Abstraction

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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
- ▶ 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
```

Is this pure?

Examples

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

Is this pure?

yes

Examples

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

Is this pure?

Examples

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

Is this pure?

Nope, it's side effectful!

Examples

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

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Examples

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

Is this pure?

Examples

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

Is this pure?

Yes!

Examples

```
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

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

Is this pure?

Nope, it's partial!

Recap

Yesterday 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

```
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 yesterday's exercises, you'll see that there's a pattern:

Recap

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

scala> height(myTree)
res0: Int = 4
```

Recap

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

scala> sum(myTree)
res1: Int = 28
```

Recap

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

scala> count(myTree)
res2: Int = 7
```

Recap

```scala
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: (tree: Tree[Int])Tree[String]

scala> toStringNodes(myTree)
res3: Tree[String] = Node(Node(Empty(),2,Empty()),1,Node(No
```

Recap

```scala
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: (tree: Tree[Int])Tree[Int]

scala> squared(myTree)
res4: Tree[Int] = Node(Node(Empty(),4,Empty()),1,Node(Node(
```
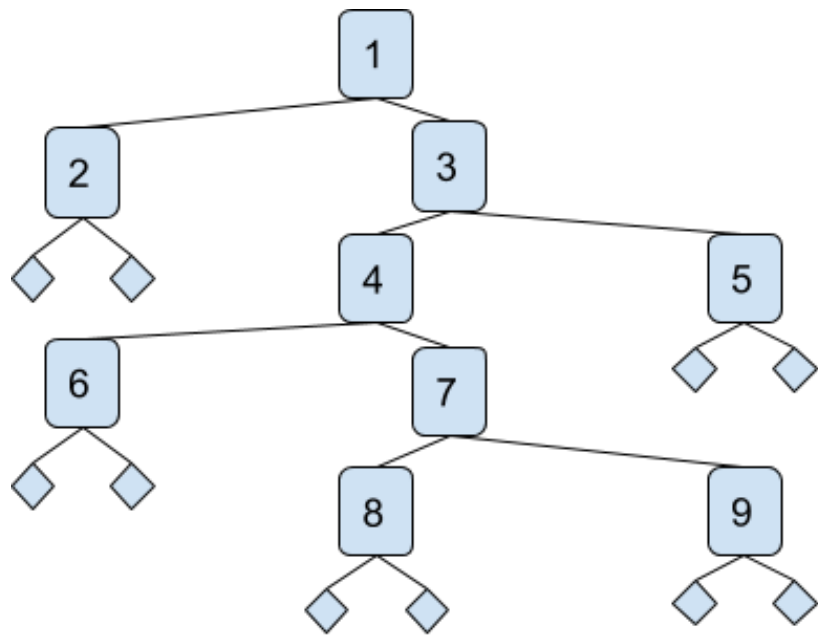
Can you create a higher order function with the common parts of
previous functions?

Identifying common functions

The pattern we've identified here is called `fold`, or more specifically, `catamorphism`.

Folds consume structures and create values out of them.

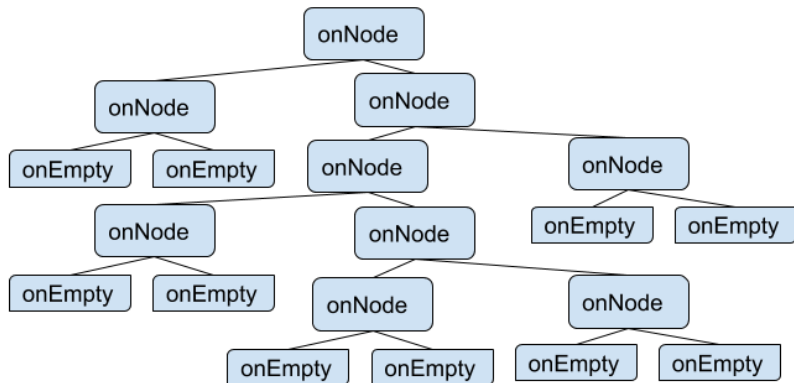# Identifying common functions

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)
     |    )
     | }
fold: [A, B](tree: Tree[A])(onEmpty: B, onNode: (B, A, B) =
```

abstraction

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

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

scala> heightWithFold(myTree)
res5: Int = 4
```

abstraction

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

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

scala> sumWithFold(myTree)
res6: Int = 28
```

abstraction

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

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

scala> countWithFold(myTree)
res7: Int = 7
```

abstraction

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

```scala
scala> def toStringNodesWithFold(tree: Tree[Int]): Tree[Str
     |   fold(tree)(Empty[String](), { (l: Tree[String], a
     |     Node[String](l, a.toString, r)
     |   })
toStringNodesWithFold: (tree: Tree[Int])Tree[String]

scala> toStringNodesWithFold(myTree)
res8: Tree[String] = Node(Node(Empty(),2,Empty()),1,Node(No
```

abstraction

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

```scala
scala> def squaredWithFold(tree: Tree[Int]): Tree[Int] =
     |     fold(tree)(Empty[Int](), { (l: Tree[Int], a: Int,
     |       Node[Int](l, a * a, r)
     |     })
squaredWithFold: (tree: Tree[Int])Tree[Int]

scala> squaredWithFold(myTree)
res9: Tree[Int] = Node(Node(Empty(),4,Empty()),1,Node(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: Tre
     |     Node[B](l, fn(a), r)
     |   })
map: [A, B](tree: Tree[A])(fn: A => B)Tree[B]
```

abstraction

And finally, implement those based on `map`!

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

scala> toStringNodesWithMap(myTree)
res10: Tree[String] = Node(Node(Empty(),2,Empty()),1,Node(N
```

abstraction

And finally, implement those based on `map`!

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

scala> squaredWithMap(myTree)
res11: Tree[Int] = Node(Node(Empty(),4,Empty()),1,Node(Node
```

Intermezzo: Higher Kinded Types

We are used to have 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 suround 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
scala> def fn[M[_], A, B](
     |     ma: M[A]
     | )(
     |     fn: A => M[B]
     | ): M[B] = ???
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 know abstractions we should be aware of

fold

fold

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

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

map

map

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

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

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

filter

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

find

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

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

functional datatypes

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`

```
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

```
def httpConnection: 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
     | }
user: String
```

Try

With Try:

```scala
scala> import scala.util.Try
import scala.util.Try

scala> def user: Try[String] = Try(findUser(3))
user: scala.util.Try[String]
```

Either

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

Without Either

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

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

Either

With Either:

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

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 callDB: Future[String] = Future(findUser(3))
```

Exercice 4