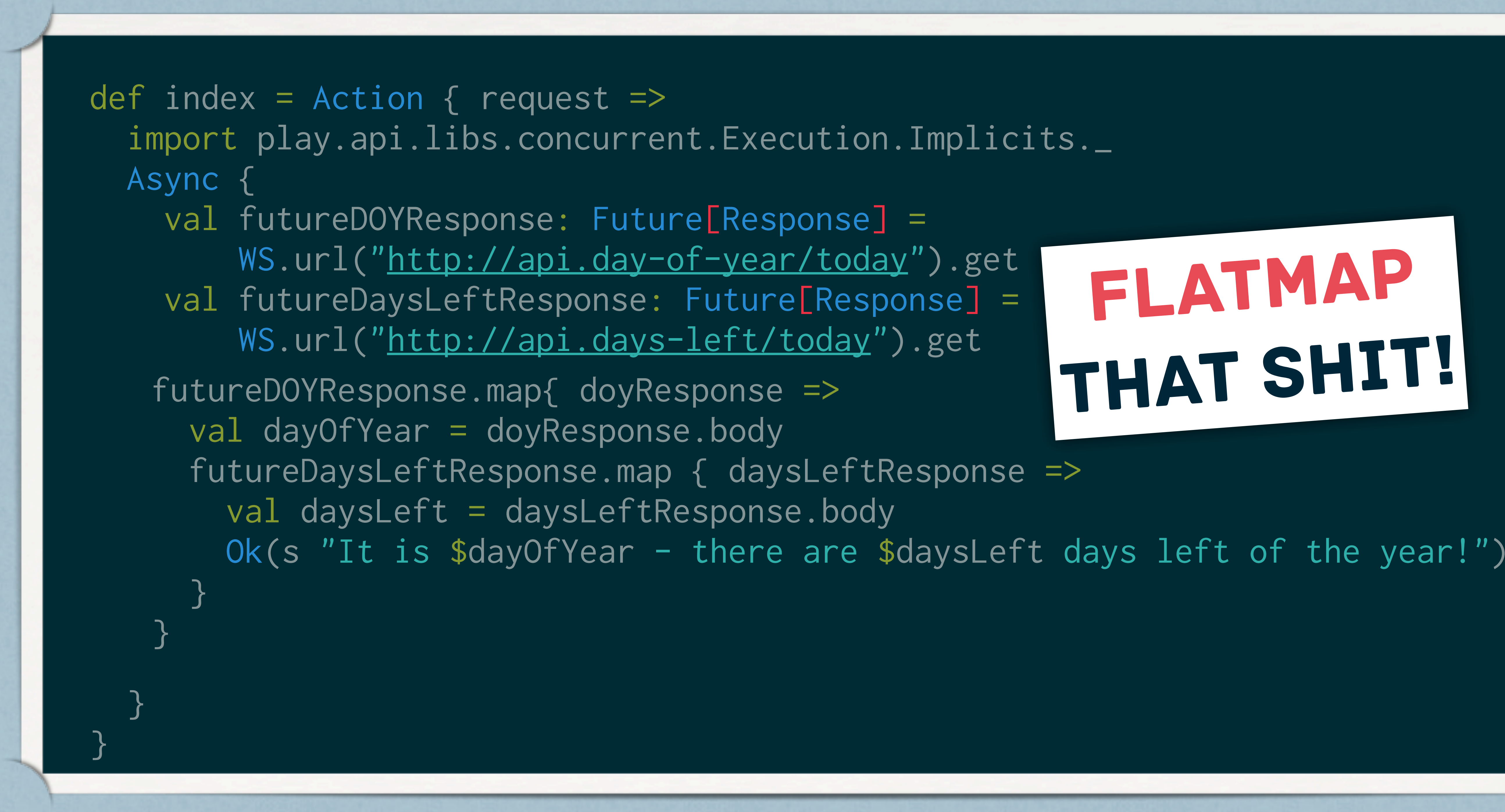
```
def index = Action { request =>
  import play.api.libs.concurrent.Execution.Implicits._
  Async {
    val futureDOYResponse: Future[Response] =
        WS.url("http://api.day-of-year/today").get
    val futureDaysLeftResponse: Future[Response] =
        WS.url("http://api.days-left/today").get








  }
}
```

FUTURE COMPOSITION IN Play



```scala
def index = Action { request =>
  import play.api.libs.concurrent.Execution.Implicits._
  Async {
    val futureDOYResponse: Future[Response] =
        WS.url("http://api.day-of-year/today").get
    val futureDaysLeftResponse: Future[Response] =
        WS.url("http://api.days-left/today").get
   futureDOYResponse.map{ doyResponse =>
     val dayOfYear = doyResponse.body
     futureDaysLeftResponse.map { daysLeftResponse =>
       val daysLeft = daysLeftResponse.body
       Ok(s "It is $dayOfYear - there are $daysLeft days left of the year!")
     }
   }

  }
}
```

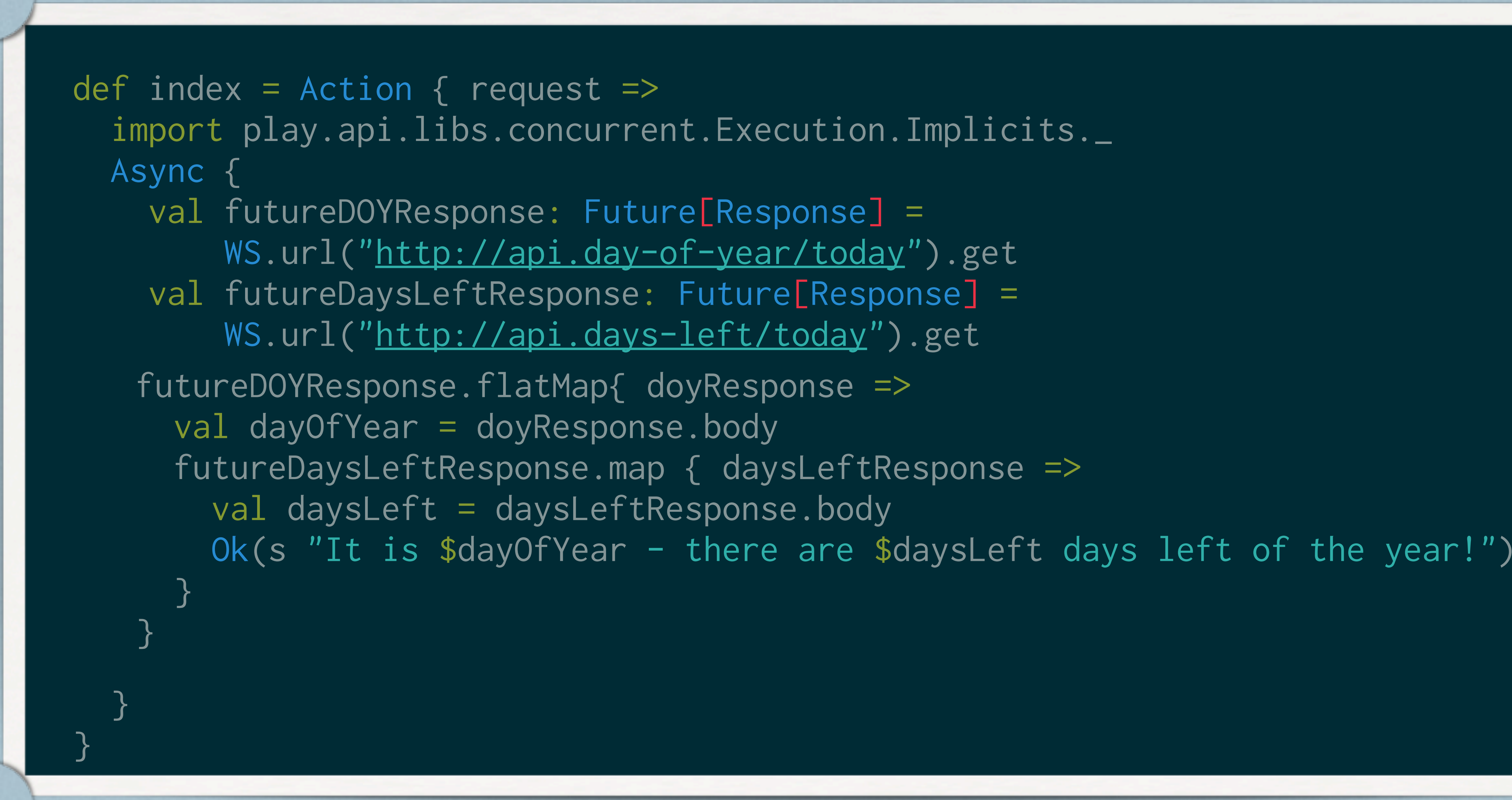
FUTURE COMPOSITION IN Play



```
def index = Action { request =>
  import play.api.libs.concurrent.Execution.Implicits._
  Async {
    val futureDOYResponse: Future[Response] =
        WS.url("http://api.day-of-year/today").get
    val futureDaysLeftResponse: Future[Response] =
        WS.url("http://api.days-left/today").get

   futureDOYResponse.map{ doyResponse =>
     val dayOfYear = doyResponse.body
     futureDaysLeftResponse.map { daysLeftResponse =>
       val daysLeft = daysLeftResponse.body
       Ok(s "It is $dayOfYear - there are $daysLeft days left of the year!")
     }
   }

  }
}
```

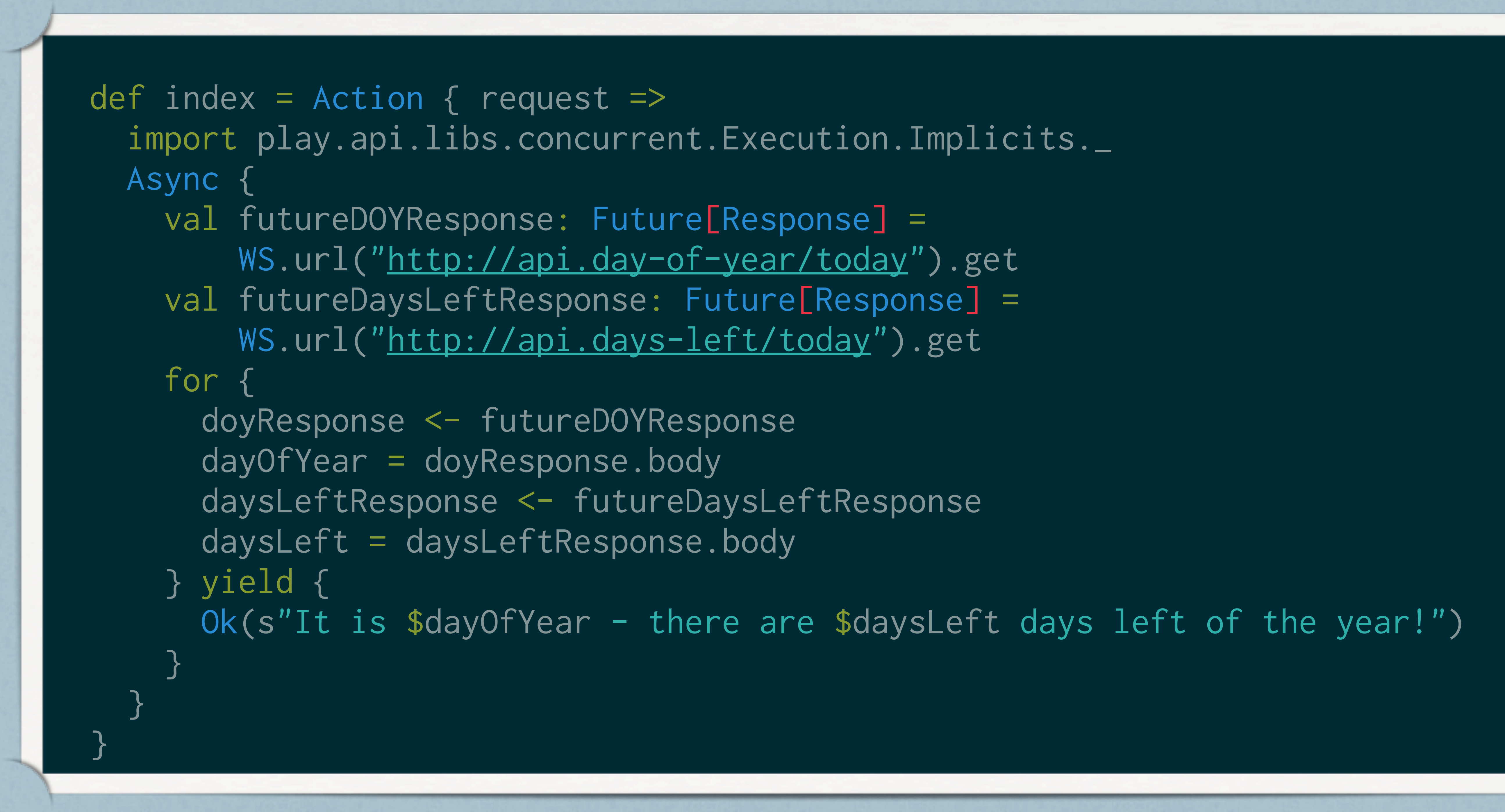
FLATMAP THAT SHIT!

FUTURE COMPOSITION IN Play



```
def index = Action { request =>
  import play.api.libs.concurrent.Execution.Implicits._
  Async {
    val futureDOYResponse: Future[Response] =
        WS.url("http://api.day-of-year/today").get
    val futureDaysLeftResponse: Future[Response] =
        WS.url("http://api.days-left/today").get
   futureDOYResponse.flatMap{ doyResponse =>
     val dayOfYear = doyResponse.body
     futureDaysLeftResponse.map { daysLeftResponse =>
       val daysLeft = daysLeftResponse.body
       Ok(s "It is $dayOfYear - there are $daysLeft days left of the year!")
     }
   }

  }
}
```

Future Composition^2 in Play



```
def index = Action { request =>
  import play.api.libs.concurrent.Execution.Implicits._
  Async {
    val futureDOYResponse: Future[Response] =
        WS.url("http://api.day-of-year/today").get
    val futureDaysLeftResponse: Future[Response] =
        WS.url("http://api.days-left/today").get
    for {
      doyResponse <- futureDOYResponse
      dayOfYear = doyResponse.body
      daysLeftResponse <- futureDaysLeftResponse
      daysLeft = daysLeftResponse.body
    } yield {
      Ok(s"It is $dayOfYear - there are $daysLeft days left of the year!")
    }
  }
}
```

FUTURE IN Play RECOVER

```
Async {
  val futureDOYResponse: Future[Response] = //...
  val futureDaysLeftResponse: Future[Response] = //...

  val futureResult = for {
    doyResponse <- futureDOYResponse
    dayOfYear = doyResponse.body
    daysLeftResponse <- futureDaysLeftResponse
    daysLeft = daysLeftResponse.body
  } yield {
    Ok(s”It is $dayOfYear - there are $daysLeft days left of the year!”)
  }

  futureResult.recover {
    case t: Throwable =>
      BadRequest(s”It is 21st December 2012 - end of the world?”)
  }
}
```

CREDITS

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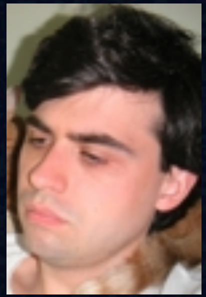
TYPESAFE


QUESTIONS?

http://docs.scala-lang.org/sips/pending/futures-promises.html

http://www.playframework.org/documentation/2.0.4/ScalaAsync