FUTURES & PROMISES

in Scala 2.10

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Typesafe

Agenda

FUTURES/PROMISES
EXECUTION CTXS
TRY

COMMON THEME:

COMMON THEME: *Pipelining*

Pipelining?

```
List(46, 34, 50, 21, 28)
```

```
map(x => x * 2)
```

```
List(92, 68, 100, 42, 56)
```

```
filter(x => x < 50)
```

```
List(42)
```

Pipelining?

```
val lst = List(46, 34, 50, 21, 28)

lst.map(x => x*2).filter(x => x<50)
```

filter(x => x < 50)

scala.concurrent.

FUTURE & PROMISE

FIRST, SOME *Motivation*

SEVERAL IMPORTANT LIBRARIES HAVE THEIR OWN FUTURE/PROMISE IMPLEMENTATION

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java.util.concurrent.	FUTURE
scala.actors.	FUTURE
com.twitter.util.	FUTURE
akka.dispatch.	FUTURE
scalaz.concurrent.	PROMISE
net.liftweb.actor.	LAFUTURE

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...

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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

Furthermore...

2 JAVA FUTURES NEITHER EFFICIENT NOR COMPOSABLE

```
val lst = List(46, 34, 50, 21, 28)

lst.map(x => x*2).filter(x => x<50)
```

Furthermore...

2 JAVA FUTURES NEITHER EFFICIENT NOR COMPOSABLE

COMPOSABILITY MEANS:

- "DRY"ER CODE.
- MORE POWERFUL CODE, BUILD/COMPOSE RICH FUNCTIONALITY FROM SMALLER PARTS

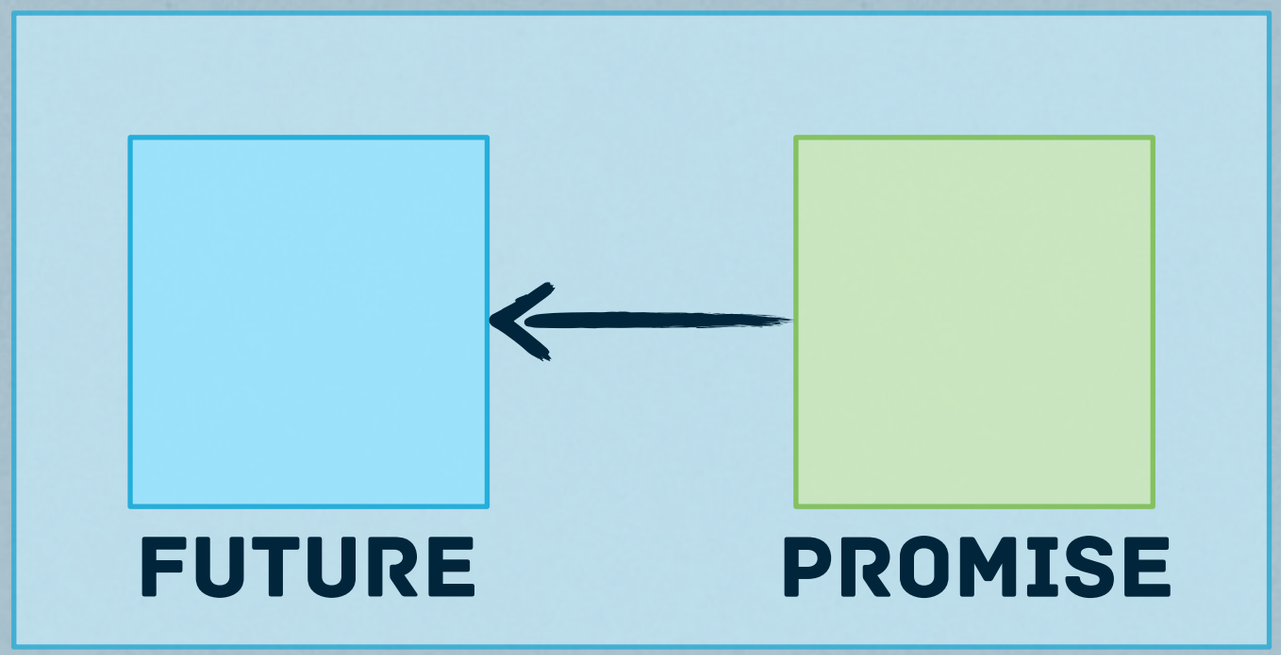
Furthermore...

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 SINGLE CONCURRENCY ABSTRACTION



Futures & Promises

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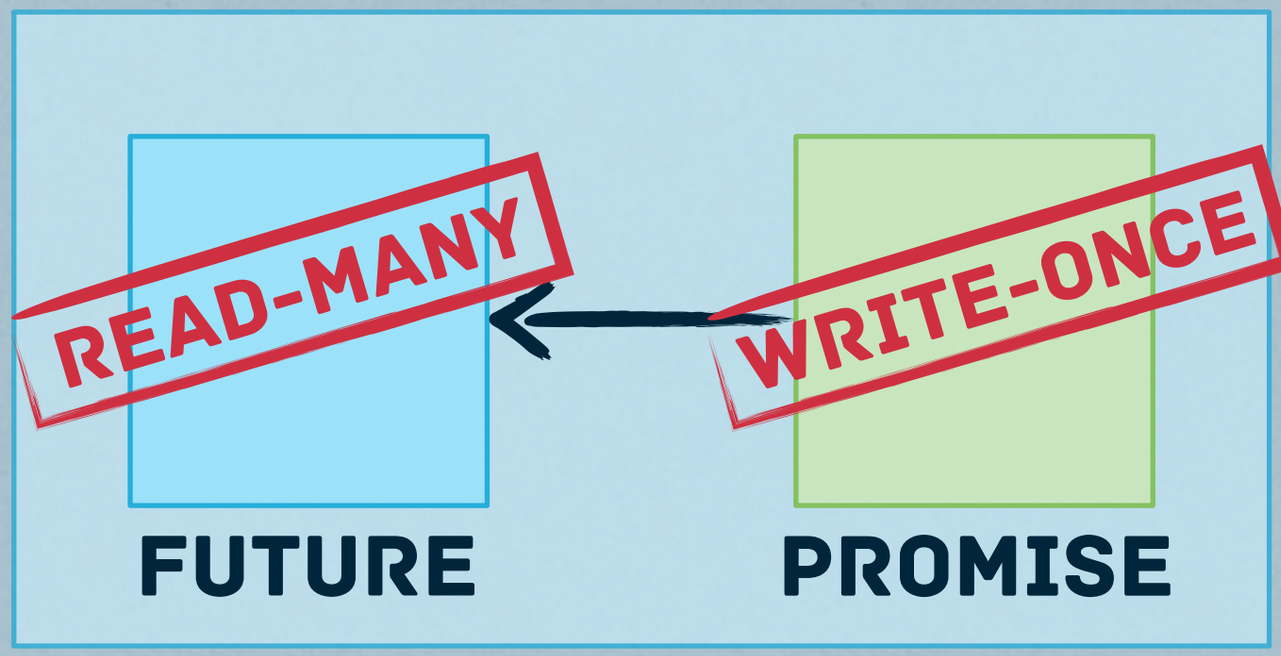

Futures & Promises

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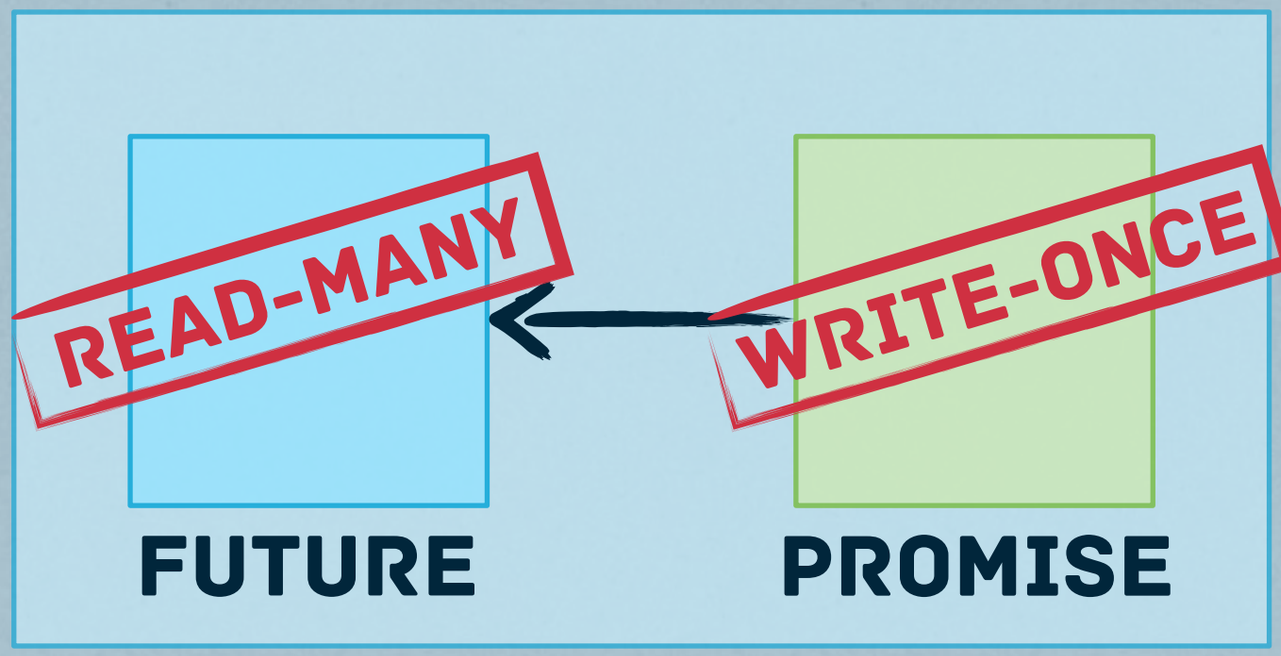
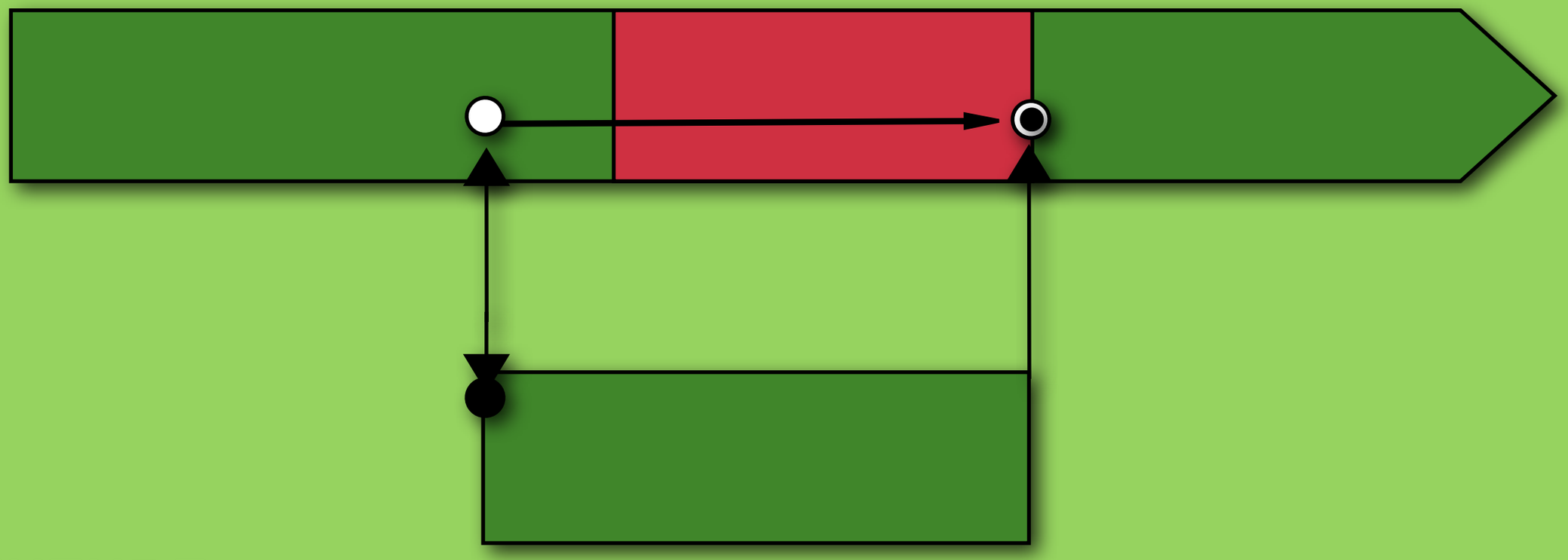


IMPORTANT OPS

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

java.util.concurrent.FUTURE

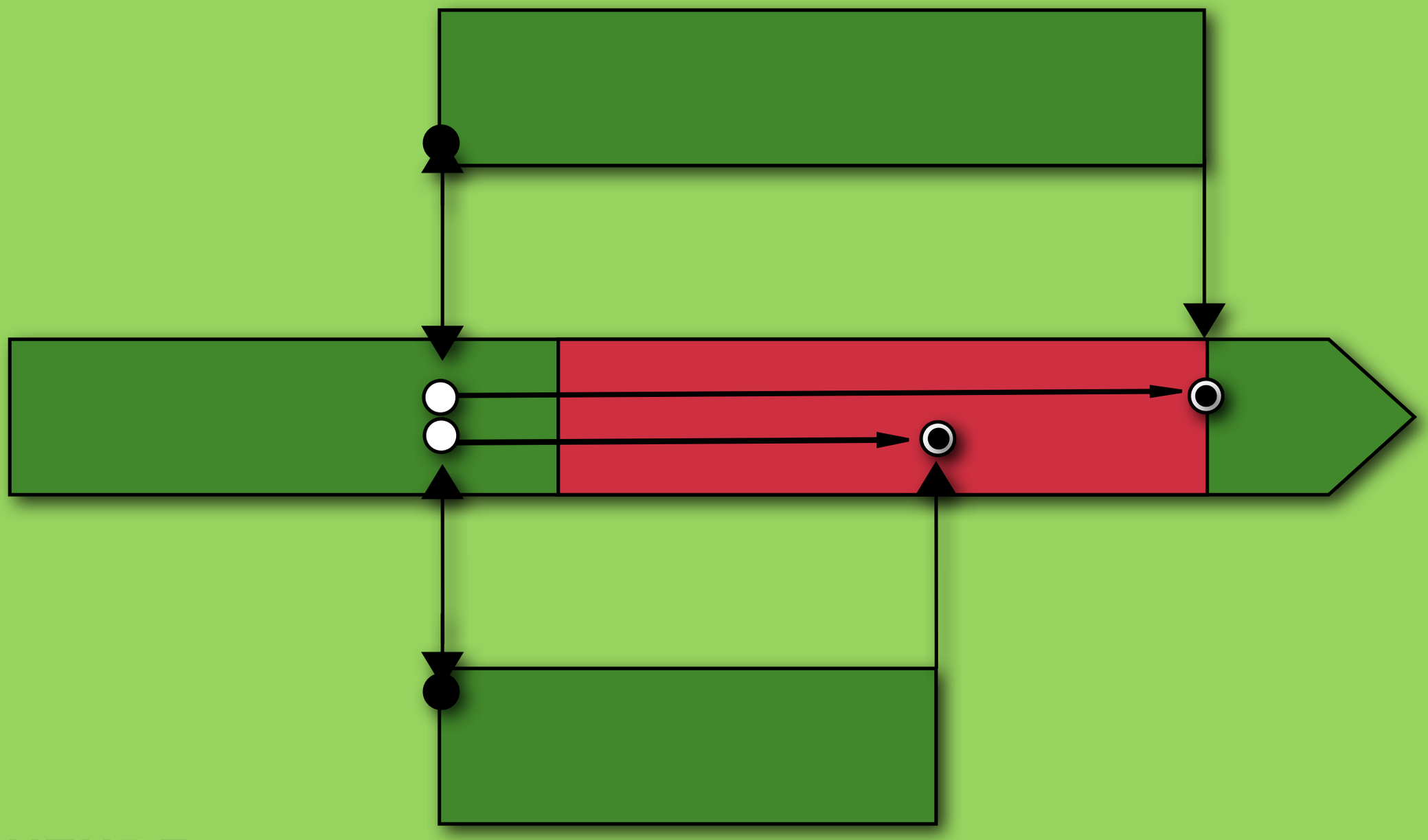


- FUTURE
- PROMISE
- FUTURE WITH VALUE

Green meaningful work

Red thread waiting on the result of another thread

java.util.concurrent.FUTURE

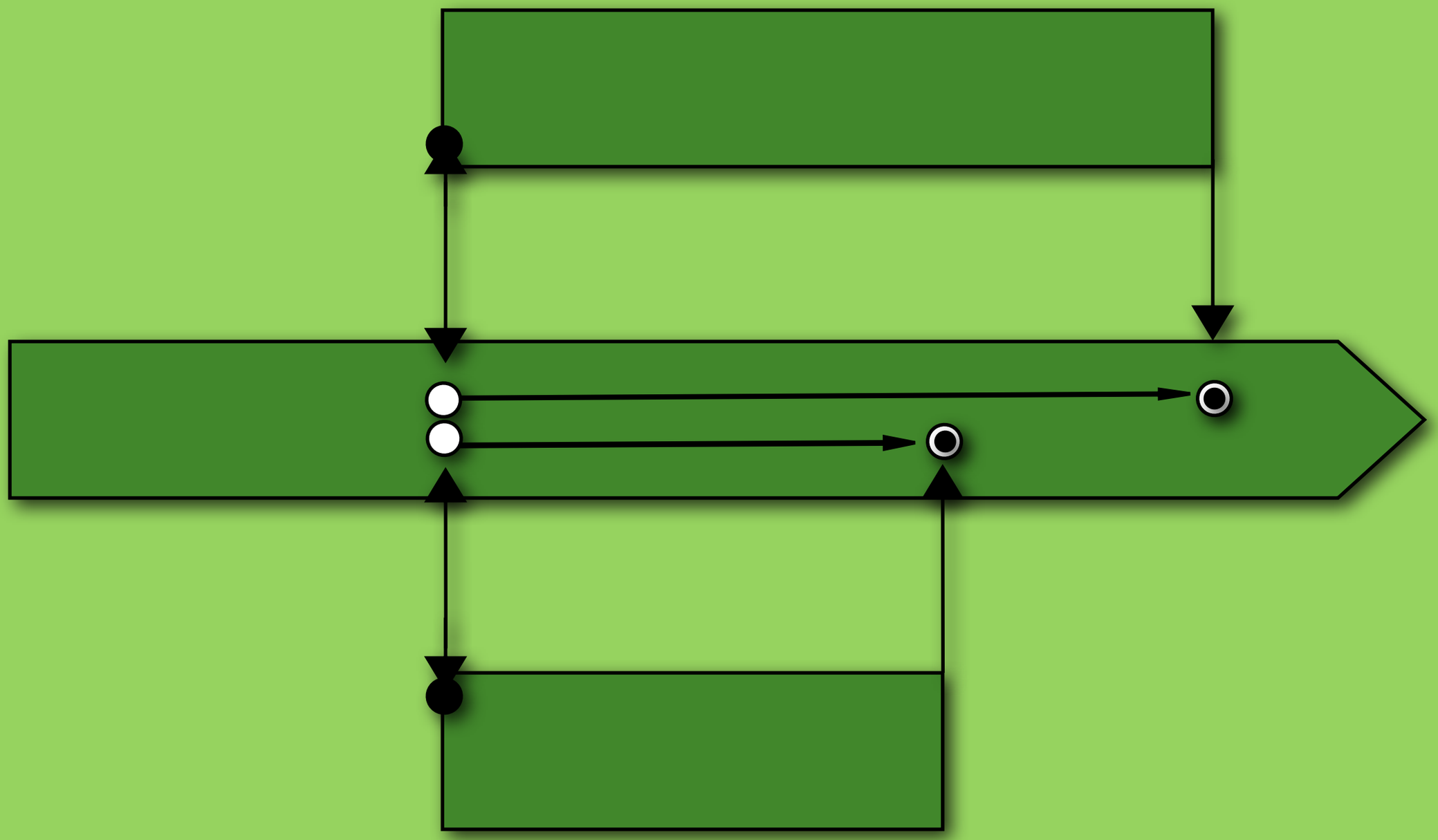


- FUTURE
- PROMISE
- FUTURE WITH VALUE

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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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!

Success & Failure

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

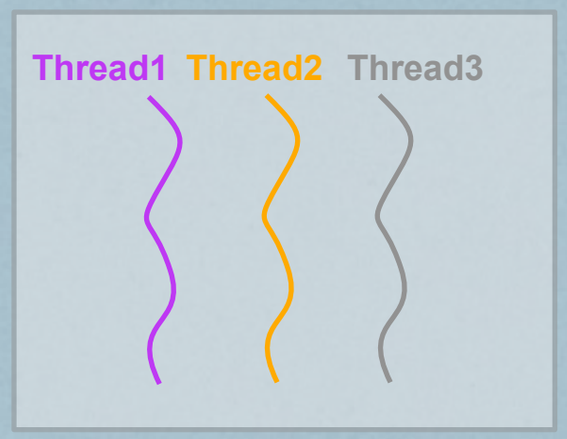
Success

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

Failure

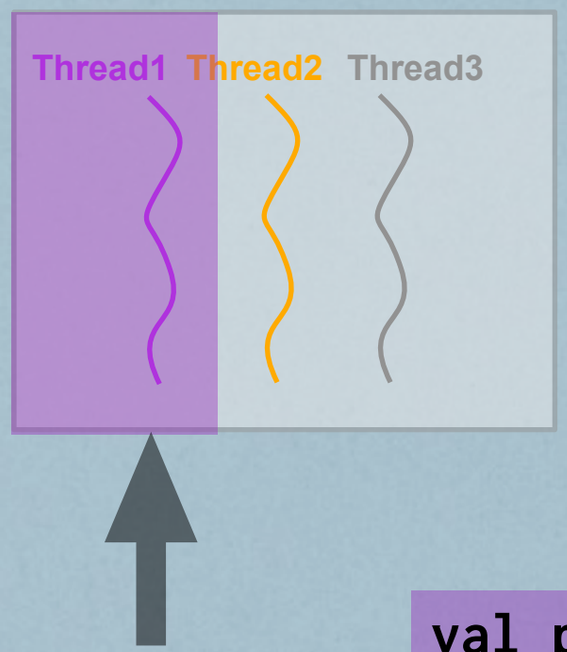
```
val exc = new Exception("something went wrong")
p.failure(exc)
```

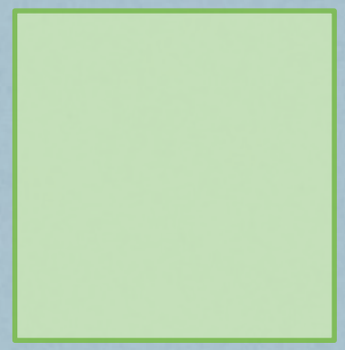
Futures&Promises
EXAMPLE



Futures&Promises

EXAMPLE





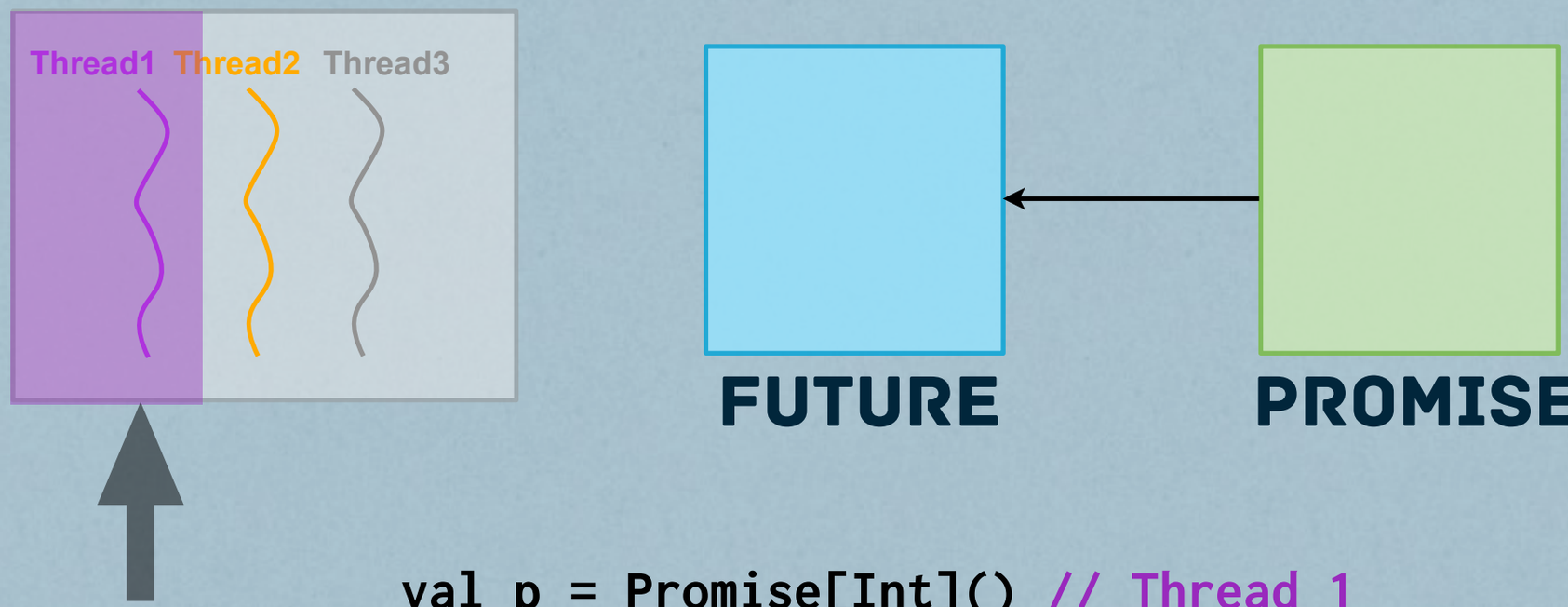
PROMISE

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

(CREATE PROMISE)

Futures&Promises

EXAMPLE



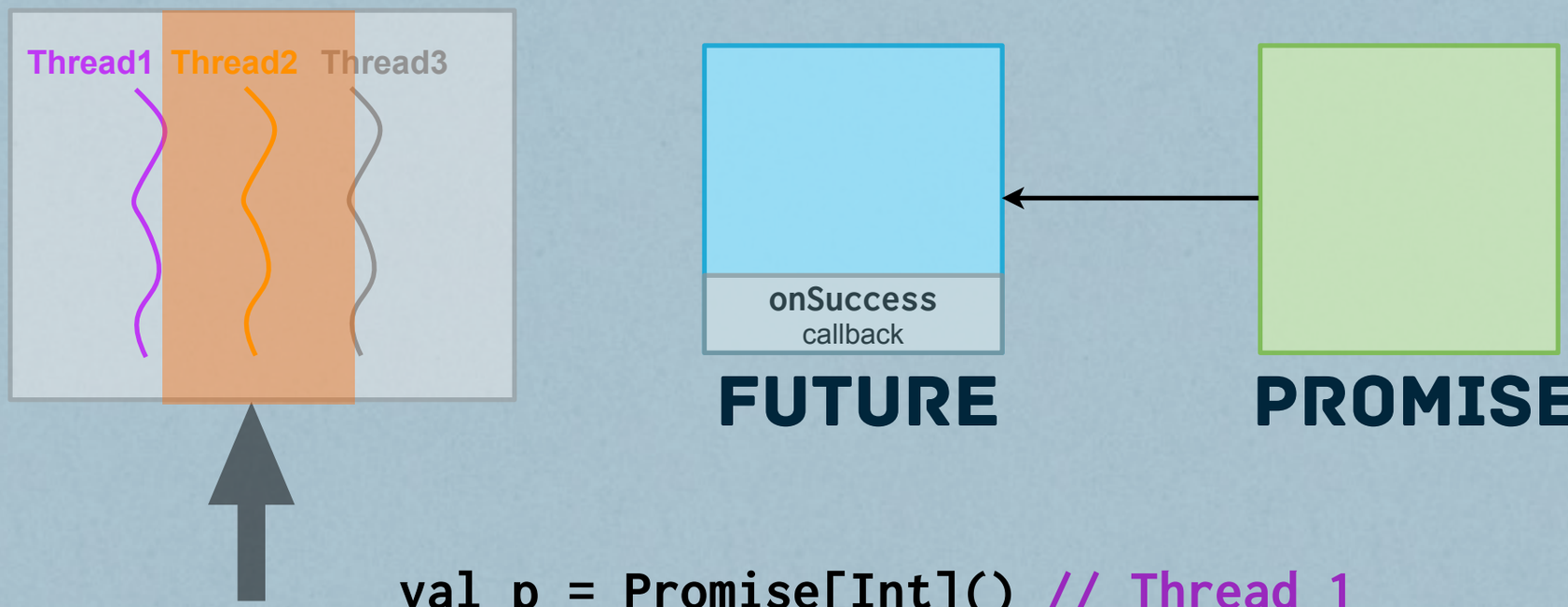

```
val p = Promise[Int]() // Thread 1
val f = p.future       // Thread 1
```

(CREATE PROMISE)

(GET REFERENCE TO FUTURE)

Futures&Promises

EXAMPLE




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

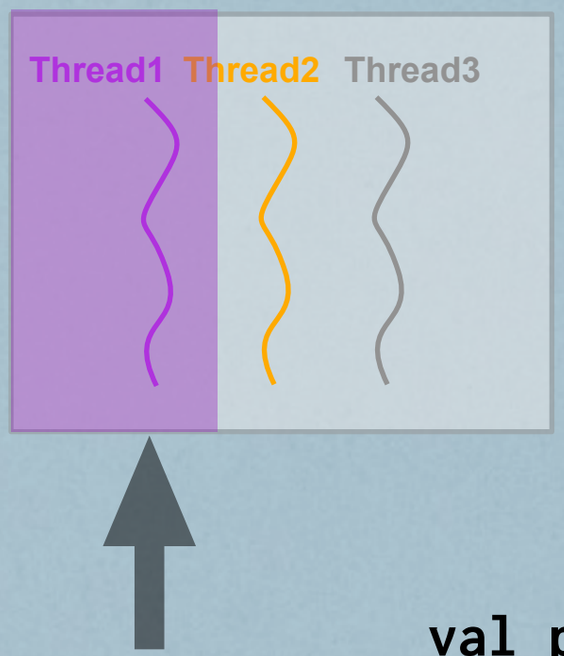
(CREATE PROMISE)

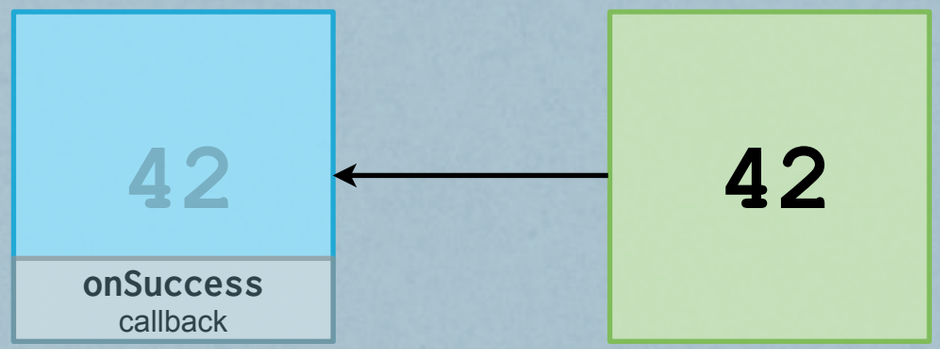
(GET REFERENCE TO FUTURE)

(REGISTER CALLBACK)

Futures&Promises

EXAMPLE





FUTURE PROMISE

```
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)

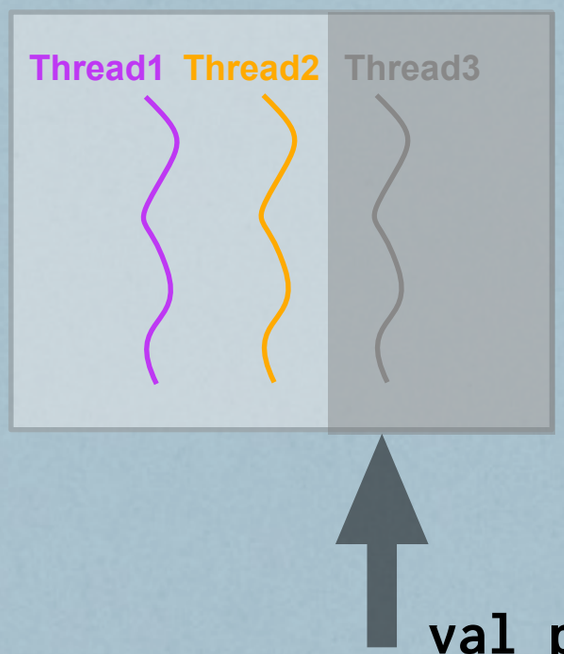
(GET REFERENCE TO FUTURE)

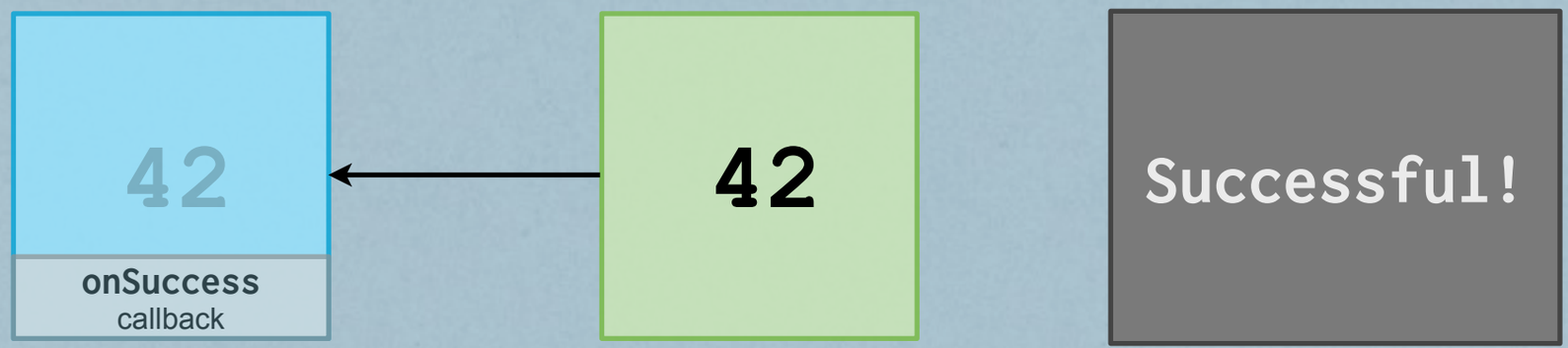
(REGISTER CALLBACK)

(WRITE TO PROMISE)

Futures&Promises

EXAMPLE





FUTURE PROMISE CONSOLE

```
val p = Promise[Int]() // Thread 1          (CREATE PROMISE)
val f = p.future       // Thread 1          (GET REFERENCE TO FUTURE)
f onSuccess {           // Thread 2         (REGISTER CALLBACK)
  case x: Int => println(“Successful!”)     (EXECUTE CALLBACK)
}                      // Thread
p.success(42)          // Thread 1          (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

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

```
def firstCompletedOf[T](futures: Traversable[Future[T]]): Future[T]
```

```
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

```
def firstCompletedOf[T](futures: Traversable[Future[T]]): Future[T]
```

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

Q: Which exceptions ARE CONSIDERED A Failure?

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A:

ONLY “NONFATAL” ONES

NonFatal

CAN DISTINGUISH FATAL EXCEPTIONS FROM NONFATAL ONES USING PATTERN MATCHING

```
try {
  // dangerous stuff
} catch {
  case NonFatal(e) => log.error(e, “Something not so bad”)
}
```

NonFatal

CAN DISTINGUISH FATAL EXCEPTIONS FROM NONFATAL ONES USING PATTERN MATCHING

```
try {
  // dangerous stuff
} catch {
  case NonFatal(e) => log.error(e, “Something not so bad”)
}
```

Examples of *fatal exceptions:*

`VirtualMachineError, LinkageError, ThreadDeath, ...`

Does `NonFatal` match an exception you want to throw?

Then just rethrow it

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.

```
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`:

```
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

```
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:

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

scala.util.TRY

AND NOW ONTO SOMETHING COMPLETELY DIFFERENT.

AND NOW ONTO SOMETHING

NOT CONCURRENT,
NOT ASYNCHRONOUS

Try
IS A SIMPLE DATA CONTAINER

Great for monadic-style exception handling.

✔ *Composable*

✔ *Combinators for exceptions*

“DIVORCING EXCEPTION HANDLING FROM THE STACK.”

Try IS A SIMPLE DATA CONTAINER

```scala
sealed abstract class Try[+T]

final case class Success[+T](value: T) extends Try[T]

final case class Failure[+T](exception: Throwable)
  extends Try[T]
```

Try IS A SIMPLE DATA CONTAINER

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final case class Success[+T](value: T) extends Try[T]

final case class Failure[+T](exception: Throwable)
  extends Try[T]
```

METHODS ON *Try*

BASIC OPS

get

```
def get: T
```

SUCCESS

Returns `value` *stored within* `Success`

FAILURE

Throws exception stored within `Failure`

METHODS ON *Try*

BASIC OPS

getOrElse

```
def getOrElse[U >: T](default: => U): U
```

SUCCESS

Returns `value` *stored within* `Success`

FAILURE

Returns the given `default` *argument if this is a* `Failure`

METHODS ON *Try*

BASIC OPS

orElse

```
def orElse[U >: T](default: => Try[U]): Try[U]
```

SUCCESS

Returns `this` *Try if this is a* `Success`

FAILURE

Returns the given `default` *argument if this is a* `Failure`

METHODS ON *Try*

MONADIC OPS

map

```
def map[U](f: T => U): Try[U]
```

SUCCESS

Applies the function `f` *to the* `value` *from* `Success`

FAILURE

Returns `this` *if this is a* `Failure`

METHODS ON *Try*

MONADIC OPS

flatMap

```
def flatMap[U](f: T => Try[U]): Try[U]
```

SUCCESS

Applies the function `f` *to the* `value` *from* `Success`

FAILURE

Returns `this` *if this is a* `Failure`

METHODS ON *Try*

MONADIC OPS

filter

```
def filter(p: T => Boolean): Try[T]
```

SUCCESS

Converts `this` *to a* `Failure` *if predicate* `p` *not satisfied.*

FAILURE

Returns `this` *if this is a* `Failure`

METHODS ON *Try*

EXCEPTION-SPECIFIC OPS

recover

```
def recover[U >: T](f: PartialFunction[Throwable, U]): Try[U]
```

SUCCESS

Returns `this` *if this is a* `Success`

FAILURE

Applies function `f` *if this is a* `Failure`. (`map` *on exptn*)

METHODS ON *Try*

EXCEPTION-SPECIFIC OPS

recoverWith

```
def recoverWith[U >: T](f: PartialFunction[Throwable, Try[U]]): Try[U]
```

SUCCESS

Returns `this` *if this is a* Success

FAILURE

Applies function `f` *if this is a* `Failure`. (`flatMap` *on exptn*)

METHODS ON *Try*

EXCEPTION-SPECIFIC OPS

transform

```
def transform[U](s: T => Try[U], f: Throwable => Try[U]): Try[U]
```

SUCCESS

Creates Try by applying function `s` *if this is a* `Success`

FAILURE

Creates Try by applying function `f` *if this is a* `Failure`

USING THESE TO BUILD *Pipelines*

USING THESE TO BUILD *Pipelines*

REMEMBER: NOT CONCURRENT, NOT ASYNCHRONOUS

SIMPLE PIPELINING ON *Try* EXAMPLE 1

```
case class Account(acctNum: Int, balance: Double, interestRate: Double)

val withdrawal = 1500
val adjustment = 0.4
val in = Try(getAcct())

val withdrawalResult = in map {
    (x: Account) => Account(x.acctNum, x.balance - withdrawal, x.interestRate)
  } filter {
    (x: Account) => x.balance > 12000 // acct in good standing
  } map {
    (x: Account) =>
    val toUpdate = Account(x.acctNum, x.balance, x.interestRate + adjustment)
    updateAcct(toUpdate)
  }
```

SIMPLE PIPELINING ON *Try* EXAMPLE 1

```
case class Account(acctNum: Int, balance: Double, interestRate: Double)

val withdrawal = 1500
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val in = Try(getAcct())

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    (x: Account) =>
    val toUpdate = Account(x.acctNum, x.balance, x.interestRate + adjustment)
    updateAcct(toUpdate)
  }
```

GETACCT MIGHT FAIL

SIMPLE PIPELINING ON *Try*

EXAMPLE 1

```
case class Account(acctNum: Int, balance: Double, interestRate: Double)

val withdrawal = 1500
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  } filter {
    (x: Account) => x.balance > 12000 // acct in good standing
  } map {
    (x: Account) =>
    val toUpdate = Account(x.acctNum, x.balance, x.interestRate + adjustment)
    updateAcct(toUpdate)
  }
```

PREDICATE MIGHT NOT BE SATISFIED

SIMPLE PIPELINING ON *Try* EXAMPLE 1

```
case class Account(acctNum: Int, balance: Double, interestRate: Double)

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val adjustment = 0.4
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  } filter {
    (x: Account) => x.balance > 12000 // acct in good standing
  } map {
    (x: Account) =>
    val toUpdate = Account(x.acctNum, x.balance, x.interestRate + adjustment)
    updateAcct(toUpdate)
  }
```

UPDATEACCT MIGHT FAIL

SIMPLE PIPELINING ON *Try*

EXAMPLE 1

```
case class Account(acctNum: Int, balance: Double, interestRate: Double)

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val adjustment = 0.4
val in = Try(getAcct())

val withdrawalResult = in map {
    (x: Account) => Account(x.acctNum, x.balance - withdrawal, x.interestRate)
  } filter {
    (x: Account) => x.balance > 12000 // acct in good standing
  } map {
    (x: Account) =>
    val toUpdate = Account(x.acctNum, x.balance, x.interestRate + adjustment)
    updateAcct(toUpdate)
  }
```

ELIMINATES NESTED TRY BLOCKS

but how can we handle these failures?

SIMPLE PIPELINING ON *Try* EXAMPLE 2

...by using recoverWith, recover, or orElse

```
case class Tweet(from: String, retweets: Int)

val importantTweets = Try {
  server.getTweetList()
} orElse {
  cachedTweetList.get
} filter { twts =>
  val avgRetweet = twts.map(_.retweets).reduce(_ + _) / twts.length
  twts.exists(_.retweets > 2 * avgRetweet)
} recover {
  case nose: NoSuchElementException => // handle individually
  case usop: ArithmeticException    => // handle individually
  case other                        => // handle individually
}
```

COMBINING Try& Futures

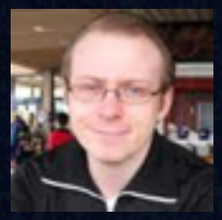
```
case class Friend(name: String, age: String)

val avgAge = Promise[Int]()

val fut = future {
  // query a social network...
  List(Friend("Zoe", "25"), Friend("Jean", "27"), Friend("Paul", "30"))
}

fut onComplete { tr =>
  // compute average age of friends
  val result = tr map {
    friends => friends.map(_.age.toInt).reduce(_ + _) / friends.length
  }
  avgAge complete result
}
```

CREDITS



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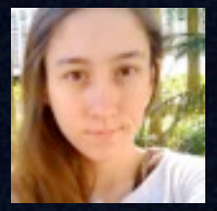

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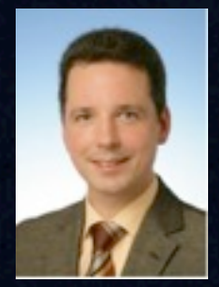

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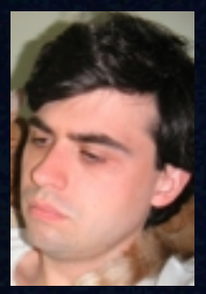

QUESTIONS?

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