Scala Course

Abstraction

47 Deg

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Pure functions

In functional programming we say that functions have some special features.

They're values

Functions can be treated as any other value in your program. They can be assigned to `vals`, returned from methods, taken as parameters…

Purity

They're pure, meaning that they perform no side effects

Idempotence

given the same input, always return the same output

Side effects

- Throwing exceptions

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- mutating variables

Idempotence

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Side effects

- Throwing exceptions
- IO
- mutating variables
- Random

Referential transparency

They're **referentially transparent**. We can safely substitute any function call with its return value, and it won't have any effect in the overall program.

Totality

They're total. Functions should operate on all values from it's input type. If they fail with an input, they're not total.

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When a function is not total, we say it's partial.

Examples

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

Examples

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

yes

Examples

```scala
def sumAndPrint(a: Int, b: Int): Int = {
  println(s"summing $a + $b")
  a + b
}
```

Is this pure?

Examples

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def sumAndPrint(a: Int, b: Int): Int = {
  println(s"summing $a + $b")
  a + b
}
```

Is this pure?

Nope, it's side effectful!

Examples

```scala
def operation(): Unit = {
  launchMissiles()
  ()
}
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Examples

```scala
def findPhone(name: String): Option[String] = None
```

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```scala
def findPhone(name: String): Option[String] = None
```

Is this pure?

Yes!

Examples

```scala
def findUser(id: Int): String = {
  db.findUser(id) match {
    case Some(x) => x
    case None => throw new Exception("No user found")
  }
}
```

Is this pure?

Examples

```scala
def findUser(id: Int): String = {
  db.findUser(id) match {
    case Some(x) => x
    case None => throw new Exception("No user found")
  }
}
```

Is this pure?

Nope, it's side effectful!

Examples

```scala
def toString(id: Int): String = id match {
  case 1 => "one"
}
```

Is this pure?

Examples

```scala
def toString(id: Int): String = id match {
  case 1 => "one"
}
```

Is this pure?

Nope, it's partial!

Recap

We implemented a binary tree

```scala
sealed trait Tree[A]
case class Empty[A]() extends Tree[A]
case class Node[A](
  l: Tree[A],
  a: A, r: Tree[A]
) extends Tree[A]
```

Recap

```scala
val myTree = Node(
  Node(Empty(), 2, Empty()),
  1,
  Node(
    Node(Empty(), 4, Empty()),
    3,
    Node(
      Node(Empty(), 6, Empty()),
      5,
      Node(Empty(), 7, Empty())
    )
  )
)
```

Recap

Abstraction is the ultimate goal of functional programming. If you see the implementations we ended up creating for previous exercises, you'll see that there's a pattern:

```scala
def height[A](tree: Tree[A]): Int =
  tree match {
    case Empty() => 0
    case Node(l, _, r) =>
      1 + (height(l).max(height(r)))
  }

height(myTree)
// res0: Int = 4
```

Recap

```scala
def sum(tree: Tree[Int]): Int = tree match {
  case Empty() => 0
  case Node(l, x, r) => x + sum(l) + sum(r)
}

sum(myTree)
// res1: Int = 28
```

Recap

```scala
def count[A](tree: Tree[A]): Int =
  tree match {
    case Empty() => 0
    case Node(l, _, r) =>
      1 + count(l) + count(r)
  }

count(myTree)
// res2: Int = 7
```

Recap

```scala
def toStringNodes(tree: Tree[Int]): Tree[String] =
  tree match {
    case Empty() => Empty()
    case Node(l, x, r) => Node(
        toStringNodes(l),
        x.toString,
        toStringNodes(r))
  }
toStringNodes(myTree)
// res3: Tree[String] = Node(
//   l = Node(l = Empty(), a = "2", r = Empty()),
//   a = "1",
//   r = Node(
//     l = Node(l = Empty(), a = "4", r = Empty()),
//     a = "3",
//     r = Node(
```

Recap

```scala
def squared(tree: Tree[Int]): Tree[Int] =
  tree match {
    case Empty() => Empty()
    case Node(l, x, r) =>
    Node(squared(l), x * x, squared(r))
  }
squared(myTree)
// res4: Tree[Int] = Node(
//   l = Node(l = Empty(), a = 4, r = Empty()),
//   a = 1,
//   r = Node(
//     l = Node(l = Empty(), a = 16, r = Empty()),
//     a = 9,
//     r = Node(
//       l = Node(l = Empty(), a = 36, r = Empty()),
//       a = 25,
```
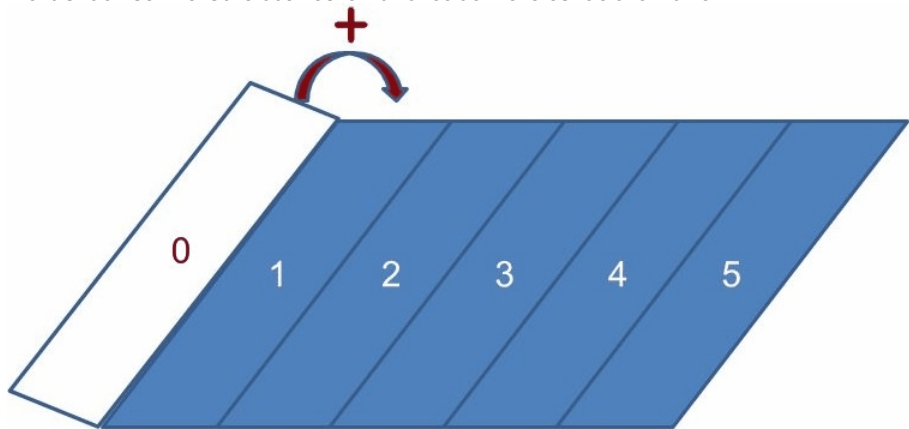
Can you create a higher order function with the common parts of previous functions?

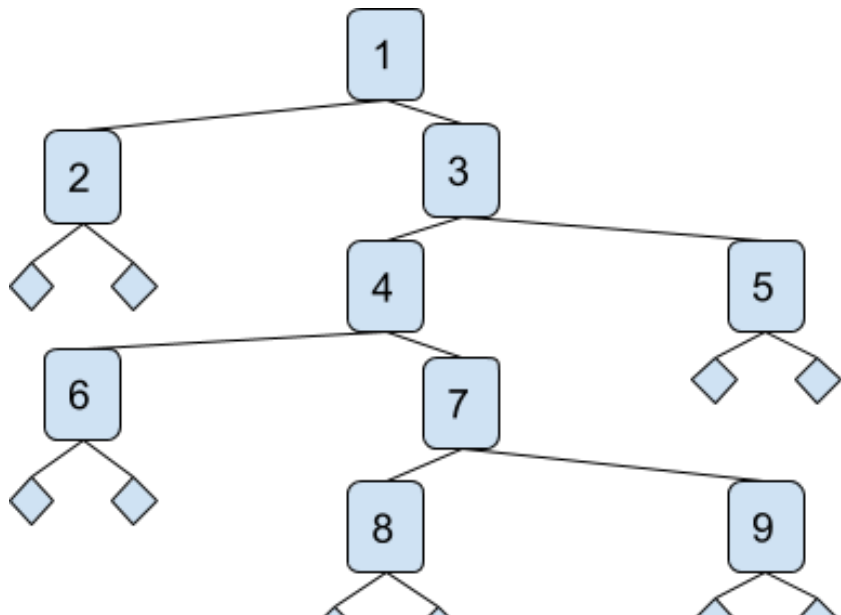# Identifying common functions

The pattern we've identified here is called `fold` (AKA `reduce`, `cata`, `catamorphism`…)

Folds consume structures and create values out of them.

Identifying common functions

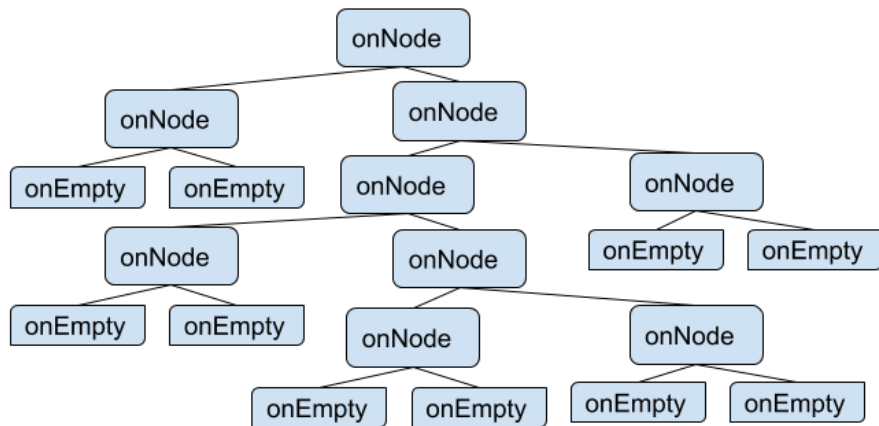# Identifying common functions

Figure 2: fold

fold

```scala
def fold[A, B](tree: Tree[A])(
  onEmpty: B,
  onNode: (B, A, B) => B
): B = tree match {
  case Empty() => onEmpty
  case Node(left, a, right) => onNode(
    fold(left)(onEmpty, onNode),
    a,
    fold(right)(onEmpty, onNode)
  )
}
```

Abstraction

Now we have created the `fold` function, let's reimplement the other functions based on it!

```scala
def heightWithFold[A](tree: Tree[A]): Int =
  fold(tree)(0, { (l: Int, _: A, r: Int) =>
    1 + (l.max(r))
  })

heightWithFold(myTree)
// res5: Int = 4
```

Abstraction

Now we have created the `fold` function, let's reimplement the other functions based on it!

```scala
def sumWithFold(tree: Tree[Int]): Int =
  fold(tree)(0, { (l: Int, a: Int, r: Int) =>
    l + a + r
  })

sumWithFold(myTree)
// res6: Int = 28
```

Abstraction

Now we have created the `fold` function, let's reimplement the other functions based on it!

```scala
def countWithFold[A](tree: Tree[A]): Int =
  fold(tree)(0, { (l: Int, _: A, r: Int) =>
    1 + l + r
  })

countWithFold(myTree)
// res7: Int = 7
```

Abstraction

Now we have created the `fold` function, let's reimplement the other functions based on it!

```scala
def toStringNodesWithFold(tree: Tree[Int]): Tree[String]
  fold(tree)(Empty[String](), {
    (l: Tree[String], a: Int, r: Tree[String]) =>
        Node[String](l, a.toString, r)
  })
toStringNodesWithFold(myTree)
// res8: Tree[String] = Node(
//    l = Node(l = Empty(), a = "2", r = Empty()),
//    a = "1",
//    r = Node(
//        l = Node(l = Empty(), a = "4", r = Empty()),
//        a = "3",
//        r = Node(
```

Abstraction

Now we have created the `fold` function, let's reimplement the other functions based on it!

```scala
def squaredWithFold(tree: Tree[Int]): Tree[Int] =
  fold(tree)(Empty[Int](), {
    (l: Tree[Int], a: Int, r: Tree[Int]) =>
        Node[Int](l, a * a, r)
  })
squaredWithFold(myTree)
// res9: Tree[Int] = Node(
//    l = Node(l = Empty(), a = 4, r = Empty()),
//    a = 1,
//    r = Node(
//        l = Node(l = Empty(), a = 16, r = Empty()),
//        a = 9,
//        r = Node(
```

Abstraction

If we look closer at our last abstractions using fold, we can notice another pattern in the last two functions. They're transforming the value of the nodes, but leaving the structure intact.

That's a `map`! and we can implement it based on `fold`!

Abstraction

```scala
def map[A, B](tree: Tree[A])(fn: A => B): Tree[B] =
  fold(tree)(Empty[B](), { (l: Tree[B], a: A, r: Tree[B])
    Node[B](l, fn(a), r)
  })
```

Abstraction

And finally, implement those based on map!

```scala
def toStringNodesWithMap(tree: Tree[Int]): Tree[String] =
  map(tree)(_.toString)

toStringNodesWithMap(myTree)
// res10: Tree[String] = Node(
//   l = Node(l = Empty(), a = "2", r = Empty()),
//   a = "1",
//   r = Node(
//     l = Node(l = Empty(), a = "4", r = Empty()),
//     a = "3",
//     r = Node(
//       l = Node(l = Empty(), a = "6", r = Empty()),
//       a = "5",
//       r = Node(l = Empty(), a = "7", r = Empty())
```

Abstraction

And finally, implement those based on map!

```scala
def squaredWithMap(tree: Tree[Int]): Tree[Int] =
  map(tree)(x => x*x)


squaredWithMap(myTree)
// res11: Tree[Int] = Node(
//   l = Node(l = Empty(), a = 4, r = Empty()),
//   a = 1,
//   r = Node(
//     l = Node(l = Empty(), a = 16, r = Empty()),
//     a = 9,
//     r = Node(
//       l = Node(l = Empty(), a = 36, r = Empty()),
//       a = 25,
//       r = Node(l = Empty(), a = 49, r = Empty())
```

Intermezzo: Higher Kinded Types

We are used to having generics in other languages now, in Java for example, we don't need to implement a new List for every datatype we want to put inside, we have a *Generic* `List<A>` that can be used for all cases.

Intermezzo: Higher Kinded Types

In Scala, we have already seen how to implement generics, we use **square brackets** to surround the generic parameters.

```scala
class Container[A](value: A)

def testGeneric[A](value: Int): A = ???
```

Intermezzo: Higher Kinded Types

In the same way we have abstracted over types, we can abstract our functions over type constructors, or Higher Kinded Types:

```scala
def fn[M[_], A, B](
  ma: M[A]
)(
  fn: A => M[B]
): M[B] = ???
```

Trivia: Can you give a name to this particular function?

Identifying functional patterns

That's all we've done in these last examples, find repetitions and try to abstract them. That's what FP is all about!

There are some well-known abstractions we should be aware of

fold

`fold` consumes a structure (`Tree` in our case) and produces a value out of it.

fold

fold consumes a structure (`Tree` in our case) and produces a value out of it.

```scala
def fold[F[_], A, B](
  f: F[A]
)(
  onEmpty: B,
  onNode: (B, A, B) => B
): B = ???
```

map

map transforms each element given a function `A => B`

map transforms each element given a function A => B

```scala
def map[F[_], A, B](f: F[A])(fn: A => B): F[B] = ???
```

flatMap

`flatMap` is similar to `map`, but the lambda we pass to it returns a `F[B]` instead of a `B`

flatMap

flatMap is similar to `map`, but the lambda we pass to it returns a
F[B] instead of a B

```scala
def flatMap[F[_], A, B](f: F[A])(fn: A => F[B]): F[B] = ?
```

filter

filter returns a new structure `F[_]` with elements that doesn't adjust to a predicate `fn: A => Boolean` filtered out.

filter

filter returns a new structure F[_] with elements that doesn't
adjust to a predicate fn: A => Boolean filtered out.

```scala
def filter[F[_], A](f: F[A])(fn: A => Boolean): F[A] = ??
```

find returns the first element in a structure F[_] that matches a predicate.

find

find returns the first element in a structure F[_] that matches a predicate.

```scala
def find[F[_], A](f: F[A])(fn: A => Boolean): Option[A] =
```

Functional datatypes

There are some datatypes in the scala standard library that help a lot with common tasks.

Option

Option is used when something may be not present. Use it whenever you'd use null `null`.

With `nulls`

```scala
def httpConnection: String = {
  if (hostDefined) {
    getHost
  } else {
    null
  }
}
```

Option

Option is used when something may be not present. Use it whenever you'd use null `null`.

With `Option`

```scala
def httpConnectionWithOption: Option[String] = {
  if (hostDefined) {
    Some(getHost)
  } else {
    None
  }
}
```

Option

You can construct options with its two constrcutors `Some` & `None`, and you can also use the `Option` constructor, that will convert nulls in `None` if they occur

Try

Try captures exceptions and represents them as `Failures` instead of throwing them!

This is very important because exceptions will now follow the path of normal values instead of bubbling on their own.

Try

Without Try:

```scala
def user: String = try {
  findUser(3)
} catch {
  case e: Exception =>
    throw e
}
```

Try

With Try:

```scala
import scala.util.Try

def userWithTry: Try[String] = Try(findUser(3))
```

Either

Either represents computations that can return two different values. One of the many use cases for `Either` is validations:

Without Either

```scala
case class ValidationError() extends Exception()

def validatePhone(
  phone: String
): String = if (phone.length == 9) {
    phone
  } else {
    throw ValidationError()
  }
```

Either

With Either:

```scala
def validatePhoneWithEither(
  phone: String
): Either[ValidationError, String] =
  if (phone.length == 9) {
    Right(phone)
  } else {
    Left(ValidationError())
  }
```

Future

Future represents computations detached from time.
You know that those computations will happen, but do not when.
It's useful when you have an expensive operation and don't want to
block the current thread.

Future

Without Future

```scala
val callDB: Runnable = new Runnable {
  def run(): Unit = {
    db.findUser(3)
  }
}

new Thread(callDB).start
```

Future

with Future

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

val callDBFuture: Future[String] = Future(findUser(3))
```

Exercise 4

Let's use all this!