Those 10000 classes I never wrote

The power of recursion schemes applied to data engineering

Greetings

- The name's Valentin (@ValentinKasas)
- Organizer of the Paris Scala User Group
- Member of the ScalaIO conference crew
- Cook
- Wannabe marathon runner

DISCLAIMER

- Too much to show in a short time
  - ⇒ no time for cat pictures or funny gifs
- A lot of code that is
  - potentially scary
  - probably doesn't compile

THE STORY OF A DATA ENGINEERING PROBLEM

Problem Statement

- Building a « meta-Datalake »
- ~100 data sources w/ ~100 tables each
- From `None` to production in 6 months
- 5 developers

MORE FUN

- Data coming in batches and streams
- Privacy by design
- Data sources enrolled on a rolling basis

Requirements

- Pipeline must be configured at runtime
- Needs a specific schema (← privacy)
- Must work with different input & output formats
  - JSON, CSV, Parquet, Avro, …

SOLUTION

One Schema to Rule Them All

- The only way to have a generic Pipeline is to build it around a schema
- That schema must contain enough information to allow the required « privacy-by-design »

Schemas are cool

With a schema we can generically

- validate data
- generate random test data
- translate data between formats

SCHEMAS ARE RECURSIVE

- a schema is composed of smaller schemas
    - that are composed of smaller schemas
        - that are composed of smaller schemas
            - … etc
- … and so is the data they represent

Explicit recursion is bad

- The compiler doesn't help much
- StackOverflowError is around the corner
- Mixed concerns
- Not reusable code

Recursion Schemes FTW !

- Originate in « Functional programming with Bananas, Lenses, Envelopes and Barbed Wire »
- Decouple the how and the what
- Scala implementation :

  github.com/slamdata/matryoshka

Families of Schemes

- **folds**: destroy a structure bottom-up

  ex: `cata`

- **unfolds**: build-up a structure top-down

  ex: `ana`

- **refolds**: combine an unfold w/ a fold

  ex: `hylo`

Recursion Scheme Recipe

To use any recursion scheme, you need:

- a Functor (called « pattern-functor »)
- a Fix-point type (most of the time)
- an Algebra and/or a Coalgebra

Pattern Functors

```scala
sealed trait Tree
final case class Node(left: Tree, right: Tree) extends Tree
final case class Leaf(label: Int)              extends Tree
```

- idea : replace the recursive « slot » by a type parameter

Pattern Functors

```scala
sealed trait TreeF[A]
final case class Node[A](left: A, right: A) extends TreeF[A]
final case class Leaf[A](label: Int)        extends TreeF[A]

object TreeF {

  implicit val treeFunctor = new Functor[TreeF] {
    def map[A, B](fa: TreeF[A])(f: A => B): TreeF[B] = fa match {
      case Node(l, r) => Node(f(l), f(r))
      case Leaf(i)    => Leaf[B](i)
    }
  }
}
```

Pattern Functors

- Problem : different shapes of trees have different types

```
val tree1 = Node(Node(Leaf(1), Leaf(2)), Node(Leaf(3), Leaf(4)))
// tree1: Node[Node[Leaf[Nothing]]] = ...

val tree2 = Node(Leaf(0), Leaf(-1))
// tree2: Node[Leaf[Nothing]] = ...

val tree3 = Node(Leaf(42), Node(Leaf(12), Leaf(84)))
// tree3: Node[TreeF[_ <: Leaf[Nothing]]] = ...
```

Fix-point types

- Solution : use a fix-point type to « swallow » recursion

```scala
final case class Fix[F[_]](unFix: F[Fix[F]])
```

FIX-POINT TYPES

- Solution : use a fix-point type to « swallow » recursion

```scala
final case class Fix[F[_]](unFix: F[Fix[F]])
```

```scala
val tree2 = Fix[TreeF](Node(
              Fix[TreeF](Leaf(0)),
              Fix[TreeF](Leaf(-1))))
// tree2: Fix[TreeF] = ...

val tree3 = Fix[TreeF](Node(
              Fix[TreeF](Leaf(42)),
              Fix[TreeF](Node(
                Fix[TreeF](Leaf(12)),
                Fix[TreeF](Leaf(84))))))
// tree3: Fix[TreeF] = ...
```

(Co)Algebras

- Define what to do with a single layer of your recursive structure
  - Algebras: collapse, 1 layer at a time

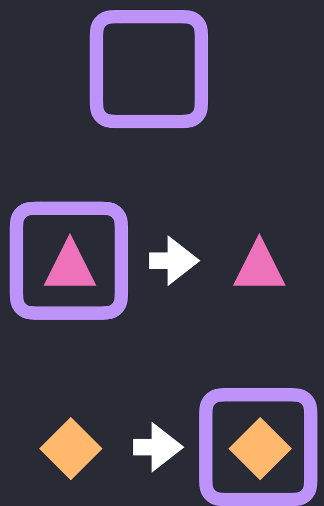
    `F[A] => A`

  - Coalgebras: build-up, 1 layer at a time

    `A => F[A]`

- `A` is referred to as the (co)algebra's carrier

Hylomorphisms



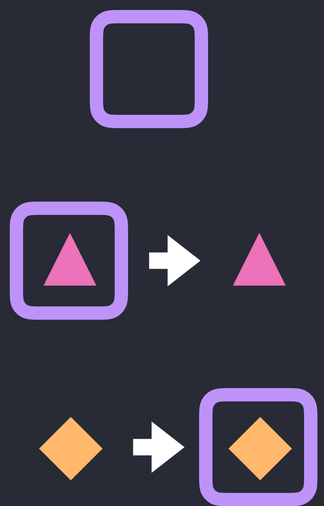
Pattern-functor

Algebra

Coalgebra

```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

HYLOMORPHISMS



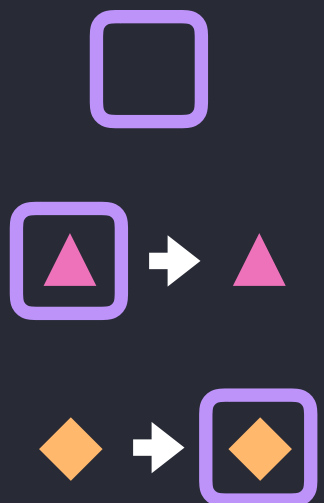
Pattern-functor

Algebra

Coalgebra

```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

HYLOMORPHISMS



Pattern-functor

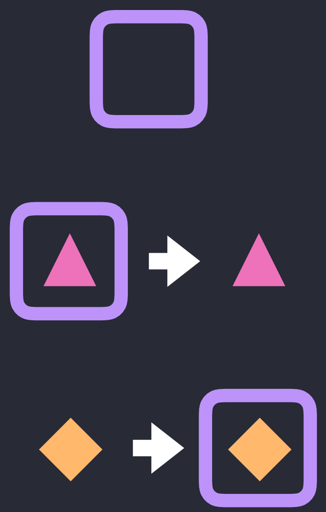
Algebra

Coalgebra

coalg(◆)

```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

Hylomorphisms



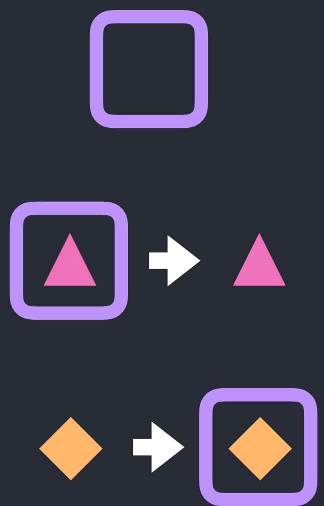
Pattern-functor

Algebra

Coalgebra

```scala
def hylo[F[_], A, B](a: A)
                   (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

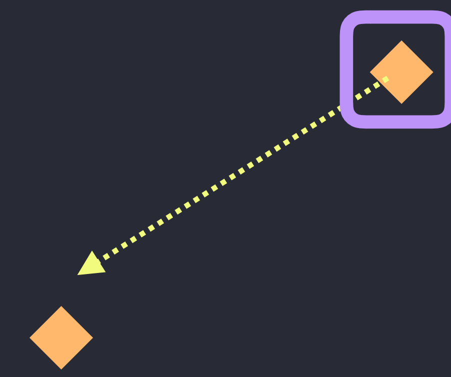
HYLOMORPHISMS



Pattern-functor

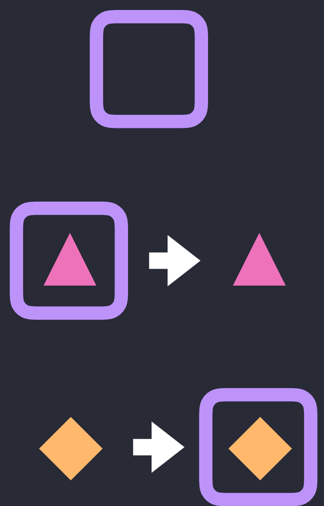
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

  alg(coalg(a) map (hylo(_)(alg, coalg)))
```

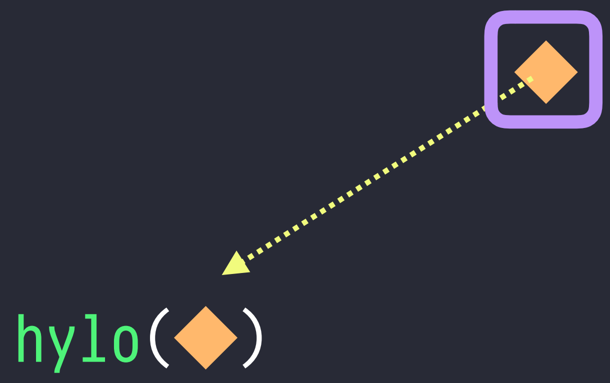
HYLOMORPHISMS



Pattern-functor

Algebra

Coalgebra



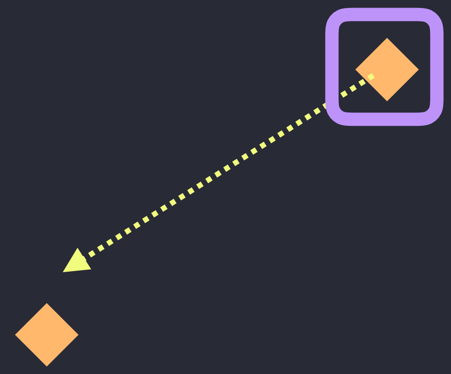

```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

HYLOMORPHISMS

Pattern-functor

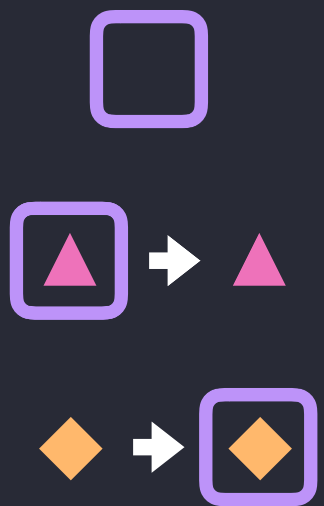
Algebra

Coalgebra



```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

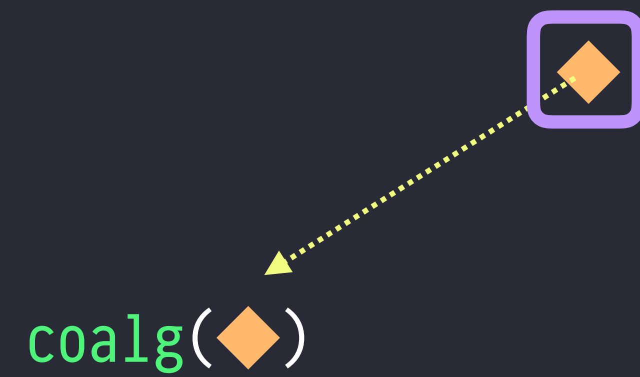
HYLOMORPHISMS



Pattern-functor

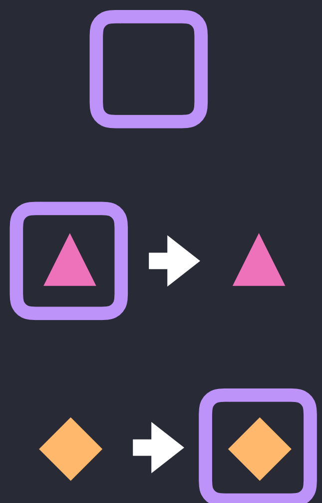
Algebra

Coalgebra




```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

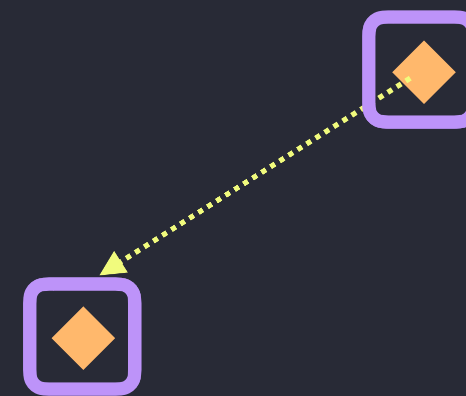
Hylomorphisms



Pattern-functor

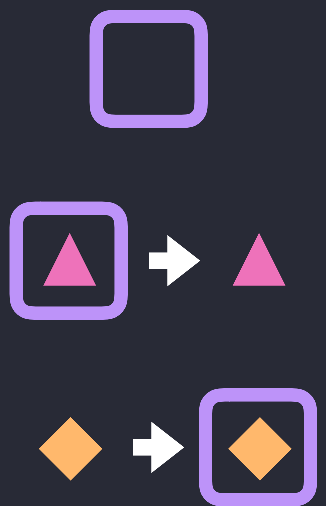
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

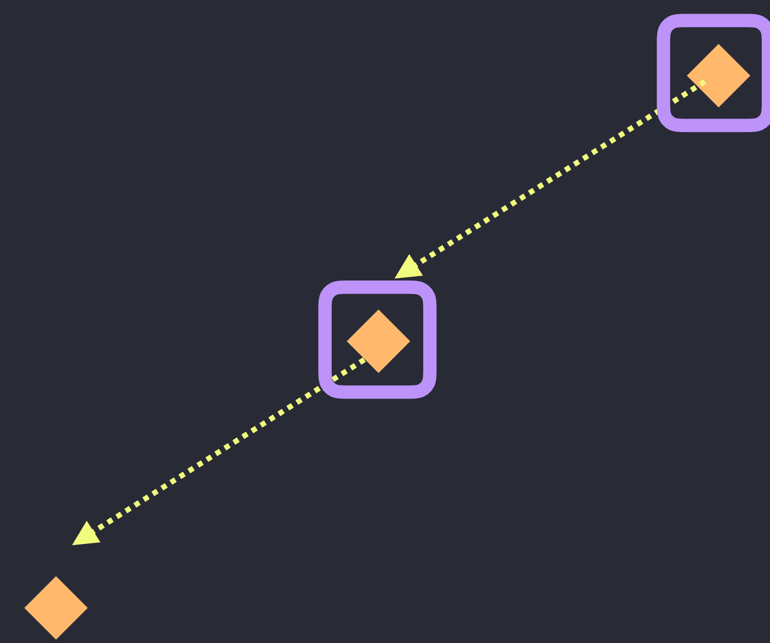
HYLOMORPHISMS



Pattern-functor

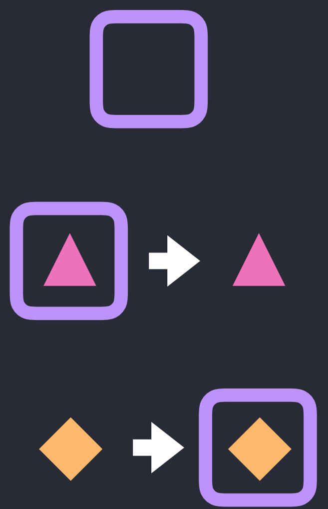
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

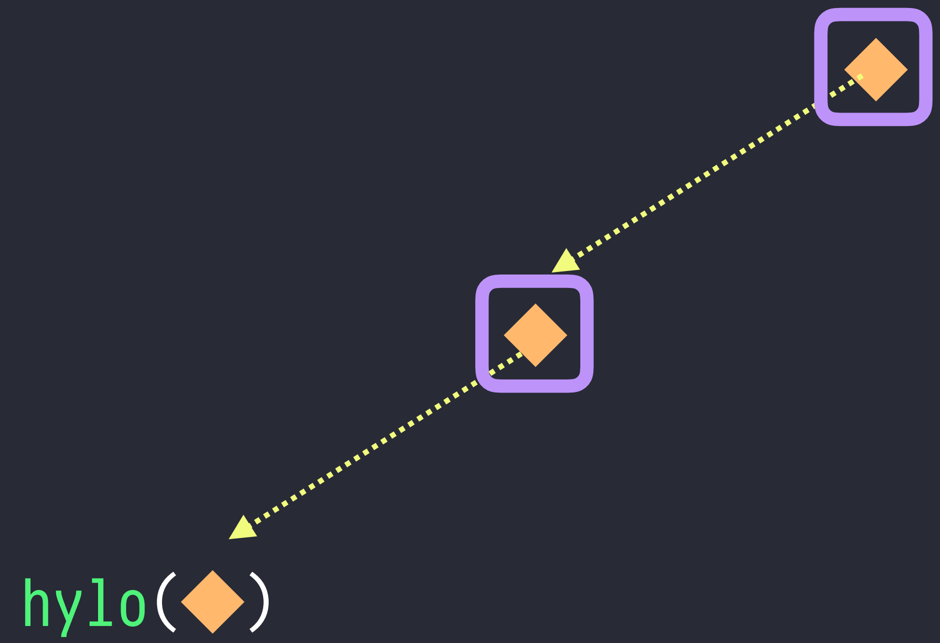
HYLOMORPHISMS



Pattern-functor

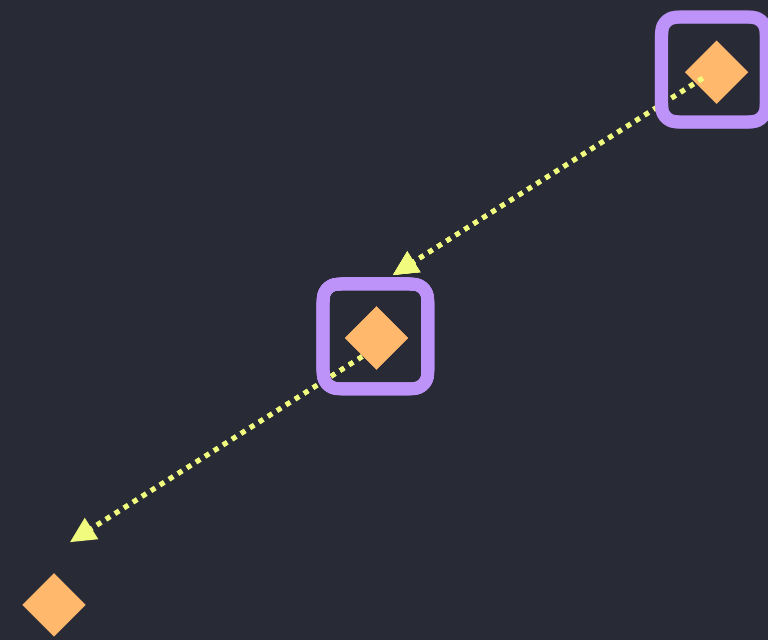
Algebra

Coalgebra



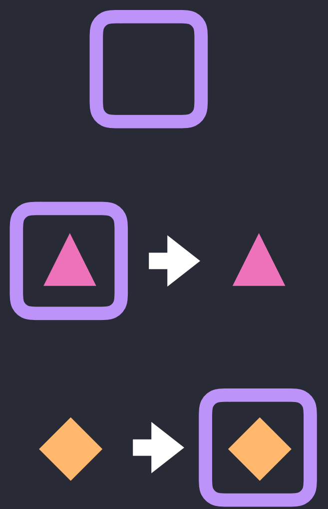

```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

  alg(coalg(a) map (hylo(_)(alg, coalg)))
```

Hylomorphisms



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

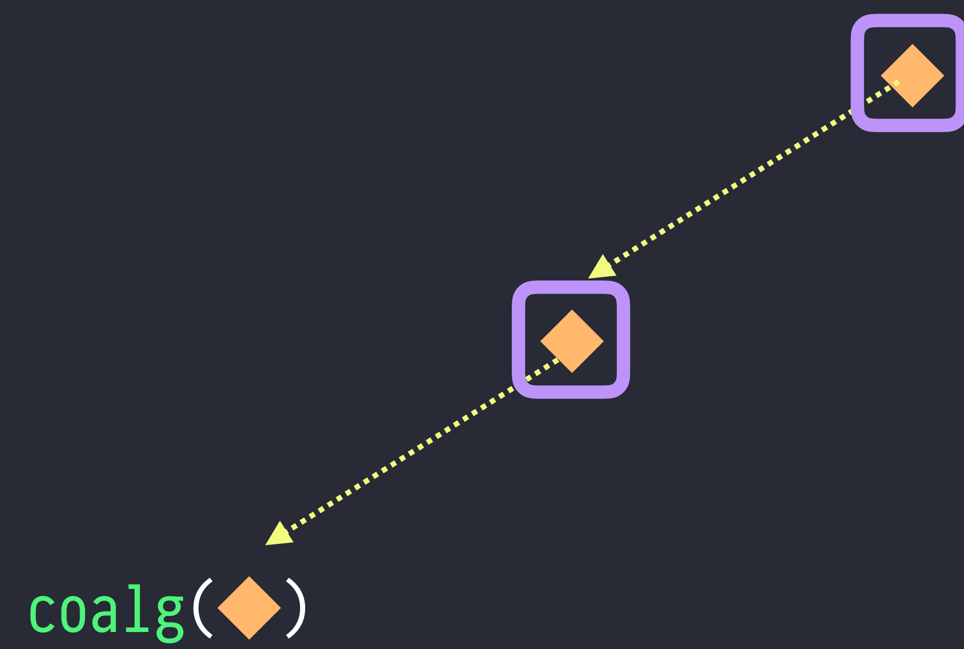
HYLOMORPHISMS



Pattern-functor

Algebra

Coalgebra



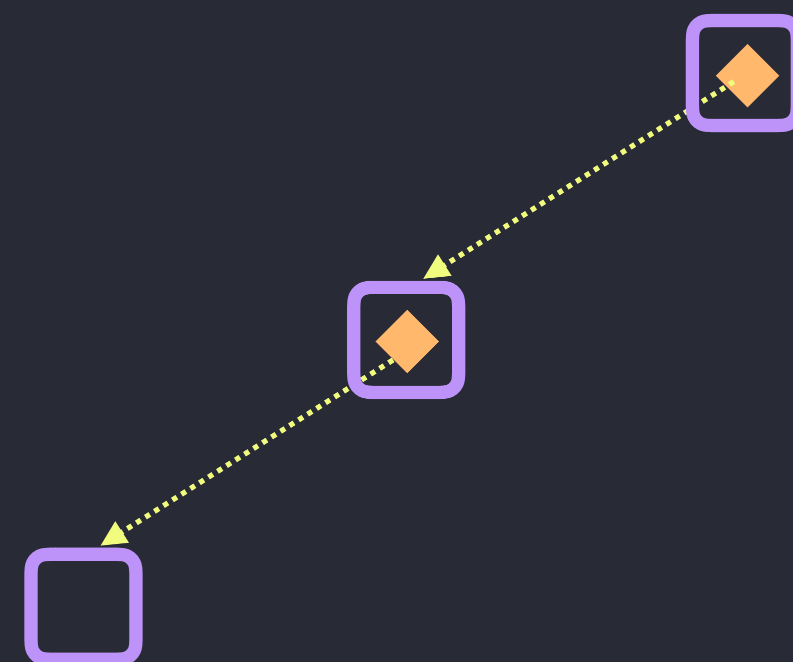

```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

Hylomorphisms

Pattern-functor

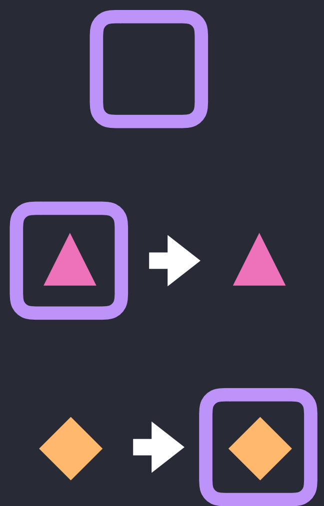
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

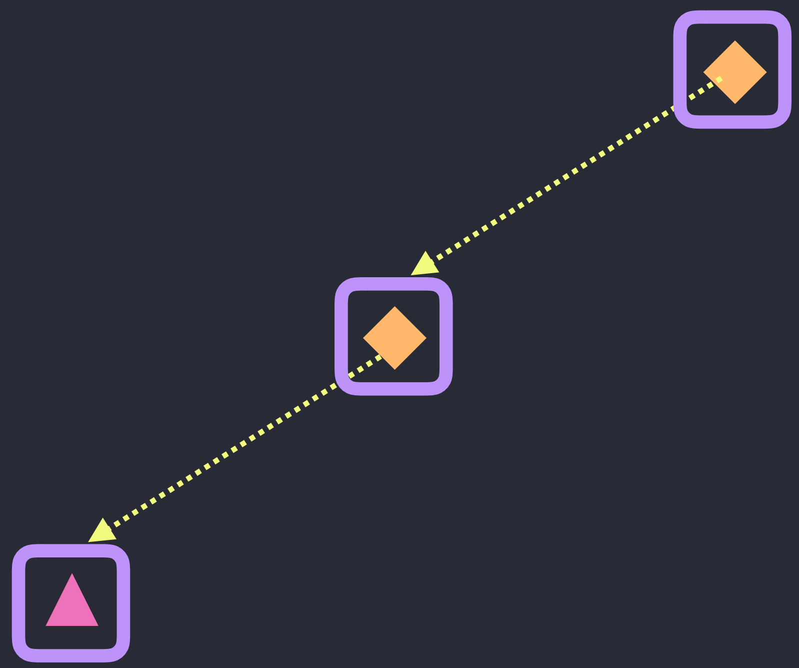
Hylomorphisms



Pattern-functor

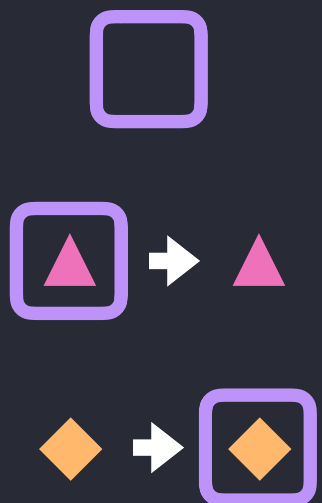
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

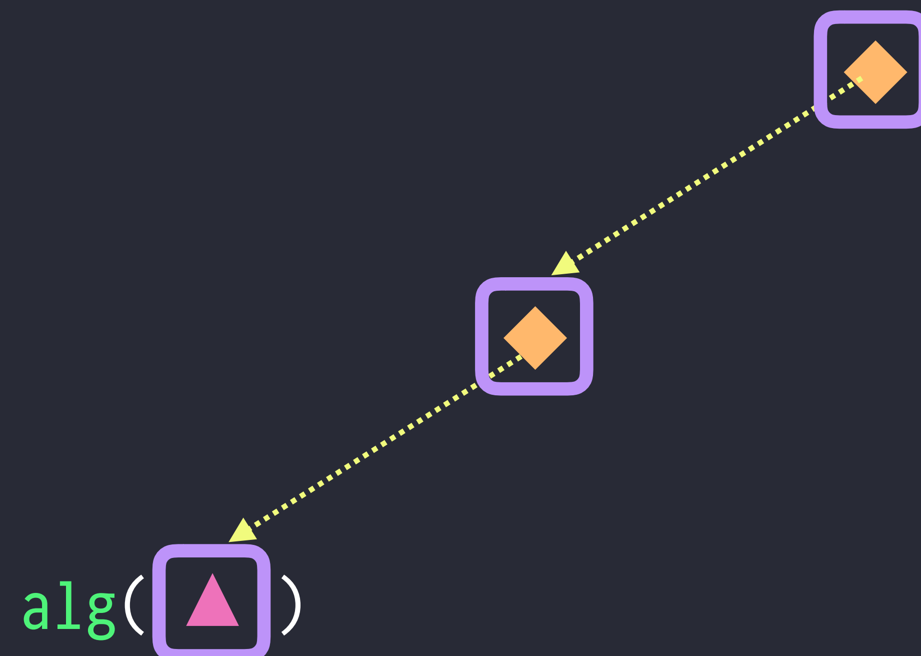
HYLOMORPHISMS



Pattern-functor

Algebra

Coalgebra



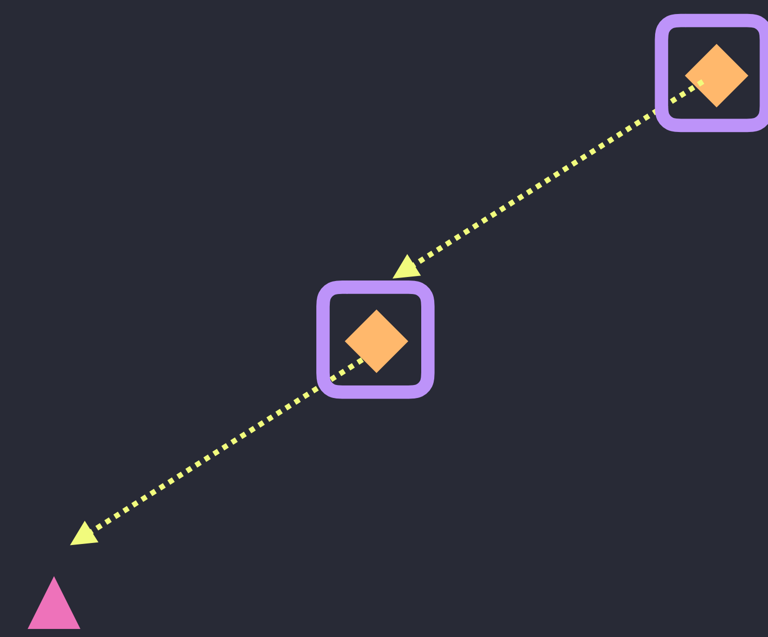

```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

Hylomorphisms

Pattern-functor

Algebra

Coalgebra



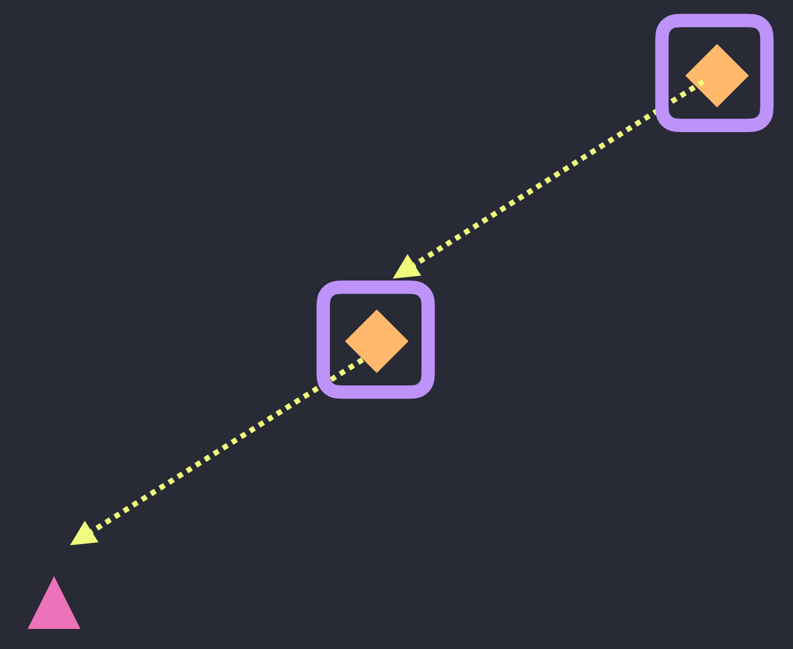
```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

HYLOMORPHISMS

Pattern-functor

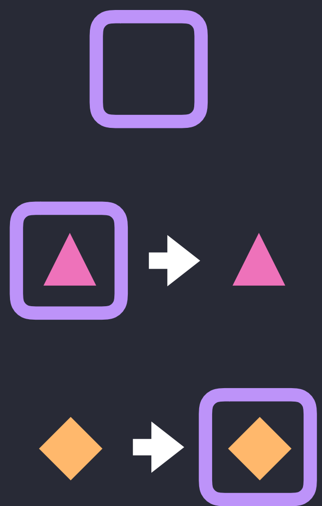
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

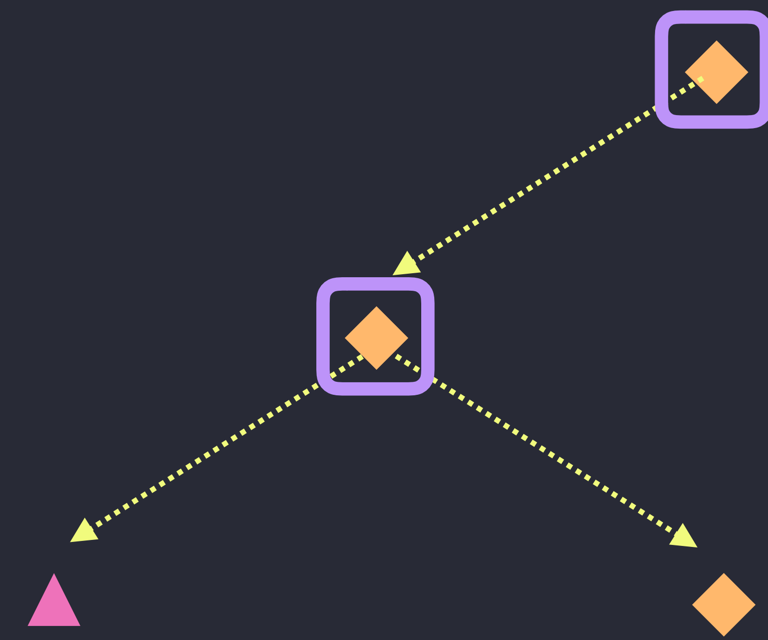
Hylomorphisms



Pattern-functor

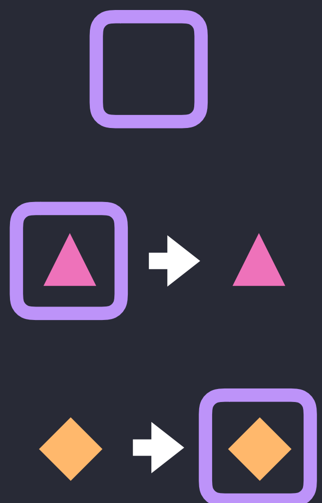
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

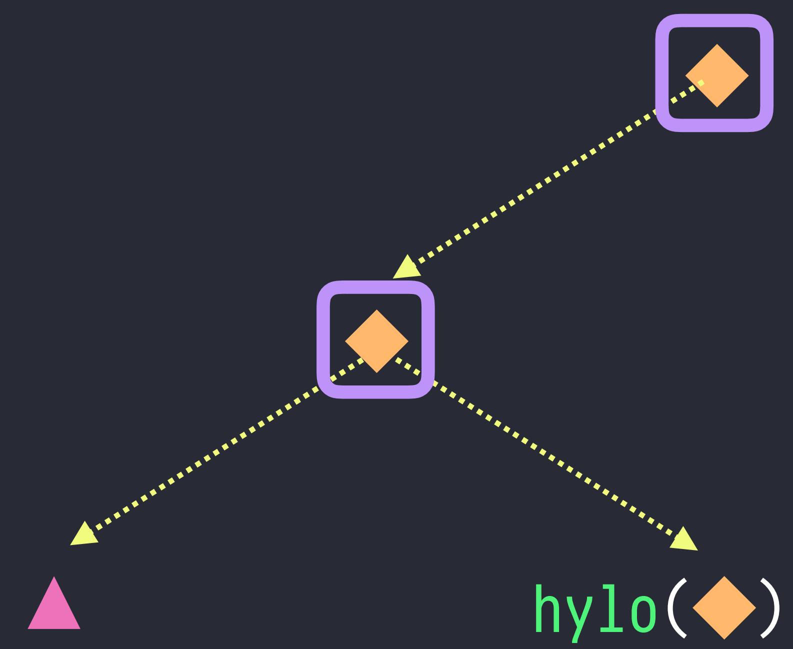
HYLOMORPHISMS



Pattern-functor

Algebra

Coalgebra



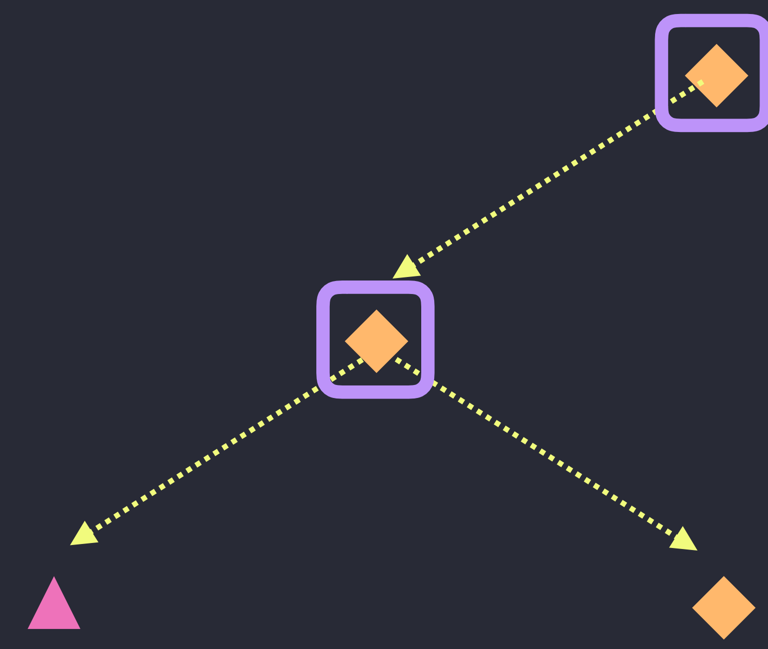

```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

  alg(coalg(a) map (hylo(_)(alg, coalg)))
```

HYLOMORPHISMS

Pattern-functor

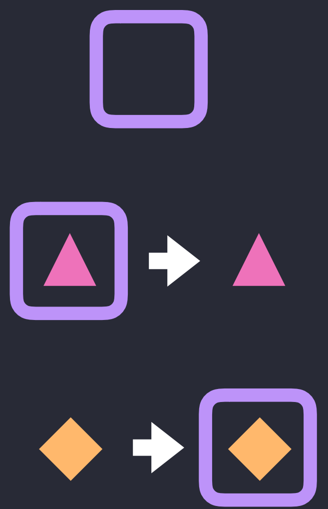
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

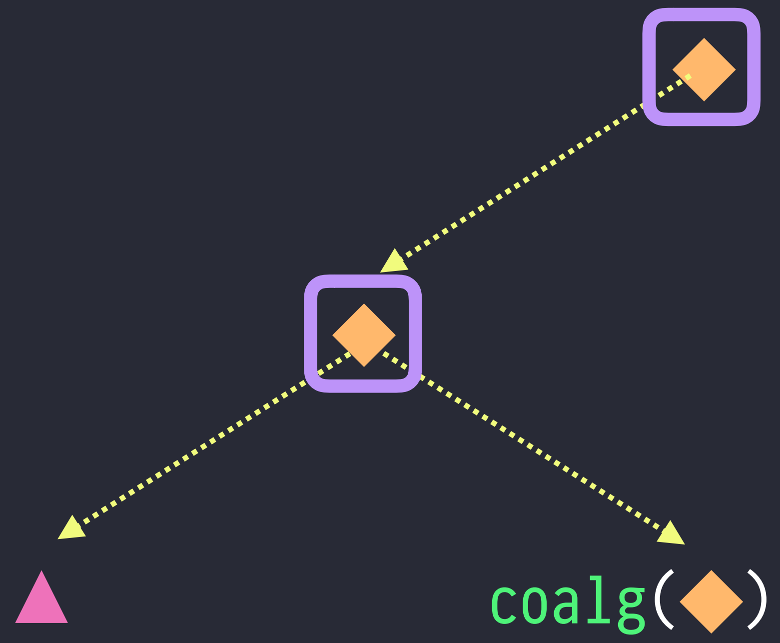
HYLOMORPHISMS



Pattern-functor

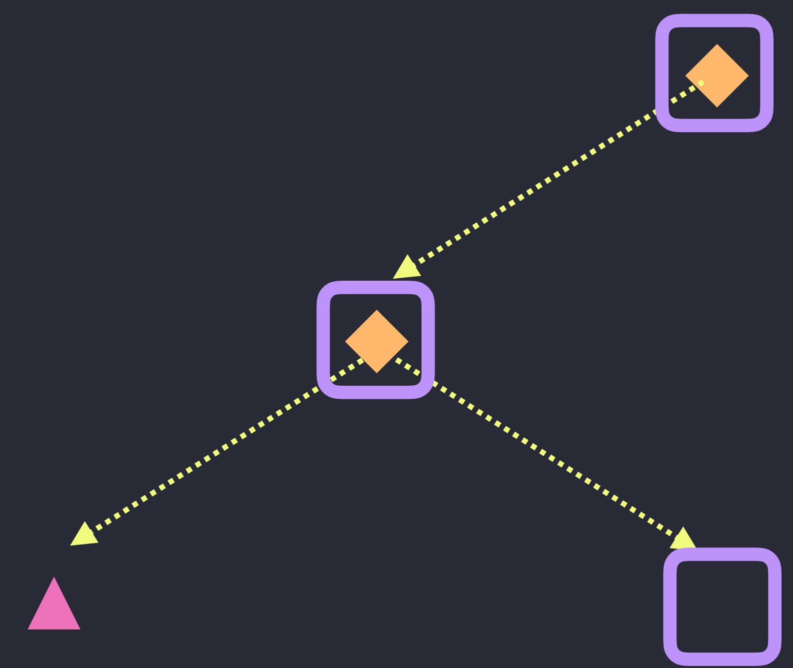
Algebra

Coalgebra



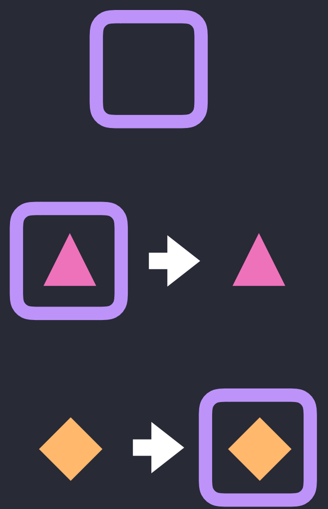

```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

Hylomorphisms



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

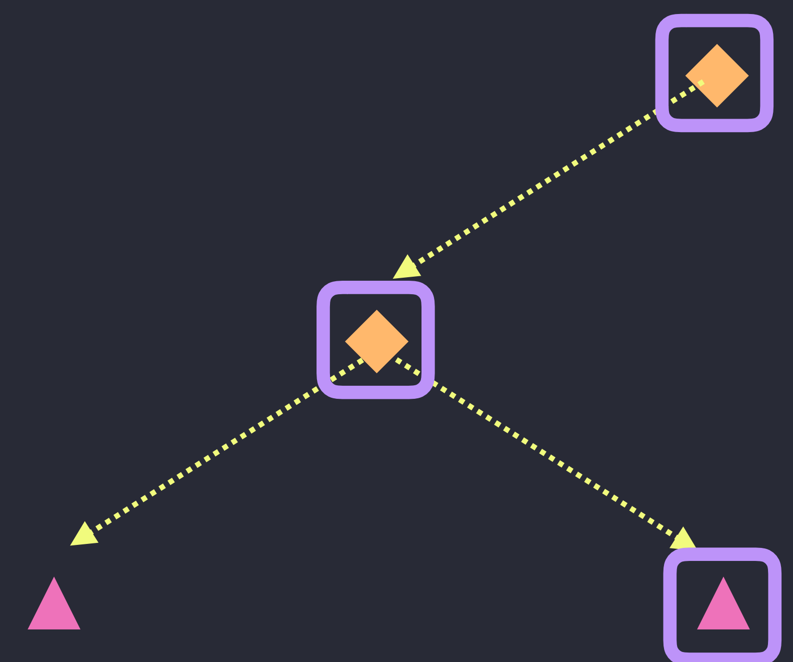
HYLOMORPHISMS



Pattern-functor

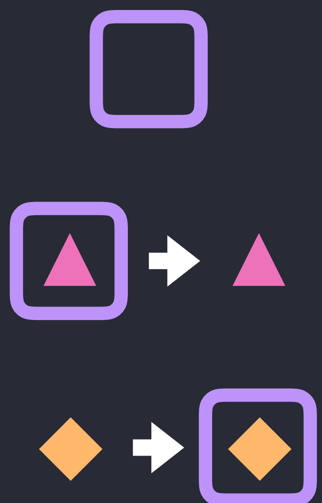
Algebra

Coalgebra



```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

  alg(coalg(a) map (hylo(_)(alg, coalg)))
```

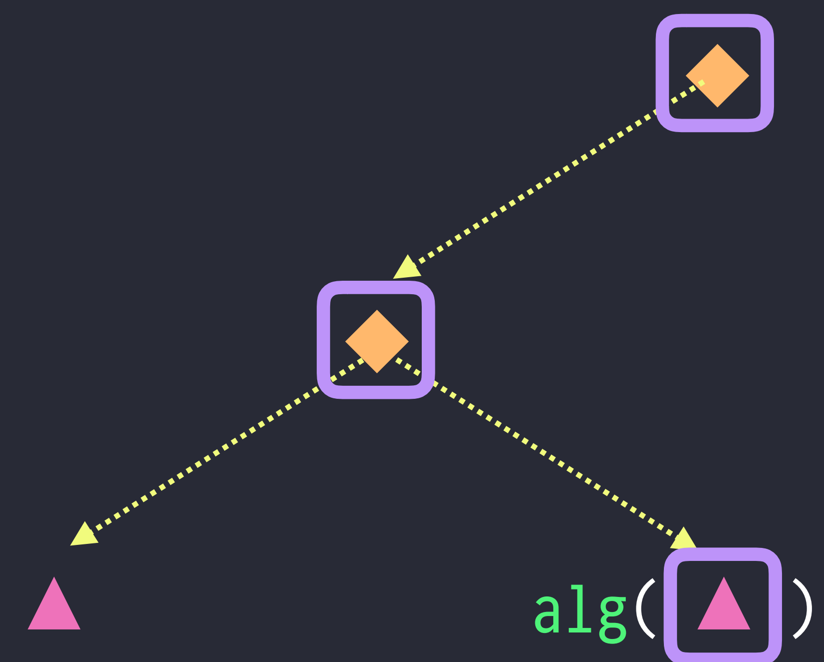
Hylomorphisms



Pattern-functor

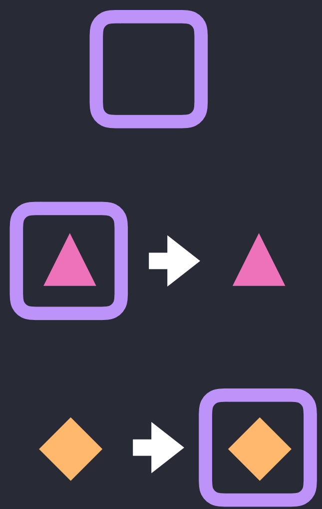
Algebra

Coalgebra




```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

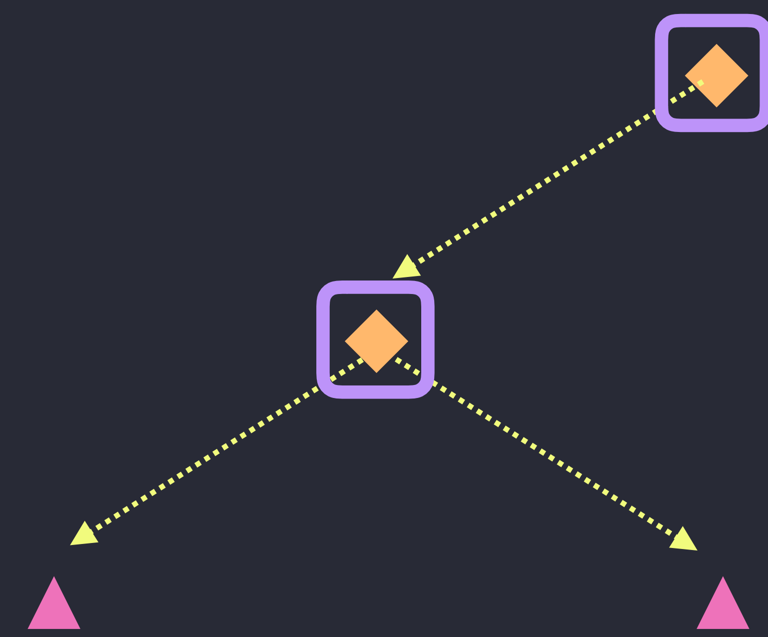
Hylomorphisms



Pattern-functor

Algebra

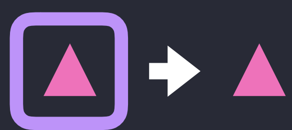
Coalgebra



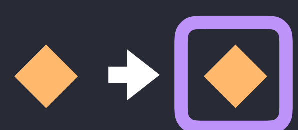
```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

HYLOMORPHISMS

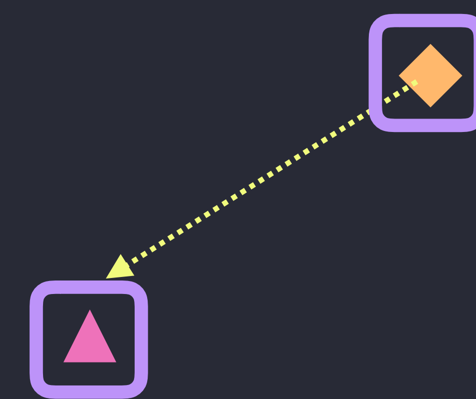
Pattern-functor



Algebra

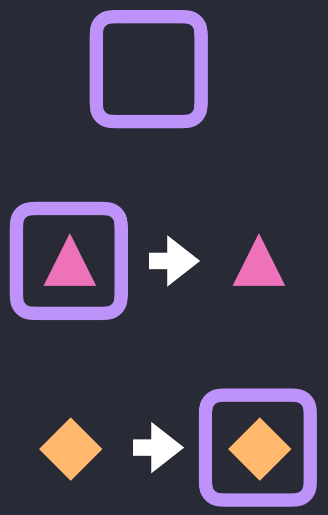


Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

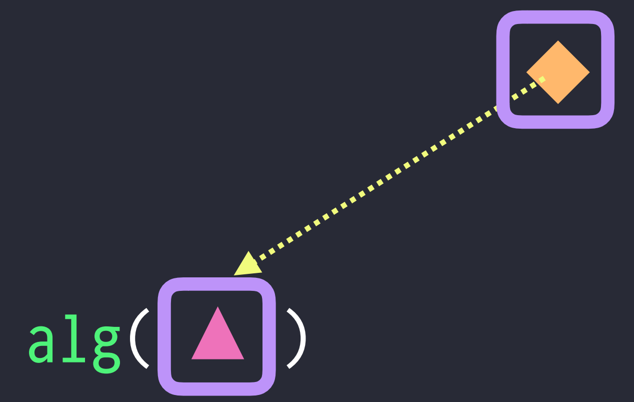
HYLOMORPHISMS



Pattern-functor

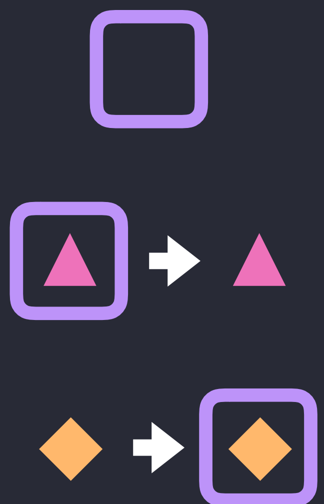
Algebra

Coalgebra




```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

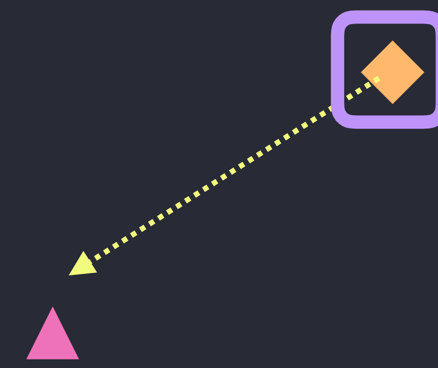
HYLOMORPHISMS



Pattern-functor

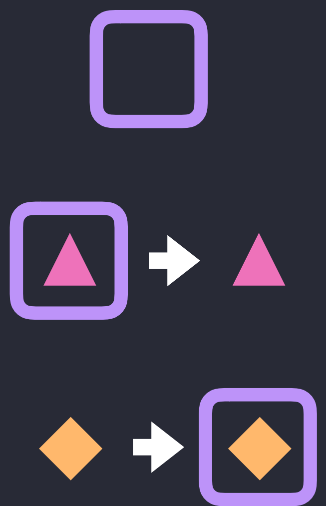
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

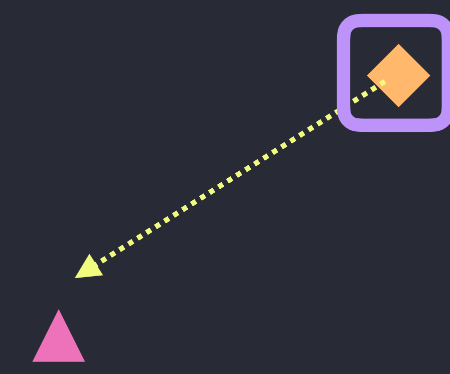
HYLOMORPHISMS



Pattern-functor

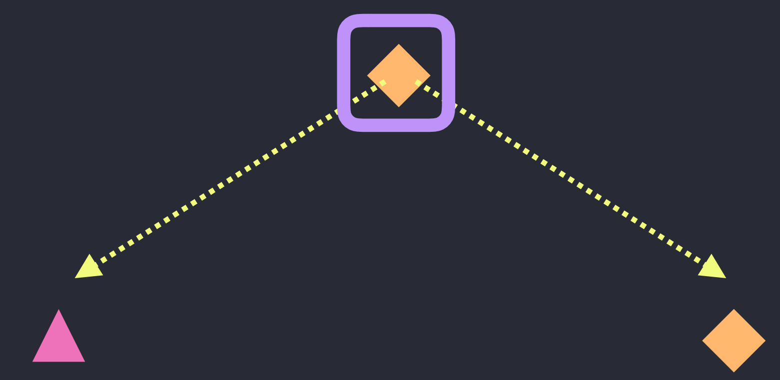
Algebra

Coalgebra



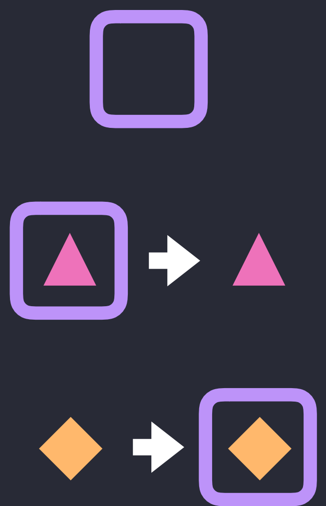
```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

Hylomorphisms



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

  alg(coalg(a) map (hylo(_)(alg, coalg)))
```

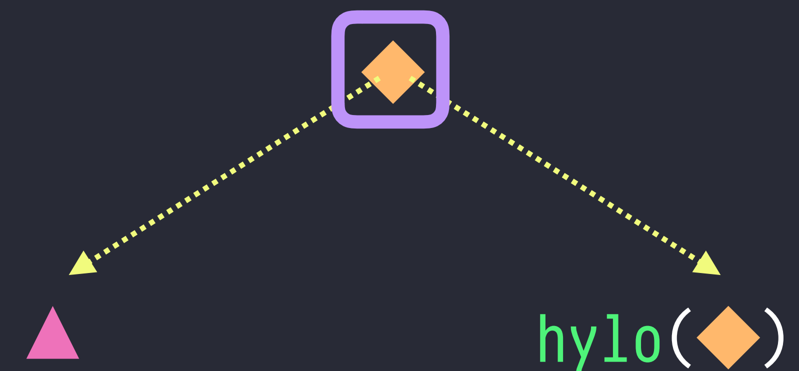
HYLOMORPHISMS



Pattern-functor

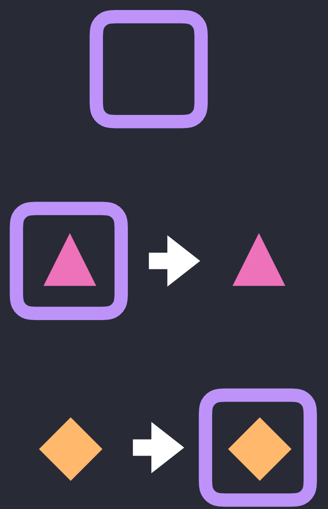
Algebra

Coalgebra




```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

  alg(coalg(a) map (hylo(_)(alg, coalg)))
```

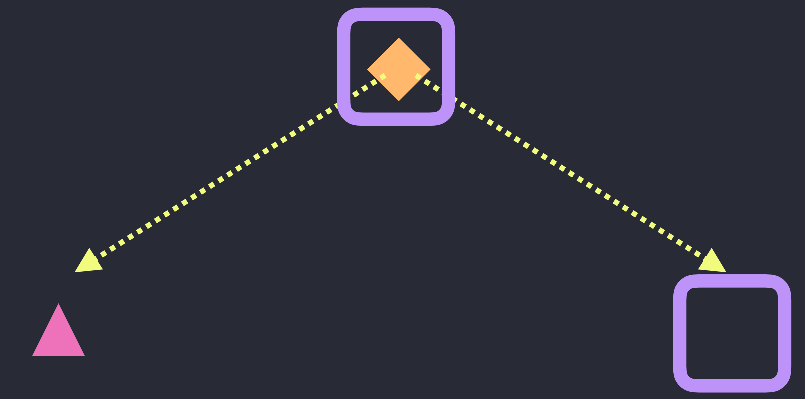
Hylomorphisms



Pattern-functor

Algebra

Coalgebra



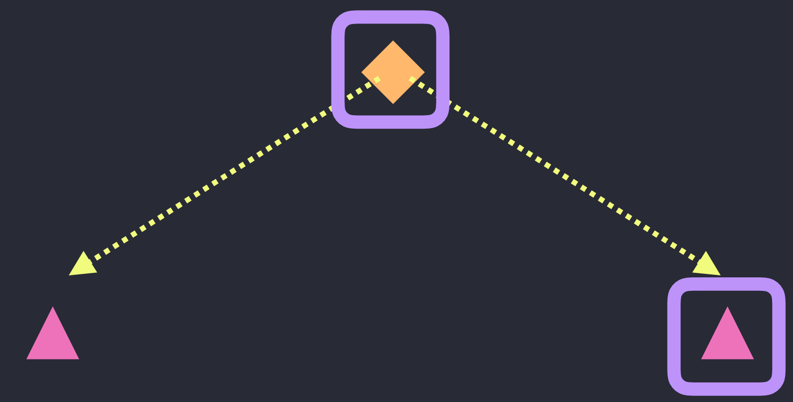
```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

HYLOMORPHISMS

Pattern-functor

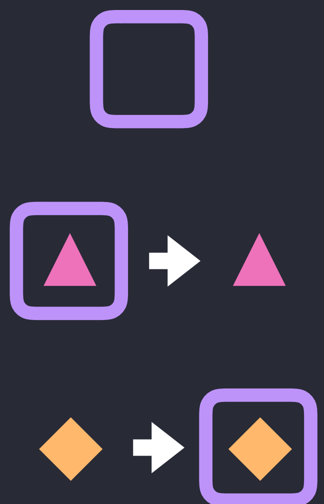
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

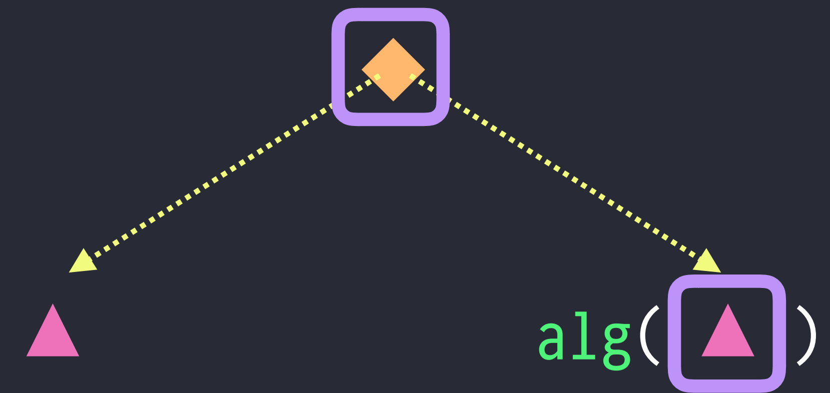
HYLOMORPHISMS



Pattern-functor

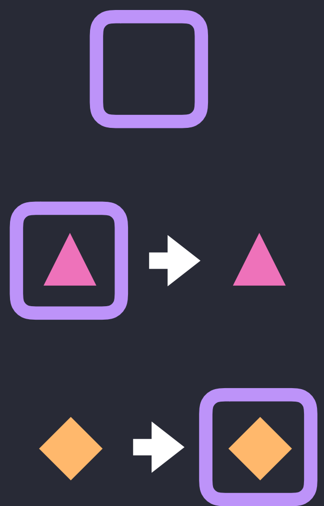
Algebra

Coalgebra




```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

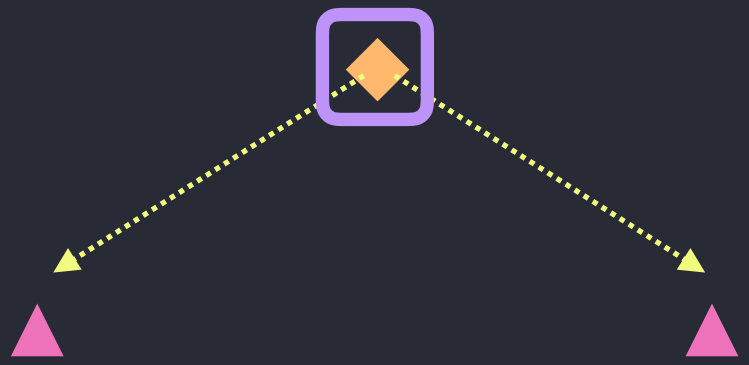
Hylomorphisms



Pattern-functor

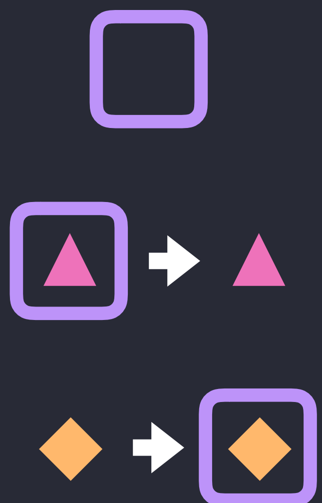
Algebra

Coalgebra



```
def hylo[F[_], A, B](a: A)
                   (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

HYLOMORPHISMS



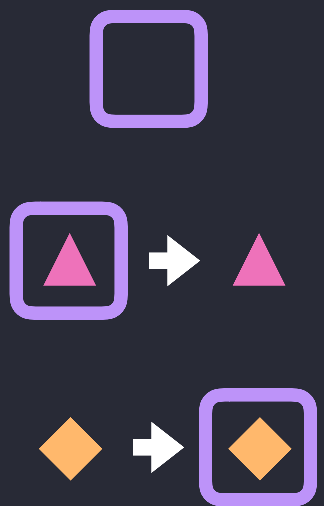
Pattern-functor

Algebra

Coalgebra

```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

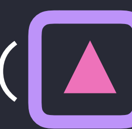
HYLOMORPHISMS



Pattern-functor

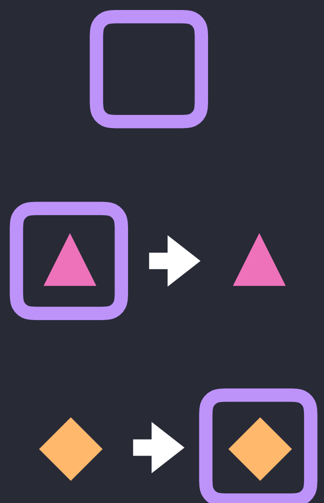
Algebra

Coalgebra

alg()

```
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

Hylomorphisms



Pattern-functor

Algebra

Coalgebra

```scala
def hylo[F[_], A, B](a: A)
                    (alg: Algebra[F, B], coalg: Coalgebra[F, A]): B =

    alg(coalg(a) map (hylo(_)(alg, coalg)))
```

GETTING REAL

ONE SCHEMA TO RULE ONE SCHEMA TO RULE THEM ALL...

Input Schema

Avro

Parquet

One schema to rule one schema to rule them all...

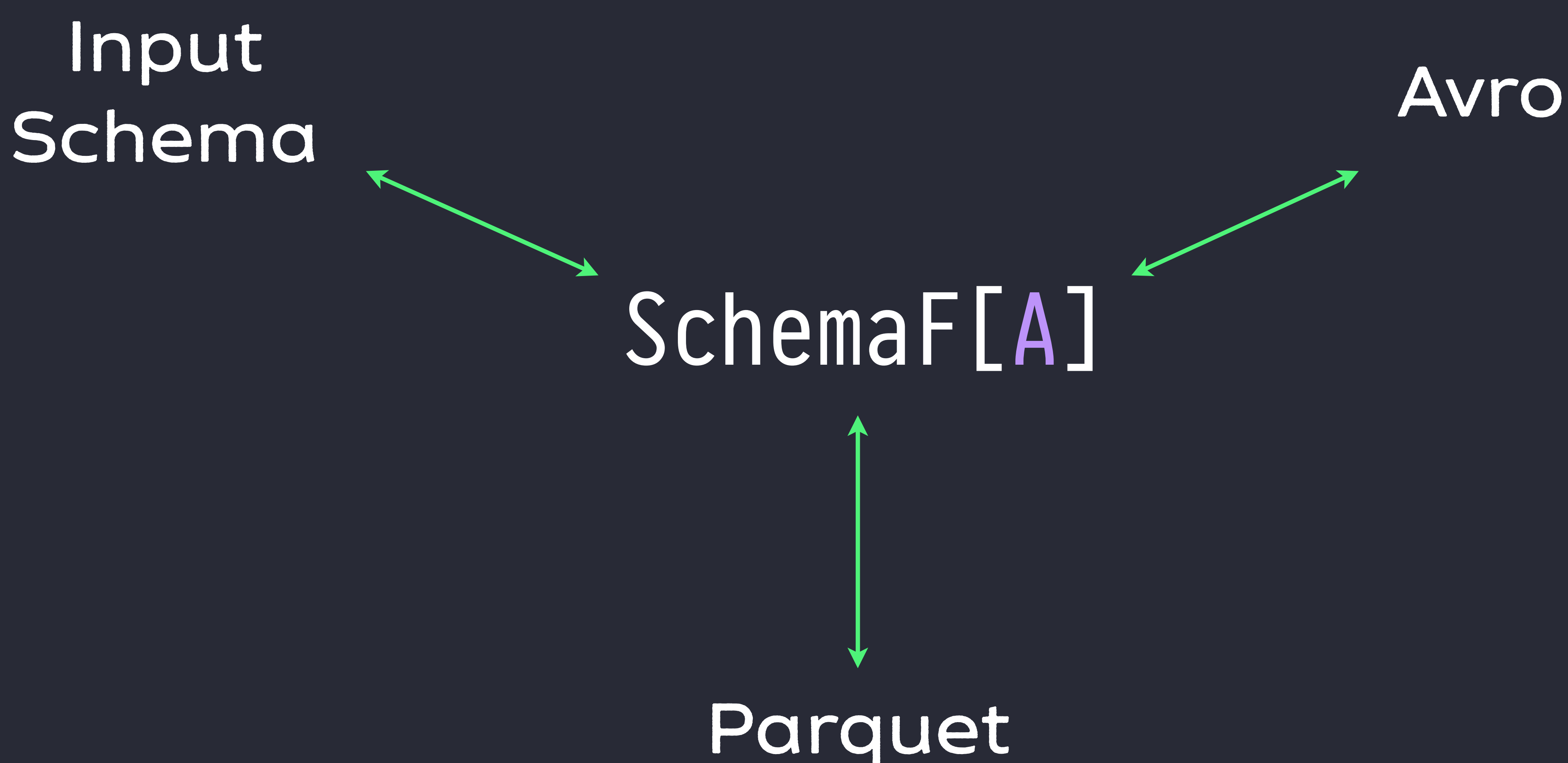
Input Schema

Avro

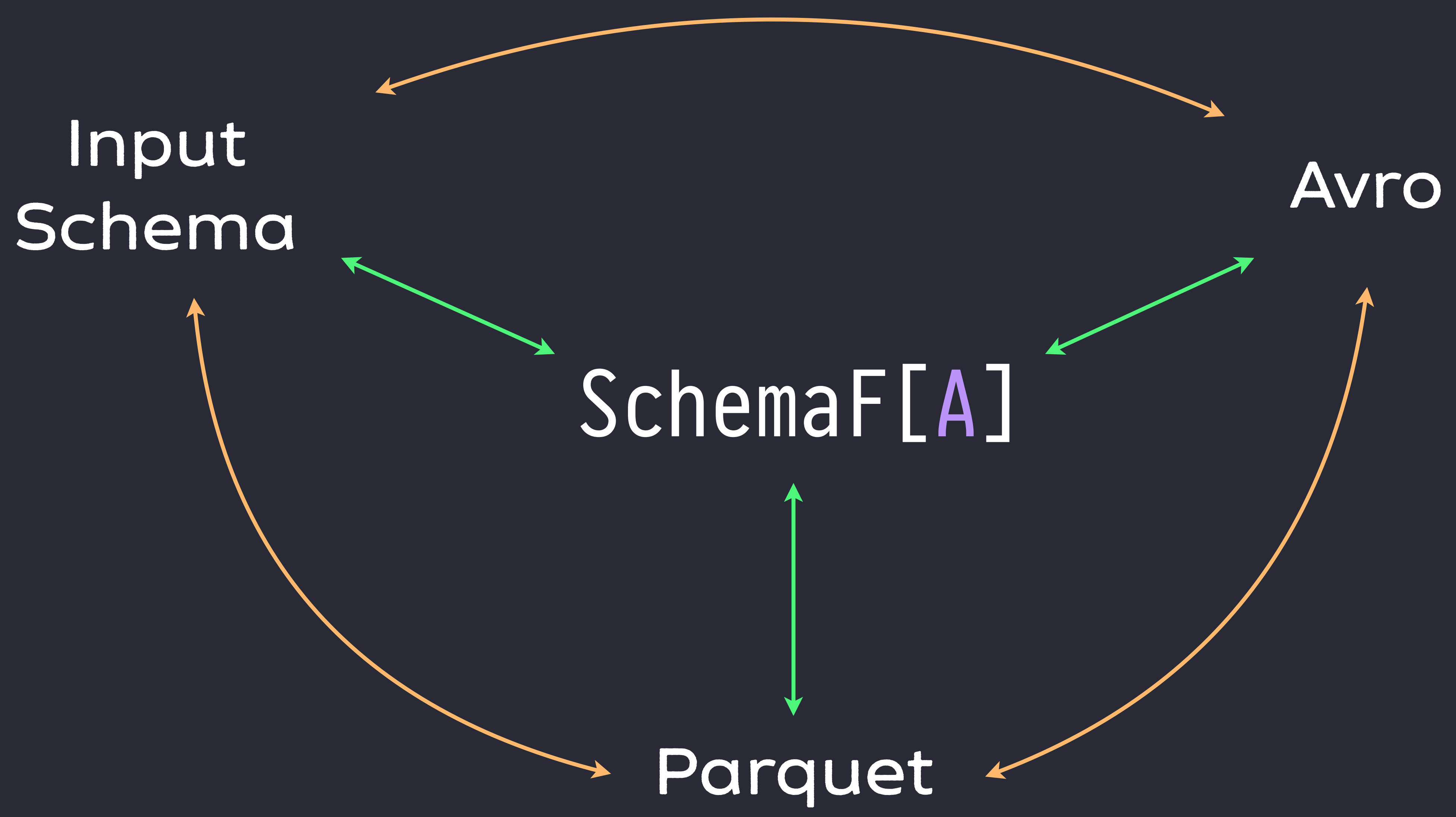
`SchemaF[A]`

Parquet

One schema to rule one schema to rule them all...



ONE SCHEMA TO RULE ONE SCHEMA TO RULE THEM ALL...



Step 1 : Pattern Functor

```scala
sealed trait SchemaF[A]

final case class StructF[A](fields: Map[String, A]) extends SchemaF[A]
final case class ArrayF[A](elementType: A)          extends SchemaF[A]
final case class IntF[A]()                          extends SchemaF[A]
final case class StringF[A]()                       extends SchemaF[A]
// etc ...

object SchemaF {

  implicit val schemaFunctor = new Functor[SchemaF] {

    def map[A, B](fa: SchemaF[A])(f: A => B): SchemaF[B] = fa match {
      case StructF(fields) => StructF(fields.mapValues(f))
      case ArrayF(elem)    => ArrayF(f(elem))
      case IntF()          => IntF[B]()
      case StringF()       => StringF[B]()
    }
  }
}
```

STEP 2 : ALGEBRAS

```scala
val schemaToParquet: Algebra[SchemaF, DataType] = {

  case StructF(fields) =>
    StructType(fields.map((StructField.apply _).tupled))
  case ArrayF(elem) => ArrayType(elem)
  case IntF()       => IntegerType
  case StringF()    => StringType

}


fixSchema.cata(schemaToParquet)
```

STEP 2.1: COALGEBRAS

```
val avroToSchema: Coalgebra[SchemaF, Schema] = { avro =>
  avro.getType match {
    case RECORD =>
      StructF(avro.getFields.map(f => f.name -> f.schema))
    case ARRAY  => ArrayF(avro.getElementType())
    case INT    => IntF()
    case STRING => StringF()
  }
}


avroSchema.ana[Fix](avroToSchema)

avroSchema.hylo(schemaToParquet, avroToSchema)
```

VALIDATING DATA

- we used github.com/jto/validation
  - defines the `Rule[I, O]` type
- we need a single ADT to represent data
  - otherwise we couldn't write algebras

```
sealed trait DataF[A]
final case class GStruct[A](fields: Map[String, A]) extends DataF[A]
final case class GArray[A](elements: List[A])       extends DataF[A]
final case class GInt[A](value: Int)                extends DataF[A]
final case class GString[A](value: String)          extends DataF[A]
```

Producing Validators

```
val validator: Algebra[SchemaF, Rule[JsValue, Fix[DataF]]] = {
  case StructF(fields) =>
    fields.toList.traverse{ case (name, validation) =>
      name -> (JsPath \ name).read(validation)
    }.map(fs => Fix(GStruct(fs.toMap)))

  case ArrayF(element) =>
    JsPath.pickList(element).map(es => Fix(GArray(es)))

  case IntF() =>
    JsPath.read[Int].map(v => Fix(GInt(v)))

  case StringF() =>
    JsPath.read[String].map(v => Fix(GString(v)))
}
```

LESS EASY STUFF

SCHEMA TO AVRO

- Impossible to write directly an `Algebra[SchemaF, Schema]`
- In an avro schema, each type must have an unique name
- Solution:
  - use the path of each node to name types
  - store previously built schemas in a registry

SOLUTION 1 : KEEP TRACK OF THE PATH

```scala
final case class EnvT[E, F[_], A](run: (E, F[A]))

type WithPath[A] = EnvT[String, SchemaF, A]

val schemaWithPath: Coalgebra[WithPath, (String, Fix[SchemaF])] = {
  case (path, Fix(StructF(fields))) =>
    EnvT((
      path,
      StructF(fields.map{case (k, v) => (s"$path.$k", Fix(v))})
    ))
  case (path, Fix(ArrayF(e))) =>
    EnvT((
      path,
      ArrayF((path, Fix(e)))
    ))
  // ...
}
```

Keeping track of the path (2)

```scala
def withPathToAvro(namespace: String)
: Algebra[EnvT[String, SchemaF, ?], Schema] = {
  case EnvT((path, StructF(fields))) =>
    SchemaBuilder
      .namespace(namespace)
      .record(path)
      ....
}
```

```scala
("", fixSchema).hylo(withPathToAvro, schemaWithPath)
```

Solution 2 : Use a registry

- Schemes come in different flavours : « classic », monadic, generalized
- Here we need the monadic flavour :

```scala
AlgebraM[M[_], F[_], A] = F[A] => M[A]
```

```scala
type FingerPrinted = (Long, Schema)

type Registry[A] = State[Map[Long, Schema], A]
```

Solution 2 : Using a Registry

```scala
val reuseTypes: AlgebraM[Registry, SchemaF, FingerPrinted] = { avro =>
  case StructF(fields) =>
    val fp = fingerPrint(fields)
    State.get.flatMap{ knownTypes =>
      if(knownTypes.contains(fp))
        State.state(fp -> knownTypes(fp))
      else {
        val schema = SchemaBuilder
          .newRecord(fp)
          ...
        State.put( knownType + (fp -> schema))
          .map(State.state(fp -> schema))
      }
    }
}

fixSchema.cataM(reuseTypes)
```

Writing Transformed Data

- Once we get a `Fix[DataF]`, we need to serialize it
    - to Parquet, using spark's `Row`
    - to Avro using `GenericRecord`

Serializing to Parquet

- We can nest `Row`s, so we can use an algebra with `Row` as the carrier
- But, we don't want our « simple » columns to be wrapped
- If we have a 2 columns table we want to output `Row(col1, col2)`, not `Row(Row(col1), Row(col2))`

PARAMORPHISM

- We need to know when we've reached the « bottom » of our tree
- `para` is a scheme that gives us the previous « tree » it has consumed
- It uses a `GAlgebra[(T, ?), F, A]`

```
GAlgebra[W[_], F[_], A] = F[W[A]] => A
```

Building Rows

```
val toRow: GAlgebra[(Fix[DataF], ?), DataF, Row] = {
  case GStruct(fields) =>
    val values = fields.map{ case (_, (fix, value)) =>
      if (isSimpleType(fix)) value.get(0) // unwrap the row
      else                   value
    }
    Row(values: _*)

  case GInt(value) =>
    Row(value)

  // etc...
}


fixData.para[Row](toRow)
```

TO BE CONTINUED ....

WELL, ACTUALLY ...

INSPIRED FROM REAL FACTS

... but inspired only

IT MIGHT SEEM HARD AT FIRST ….

IT MIGHT SEEM HARD AT FIRST ....

… BUT IT GETS BETTER

.... BUT IT GETS BETTER