# Repurposing Scala's Pattern Matching for Deeply Embedded DSLs

Tomas Mikula

Nov 7th, 2024

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**Write** DSL programs using **Scala**-embedded syntax

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f(a) switch {
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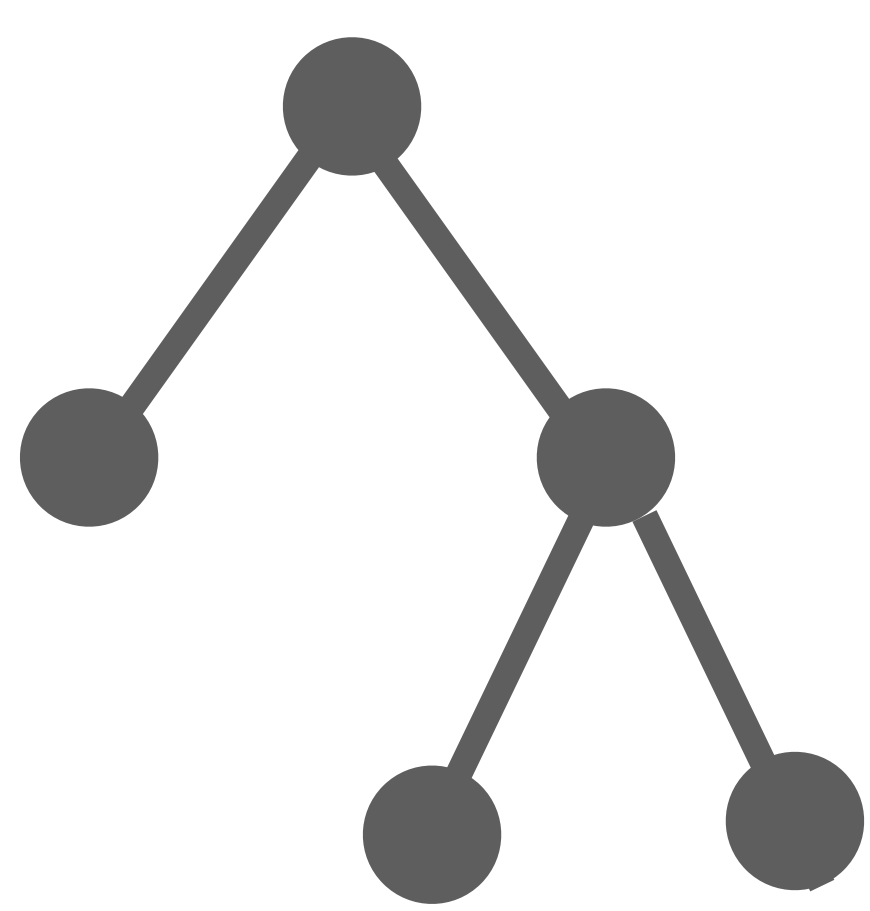

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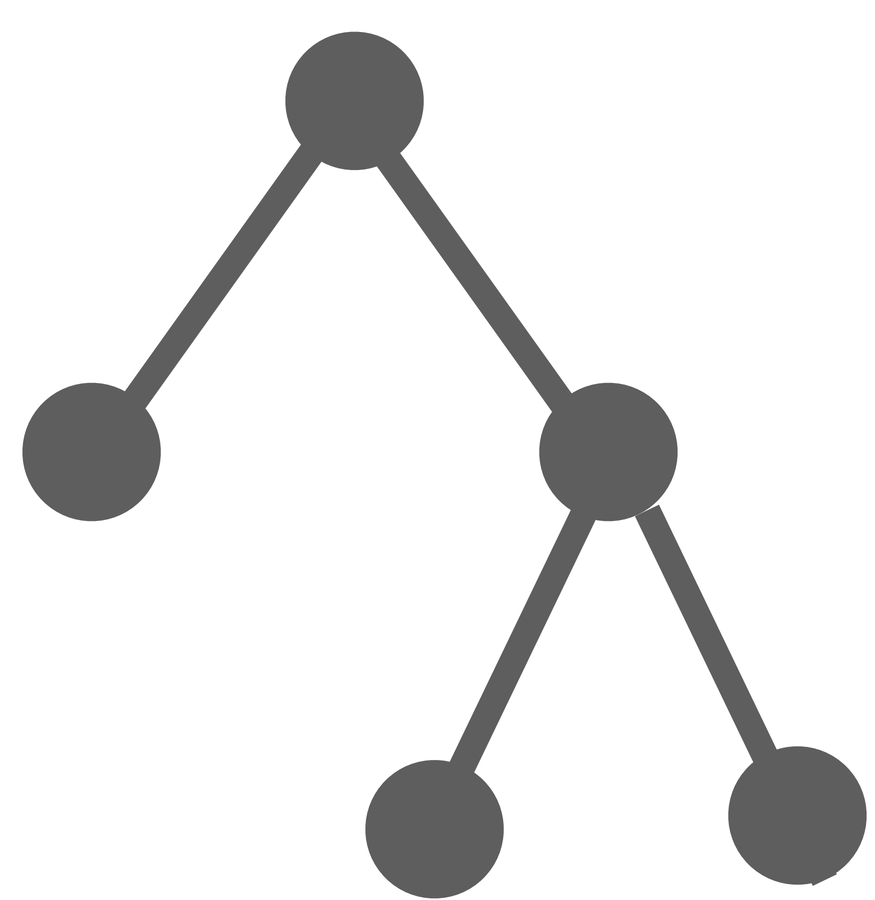

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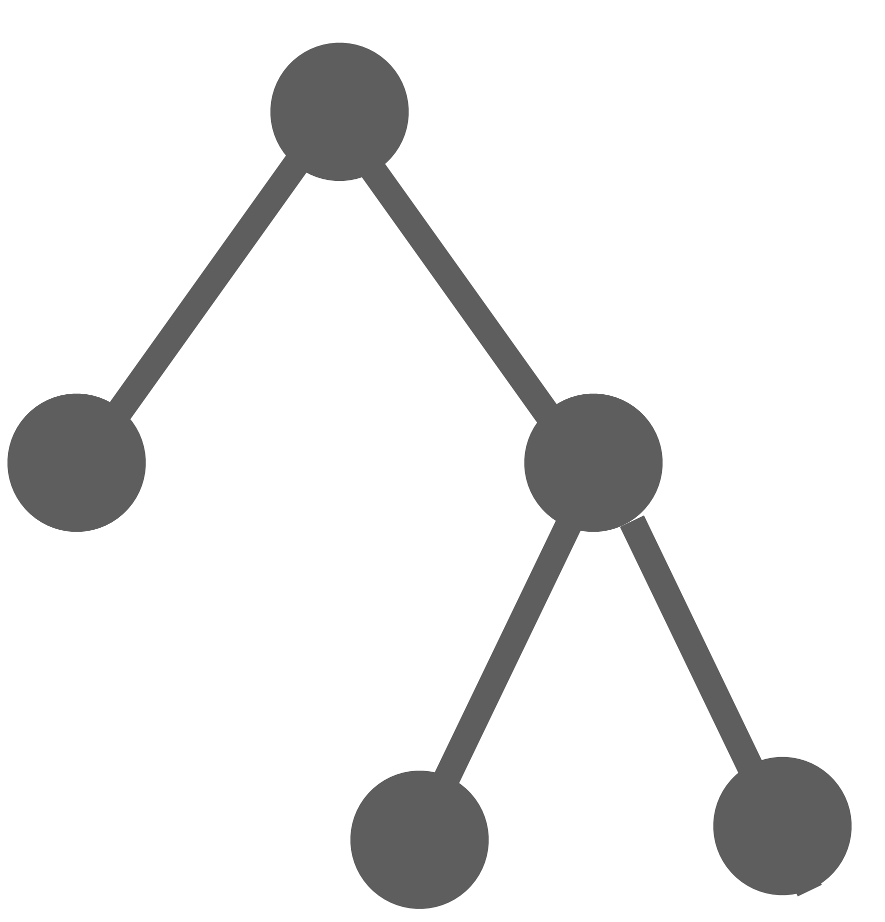

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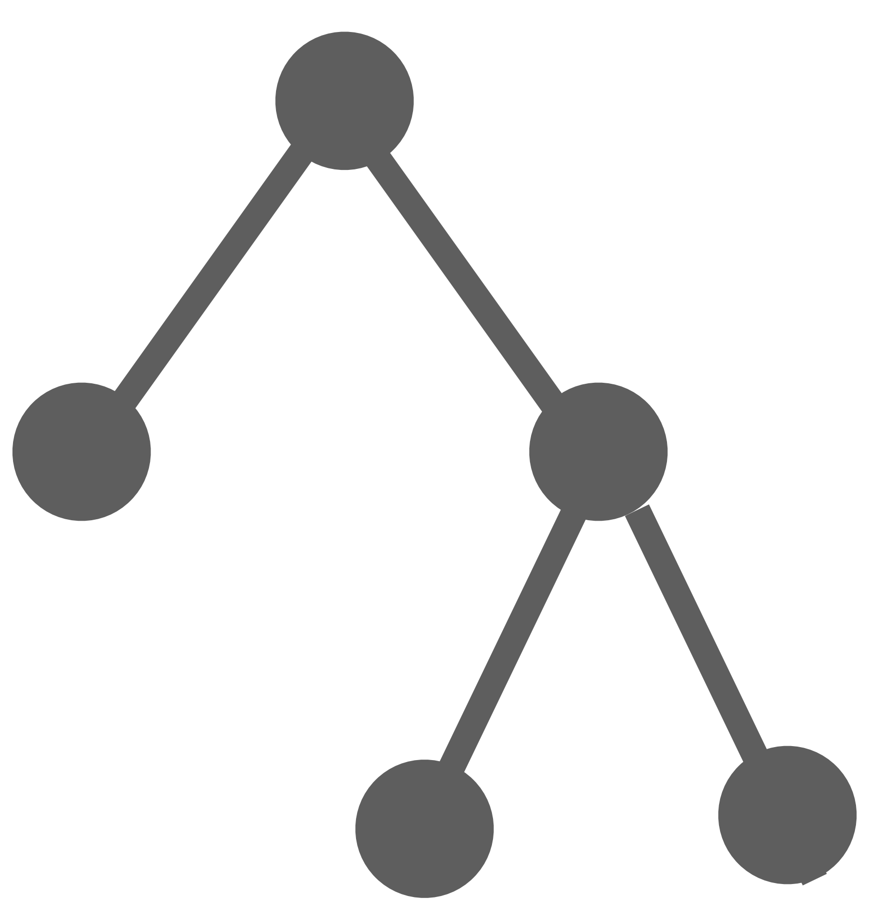

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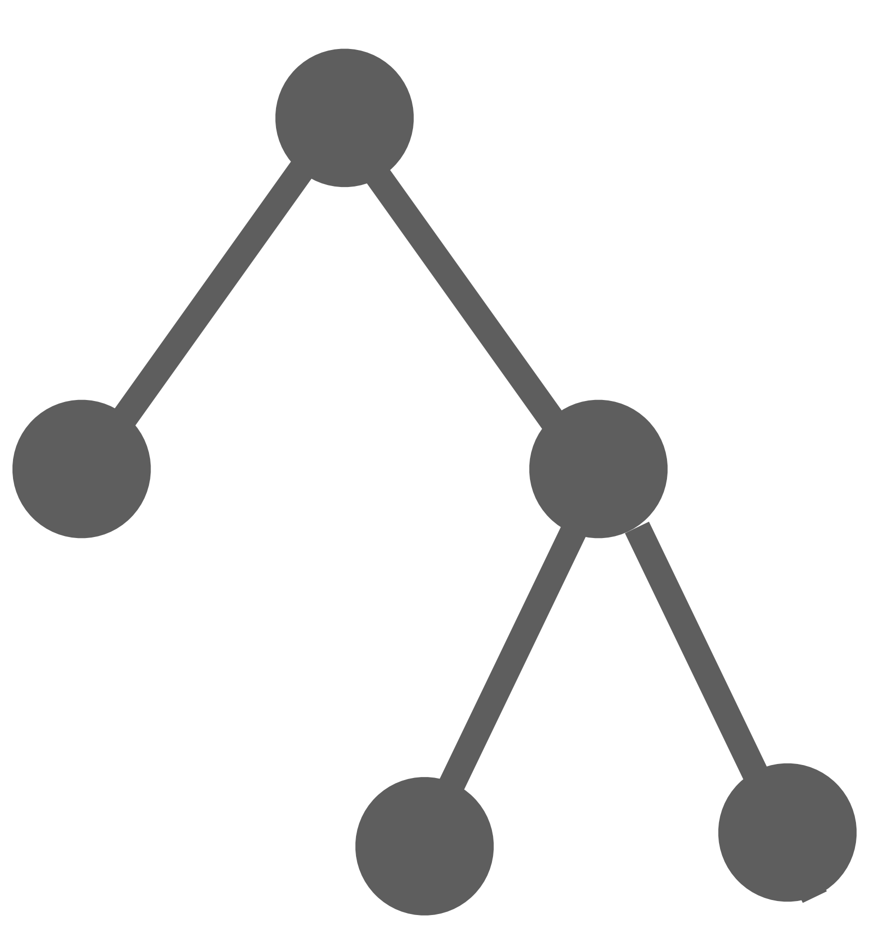

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*"DIY Scala Virtualized"* *(sort of)*

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Use case coming in a minute.

# Aspects of a deeply-embedded DSL

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Domain

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Syntax

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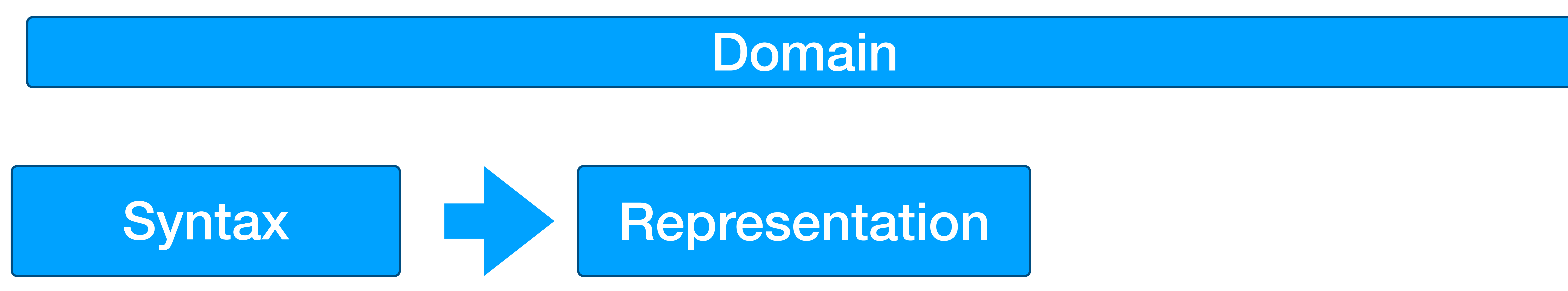
What we write

# Aspects of a deeply-embedded DSL

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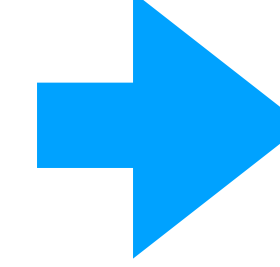

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What we write

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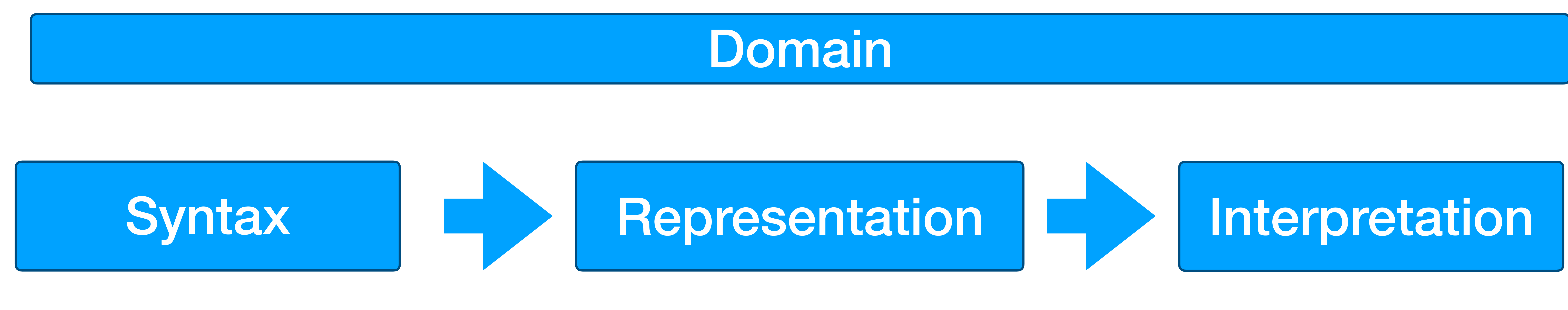


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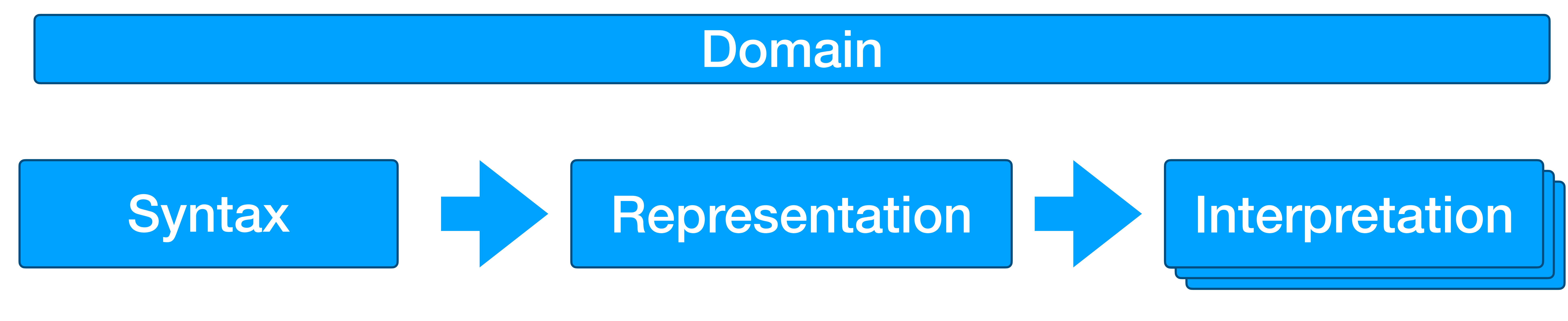


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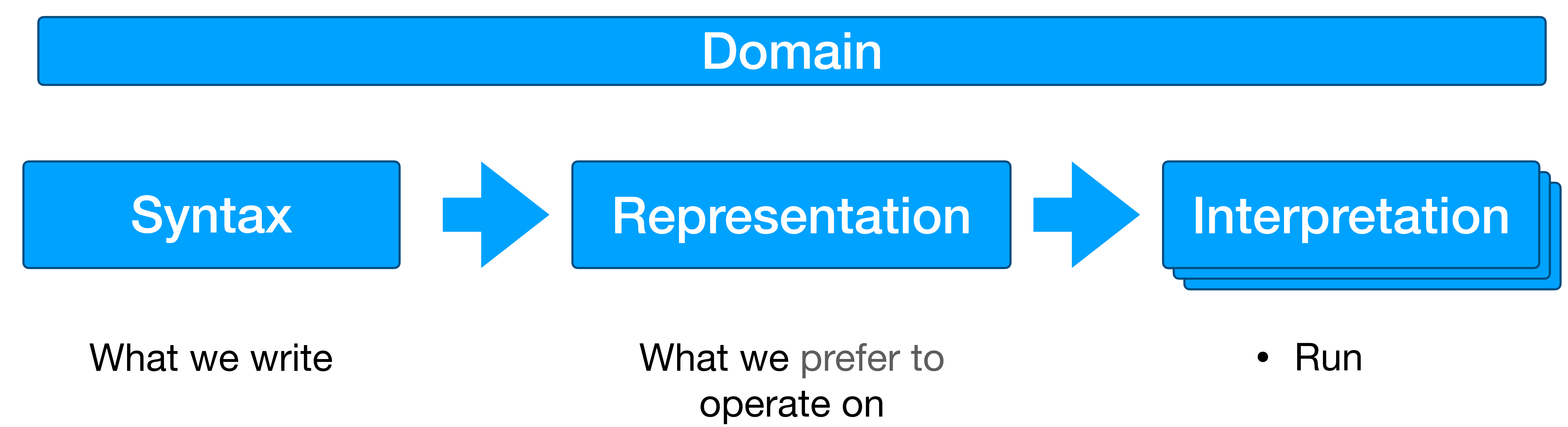

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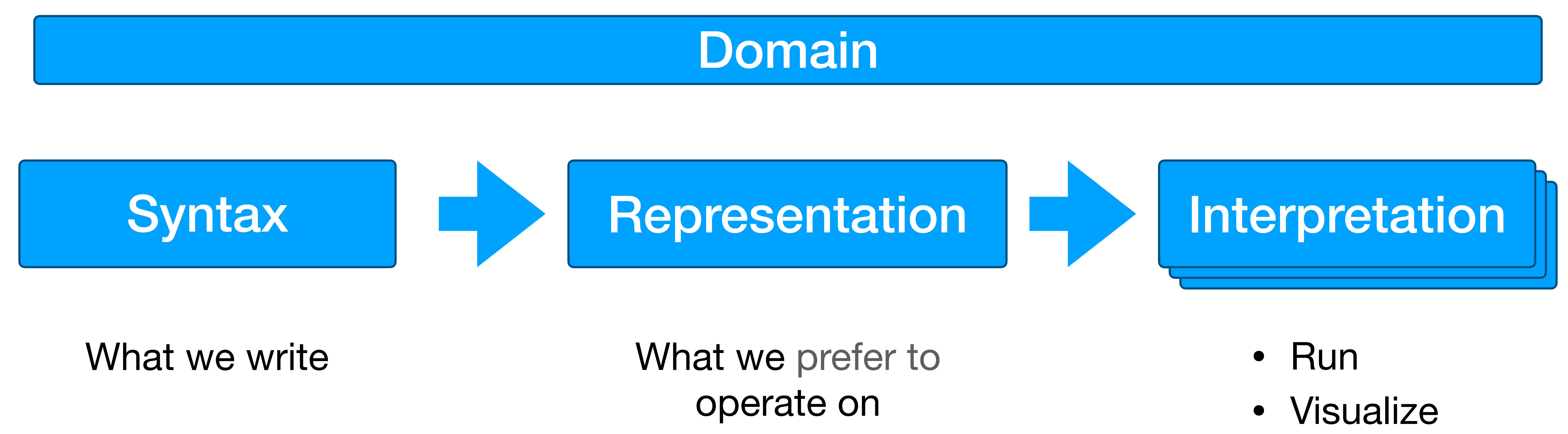

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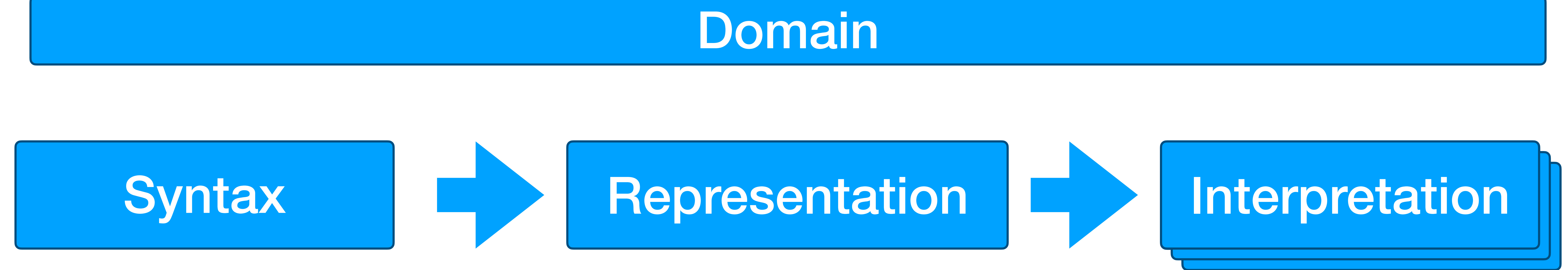


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- Run
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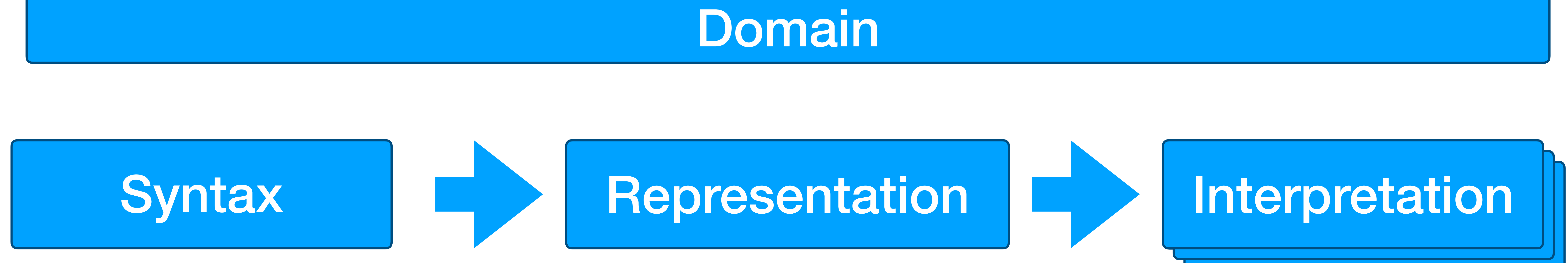


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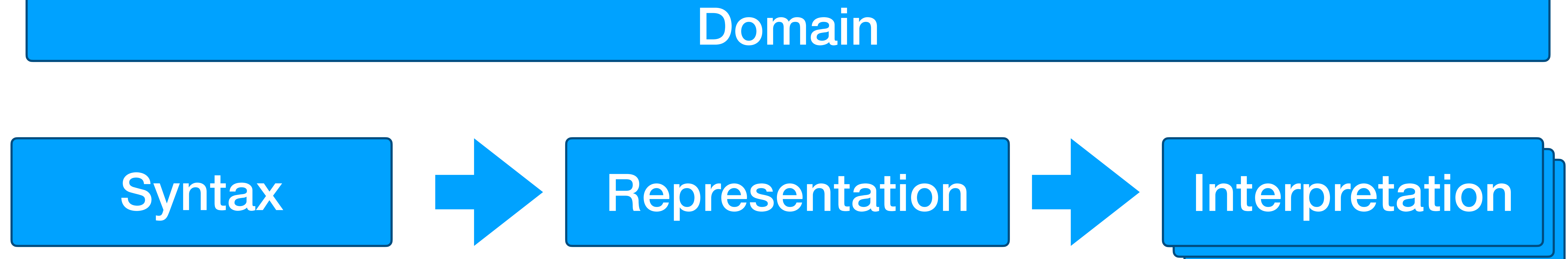


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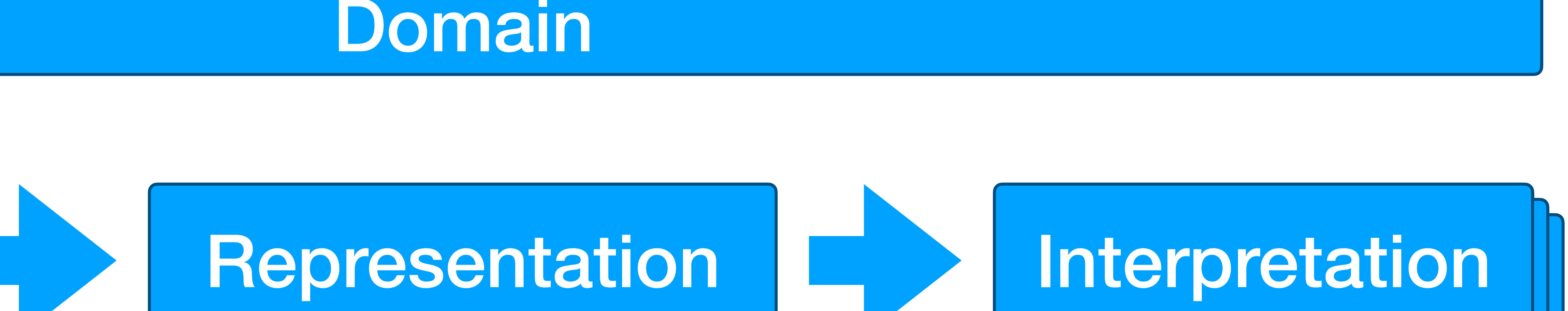


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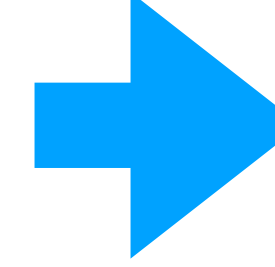

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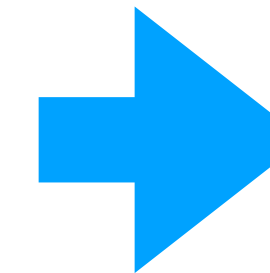

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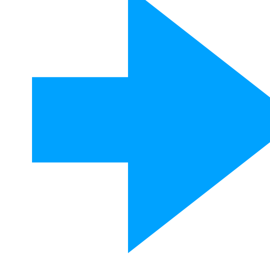

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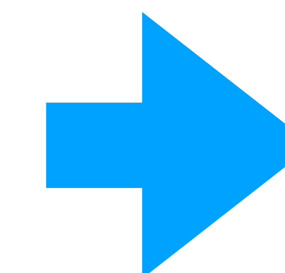

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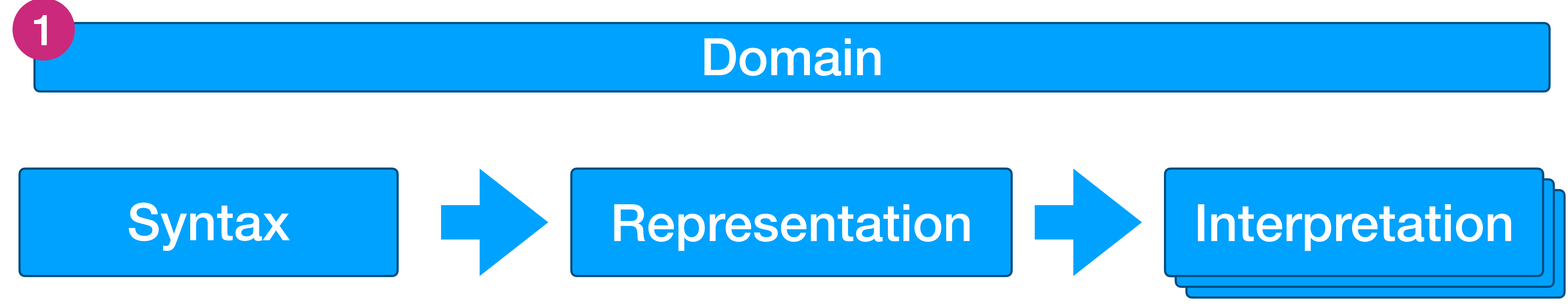


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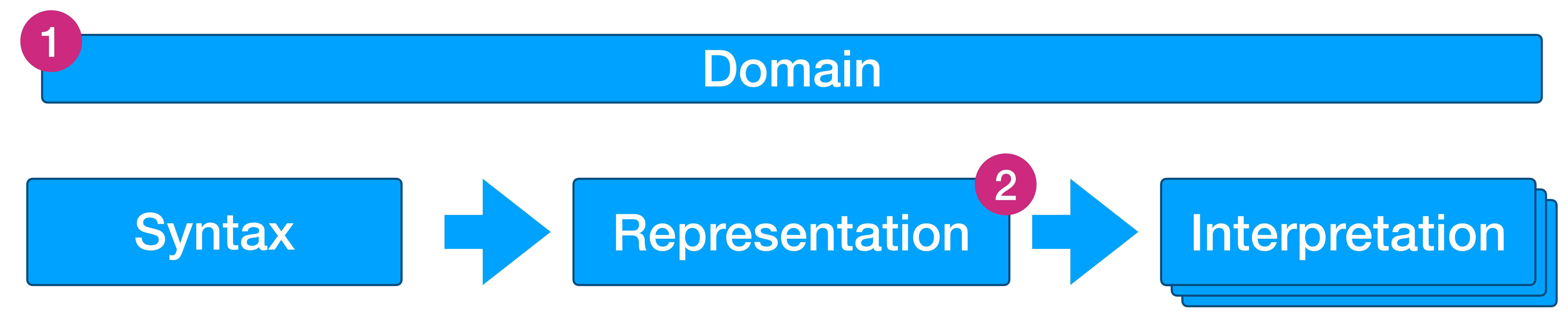


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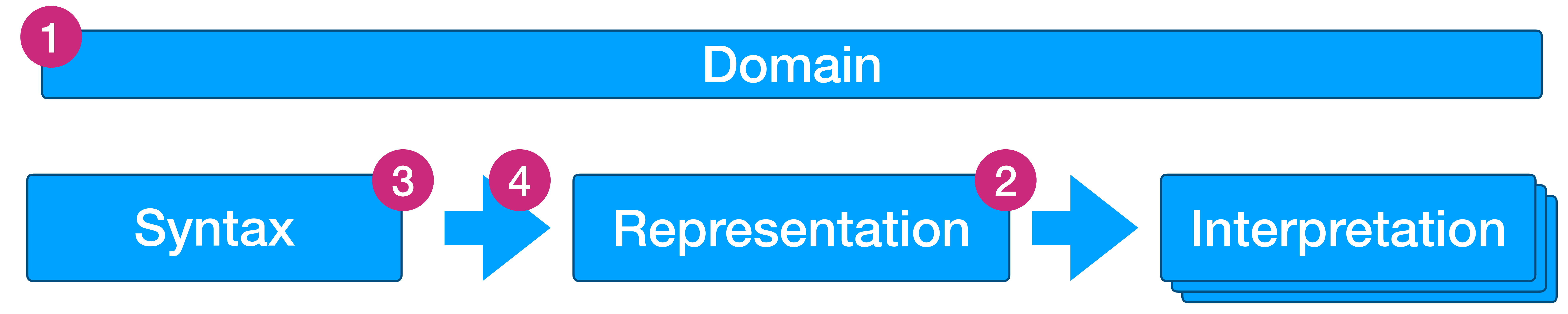


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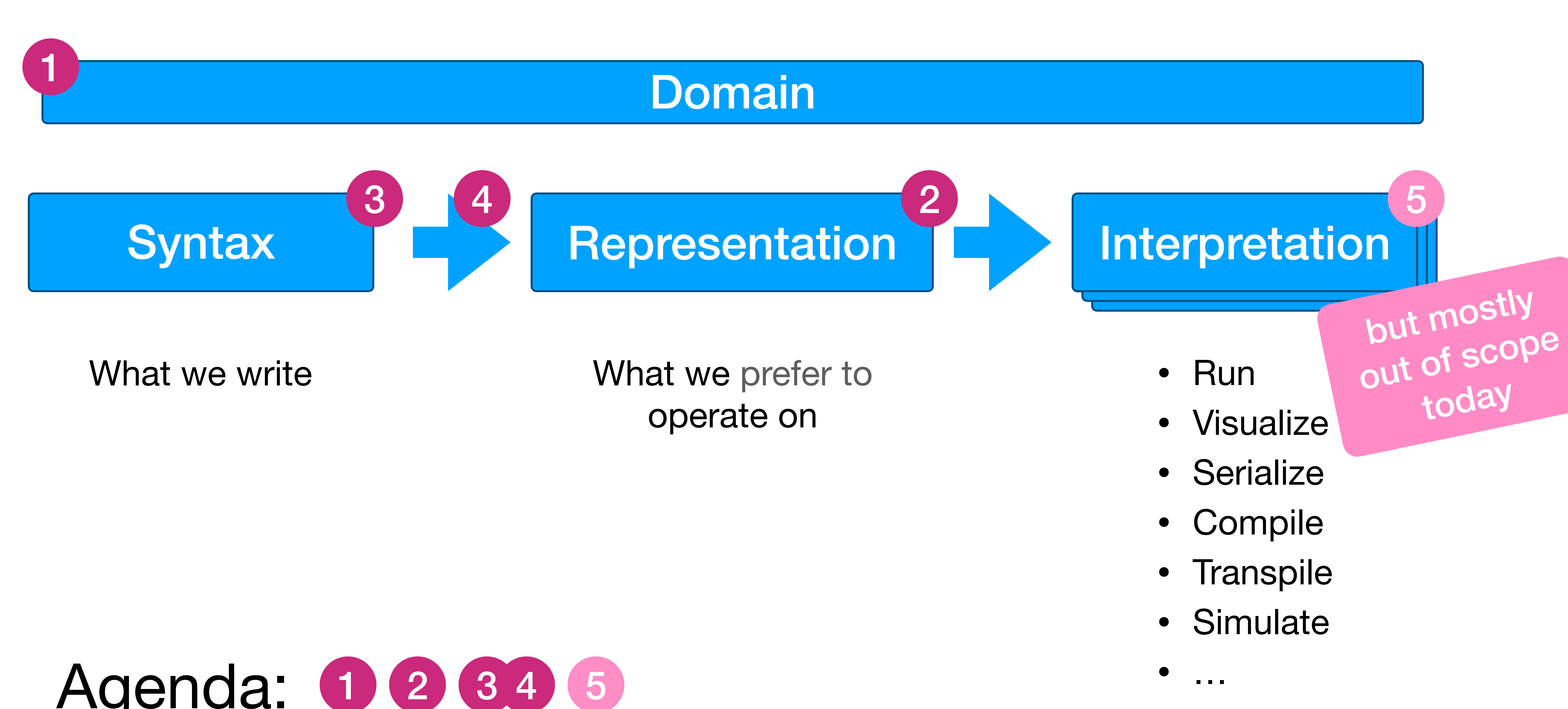

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  - **without explicit database**

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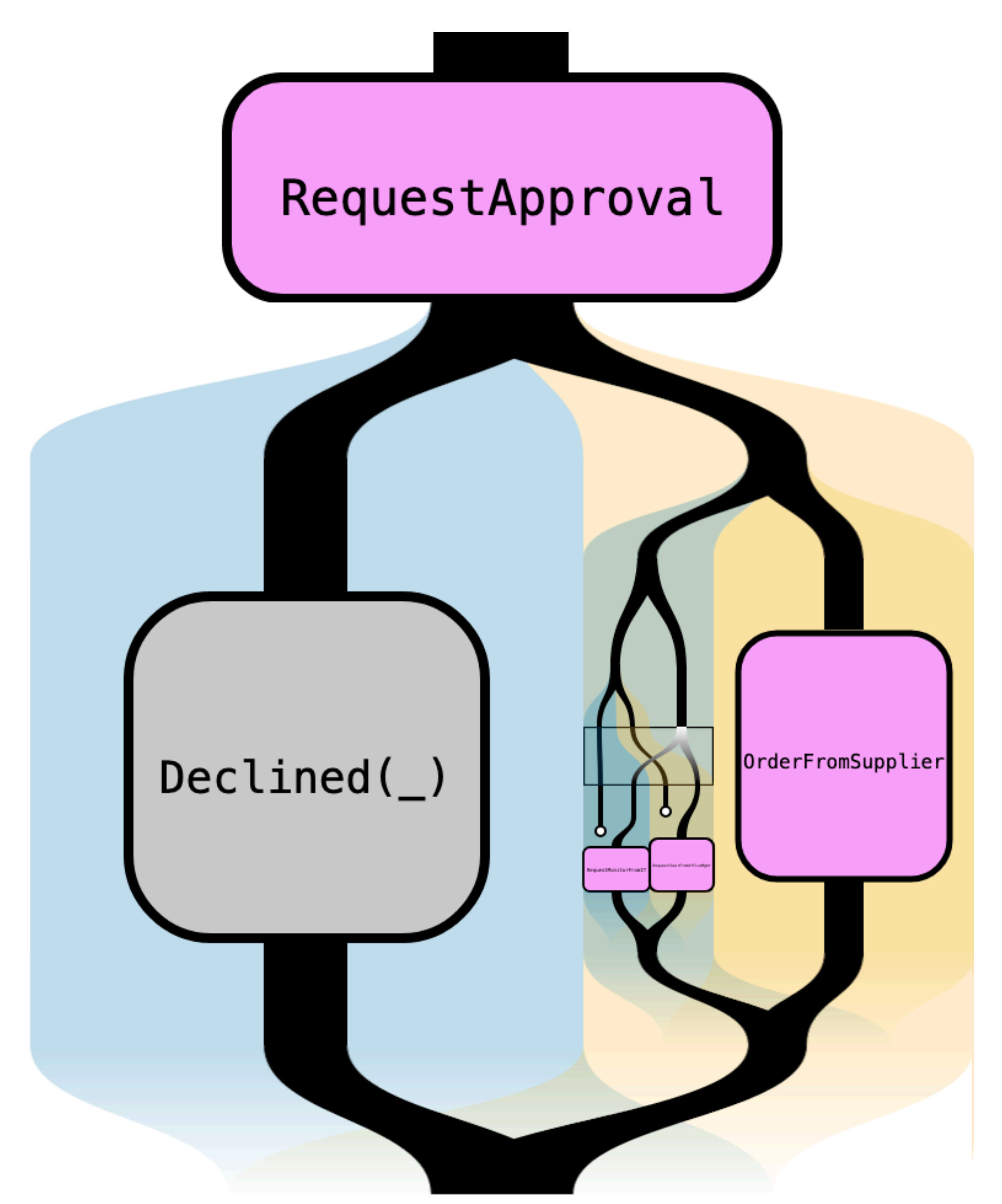

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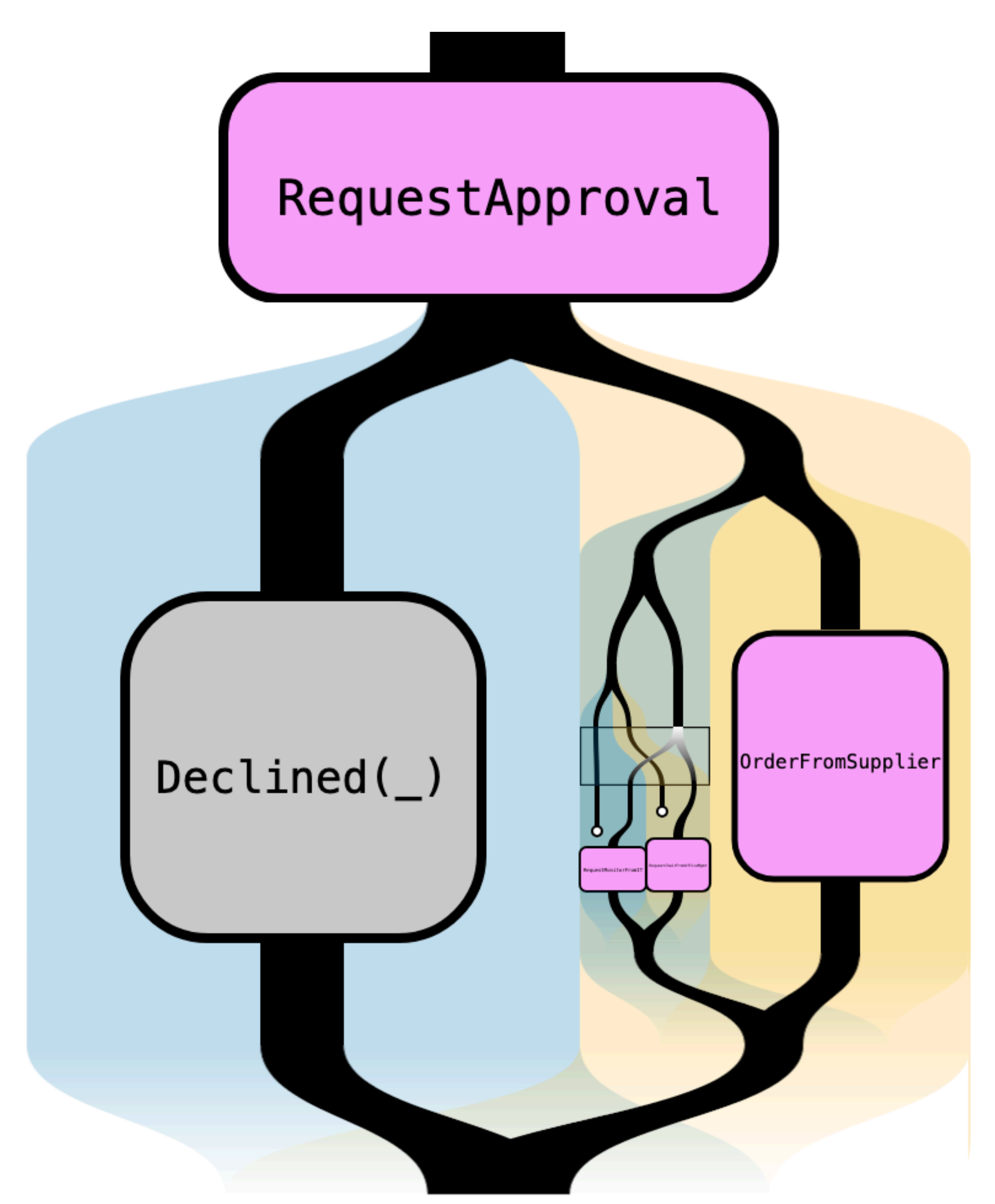


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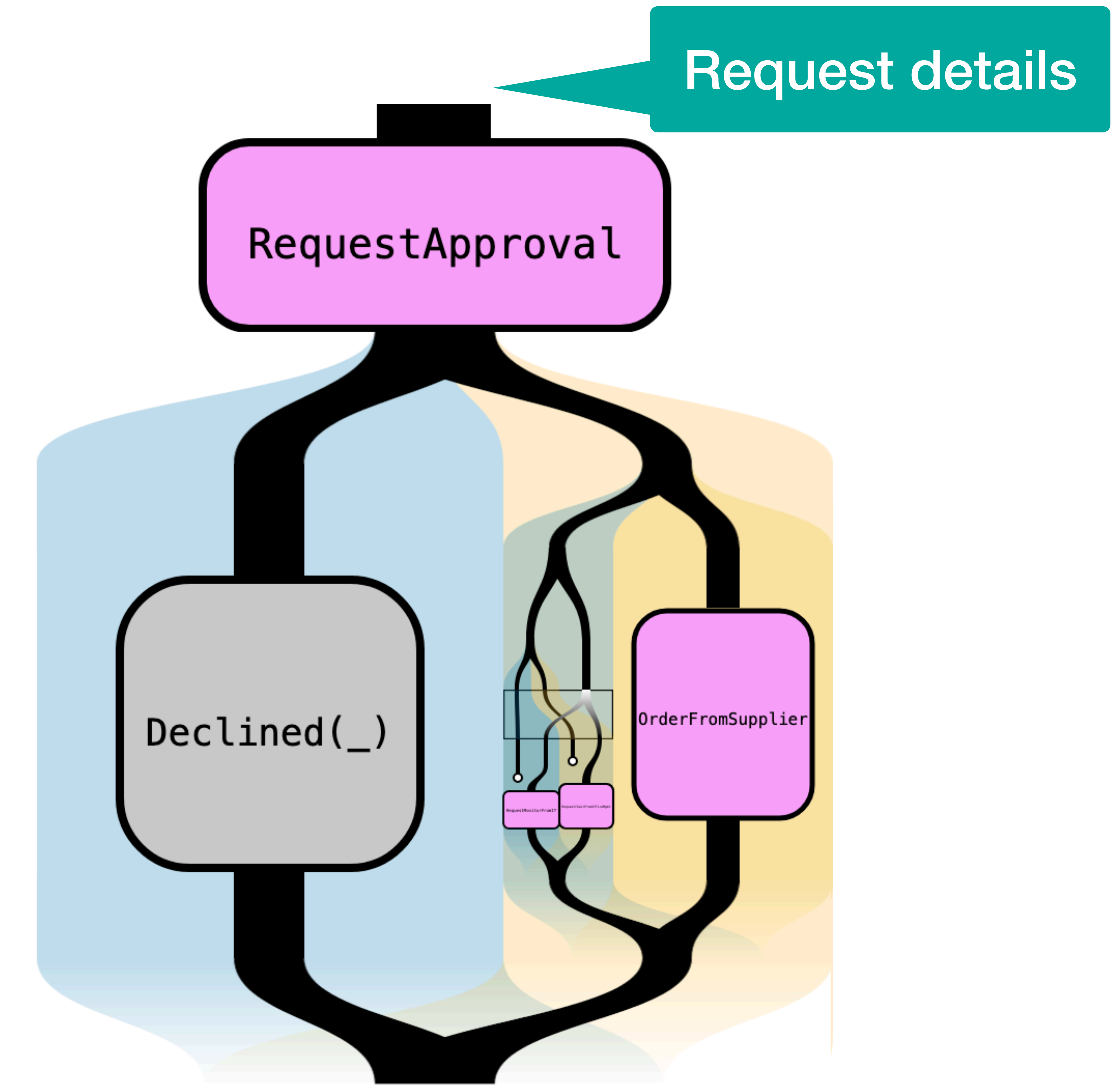


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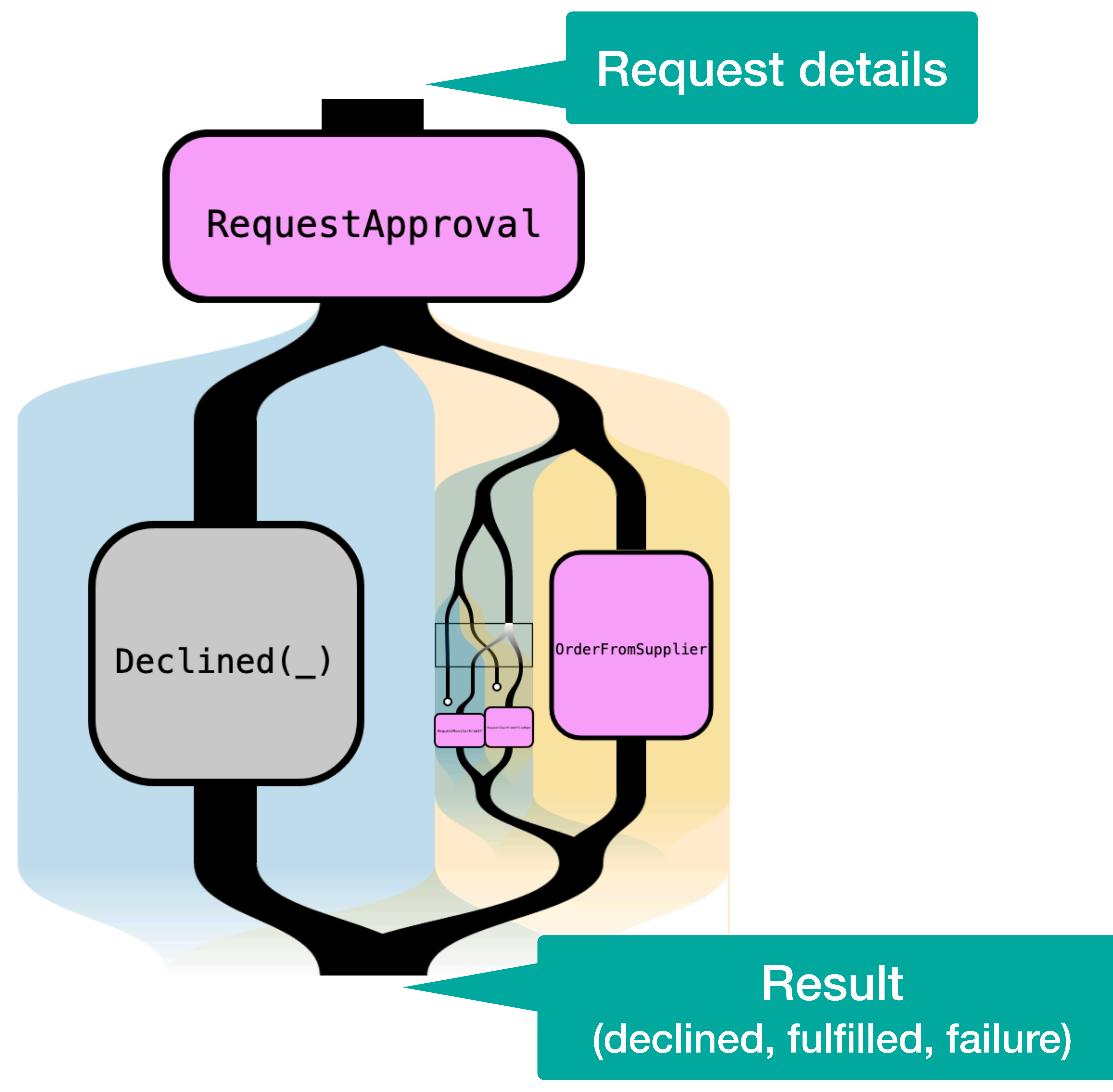


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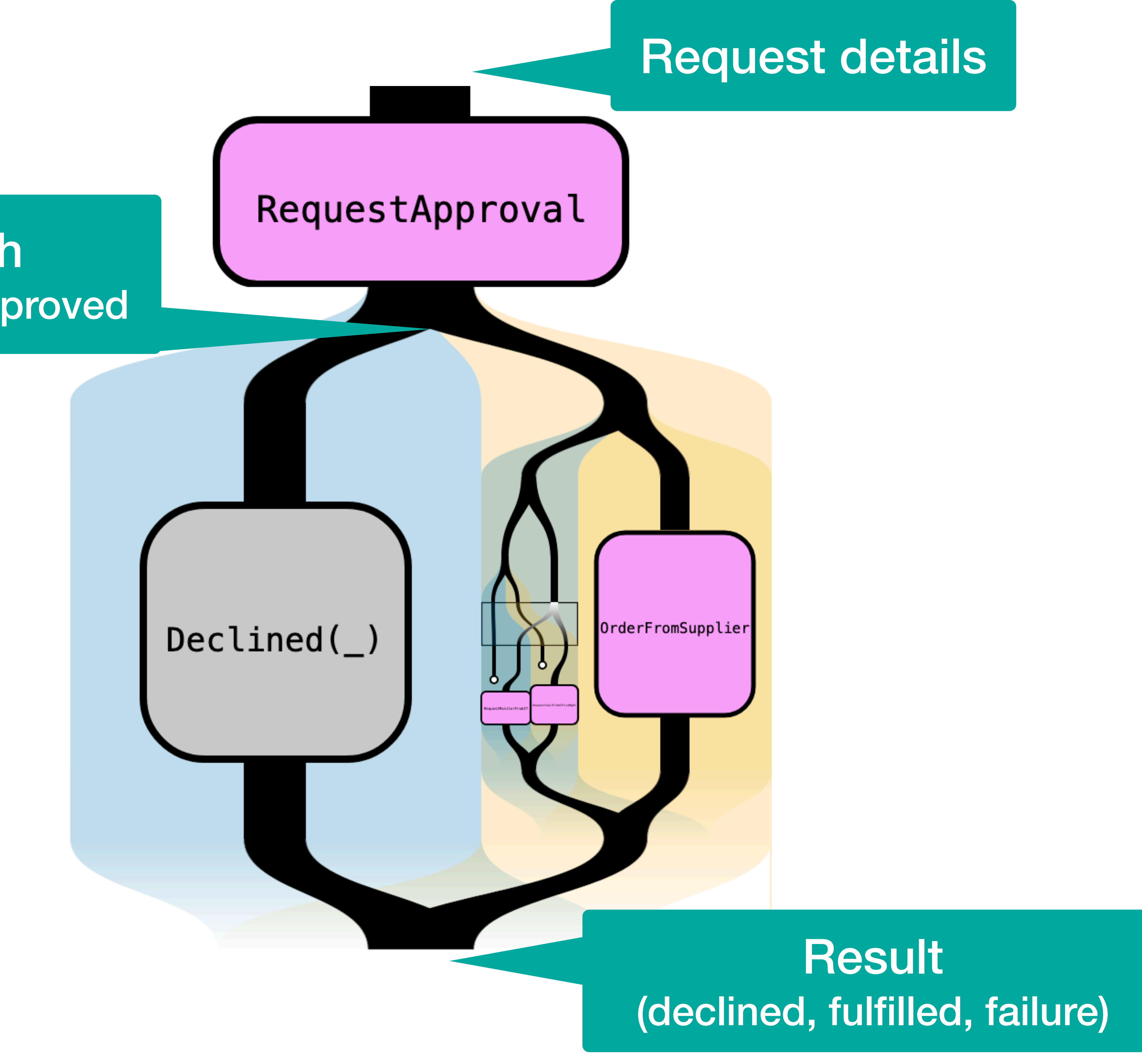


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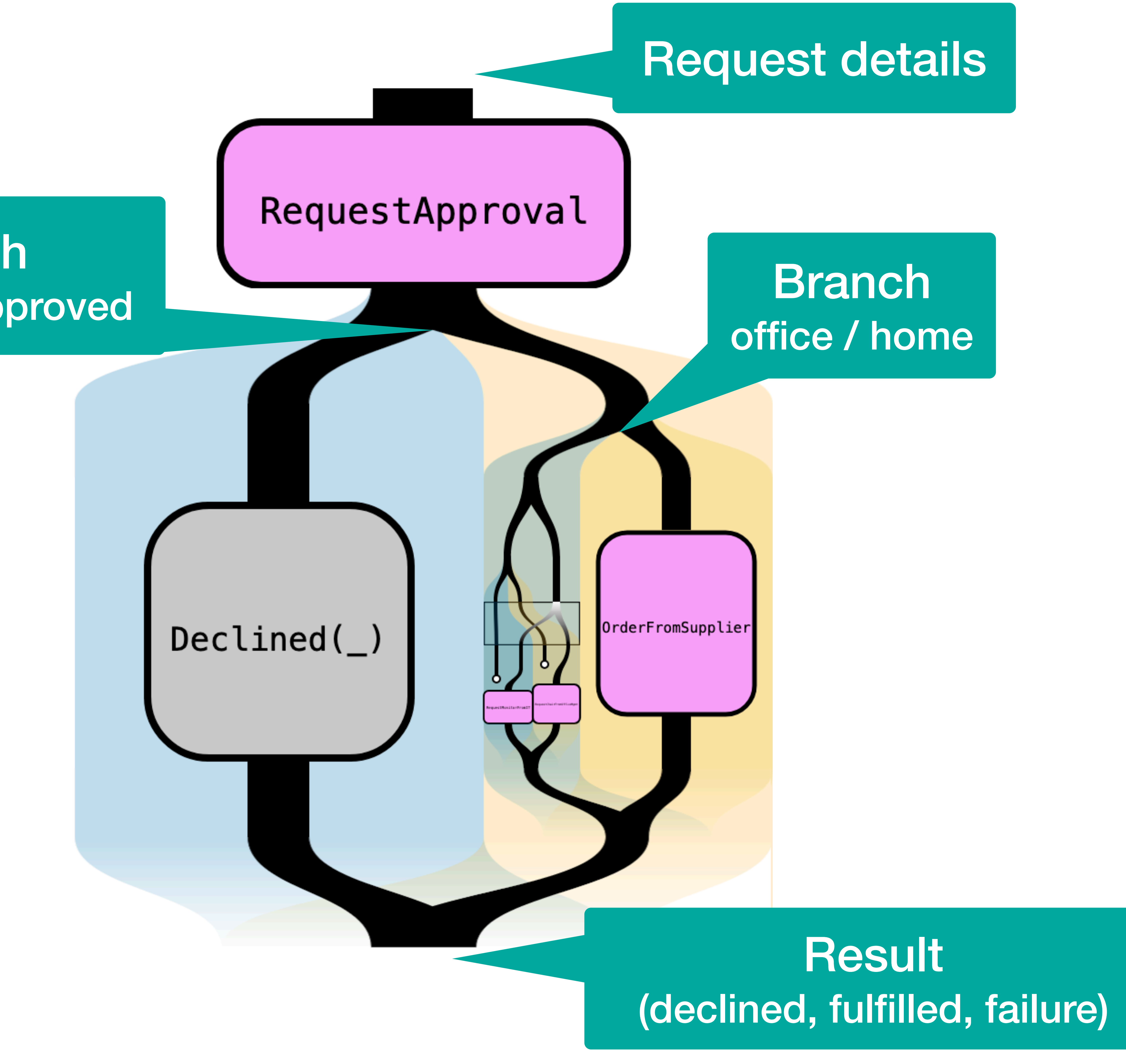


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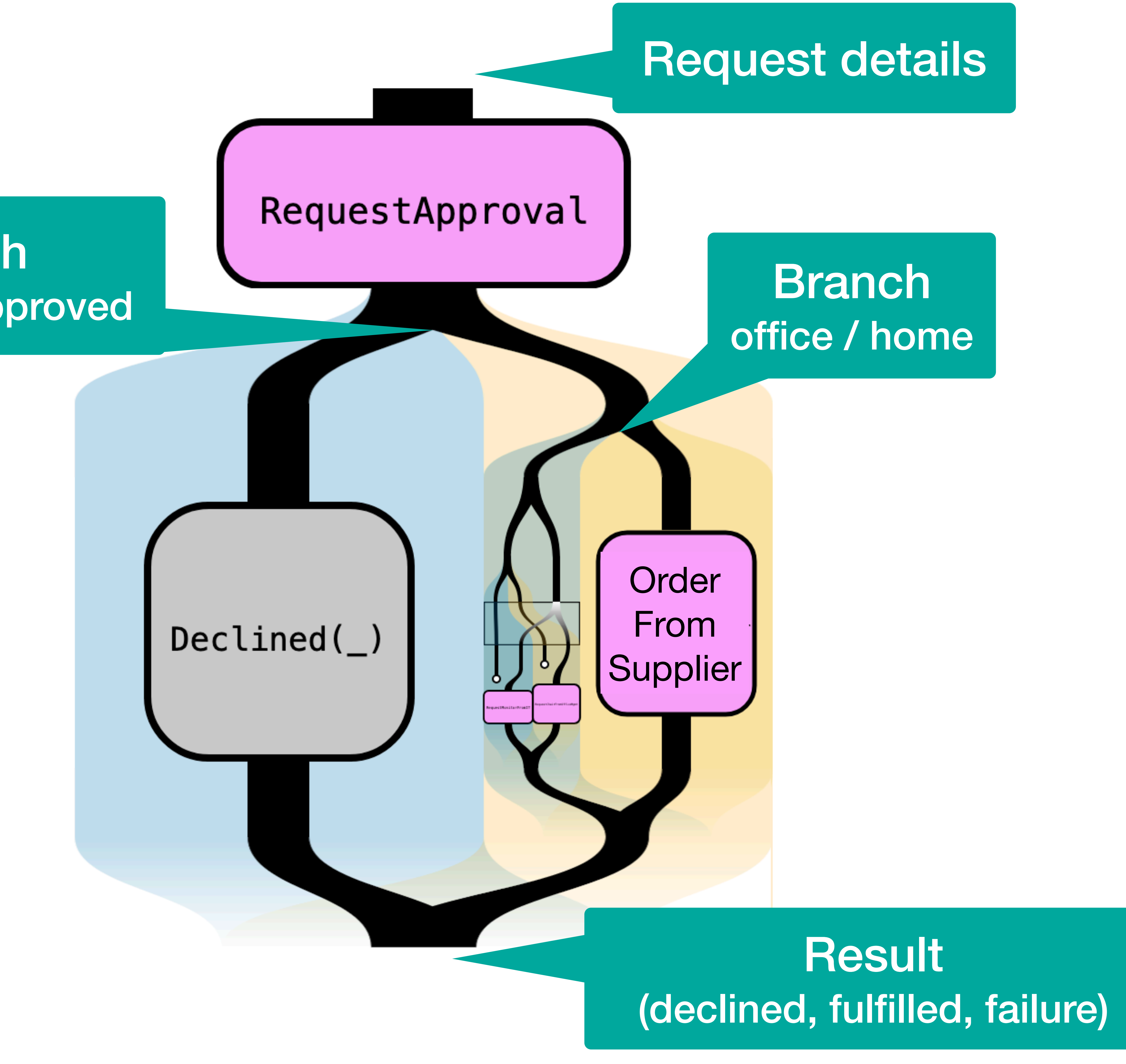


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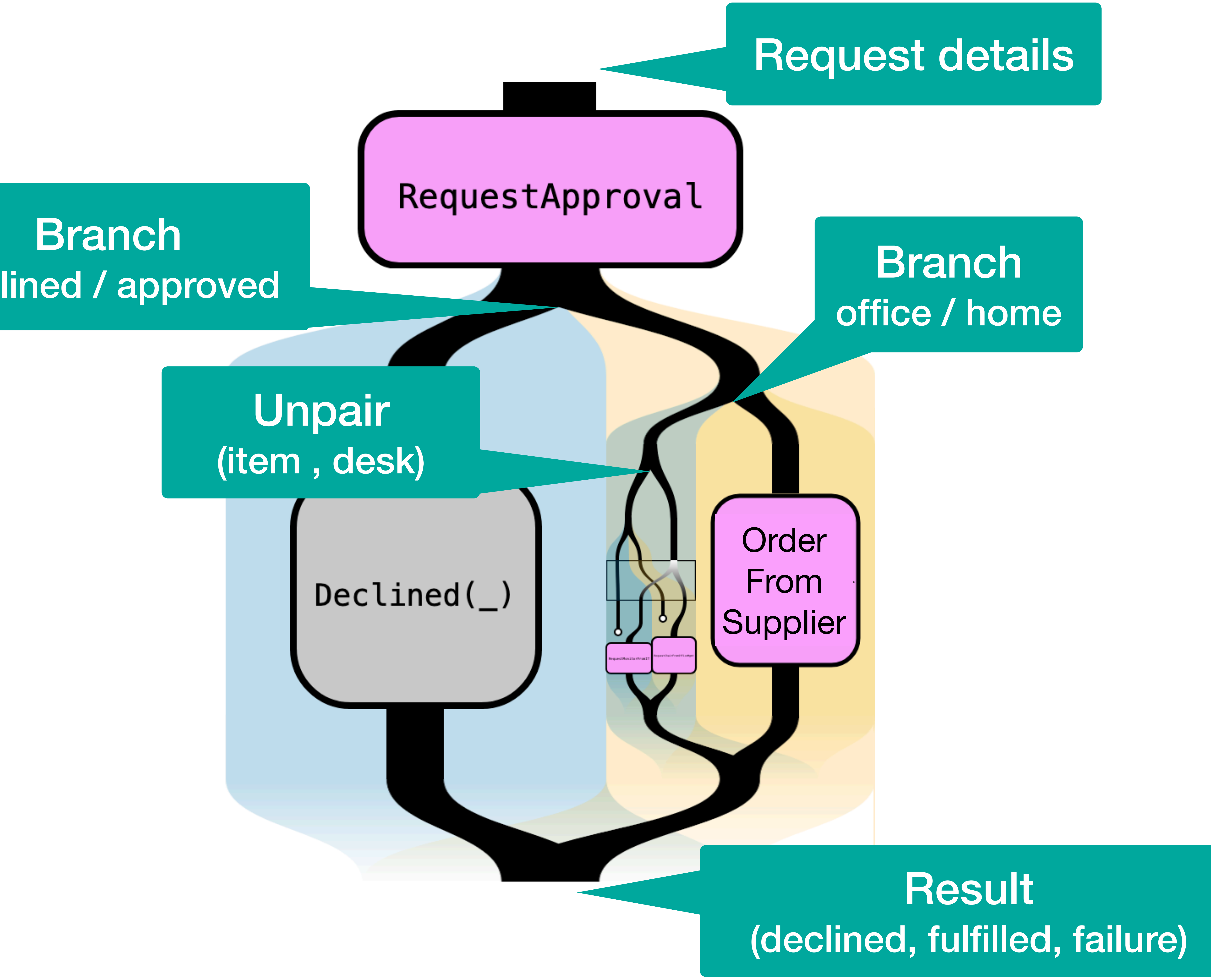


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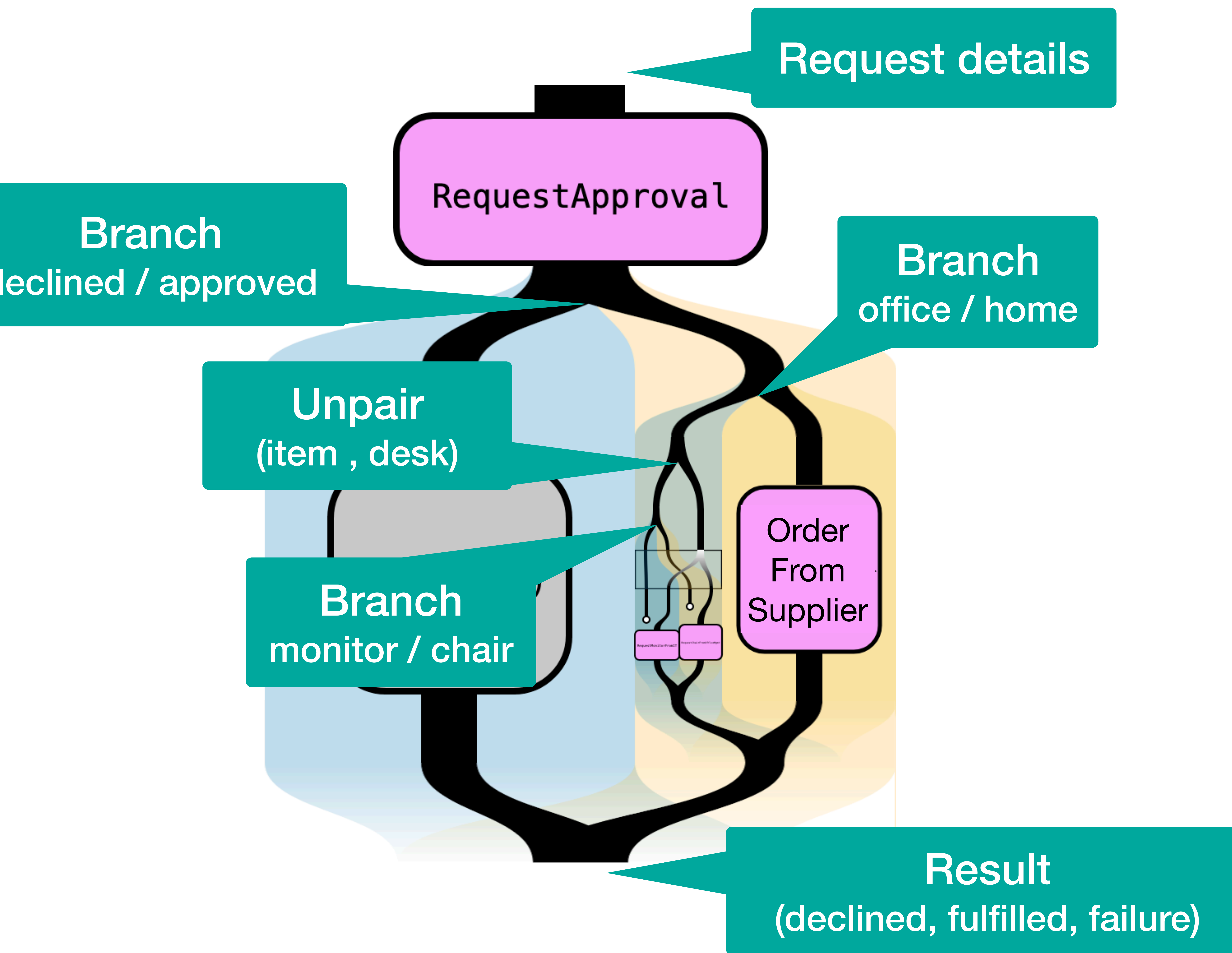


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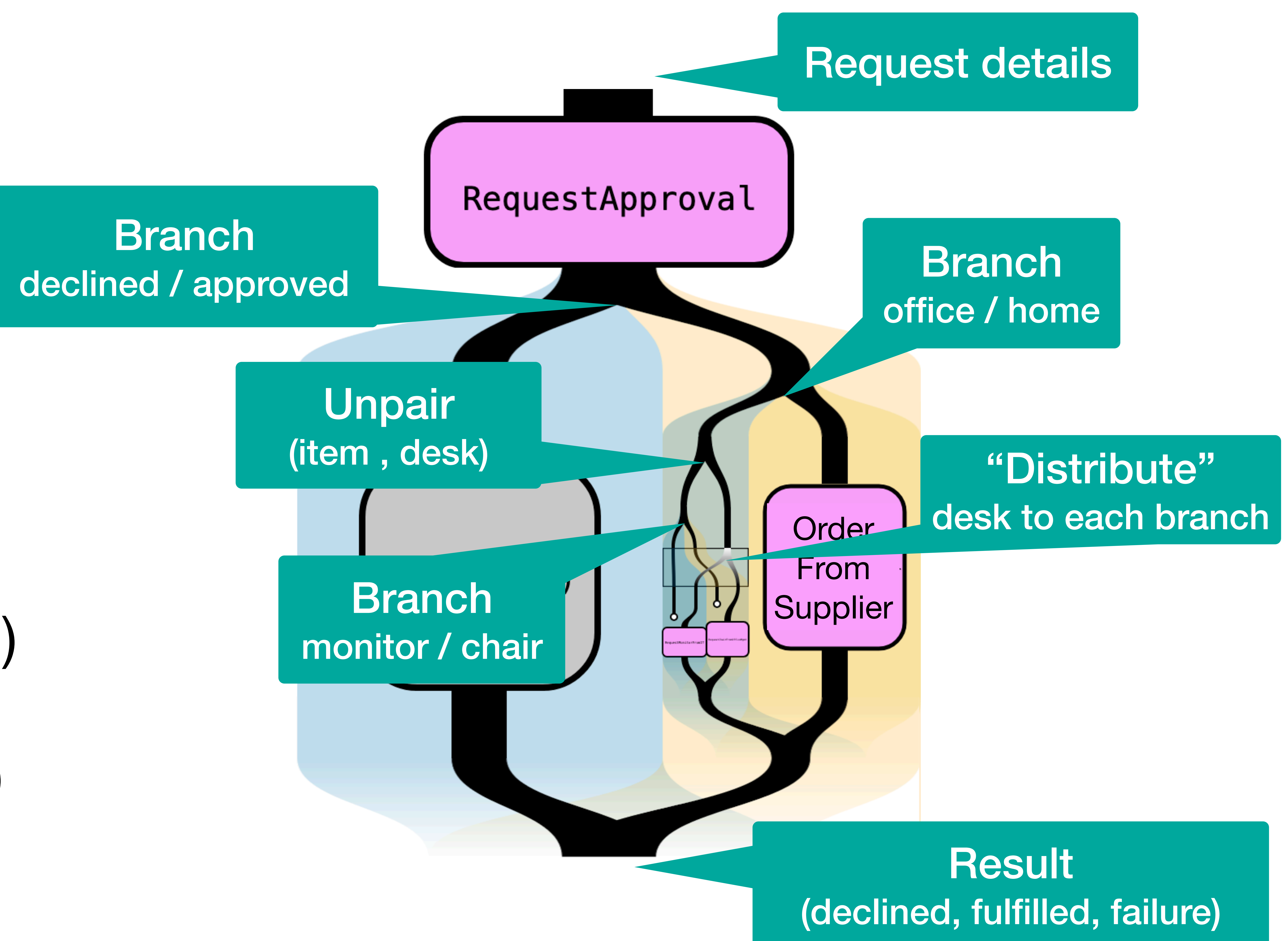


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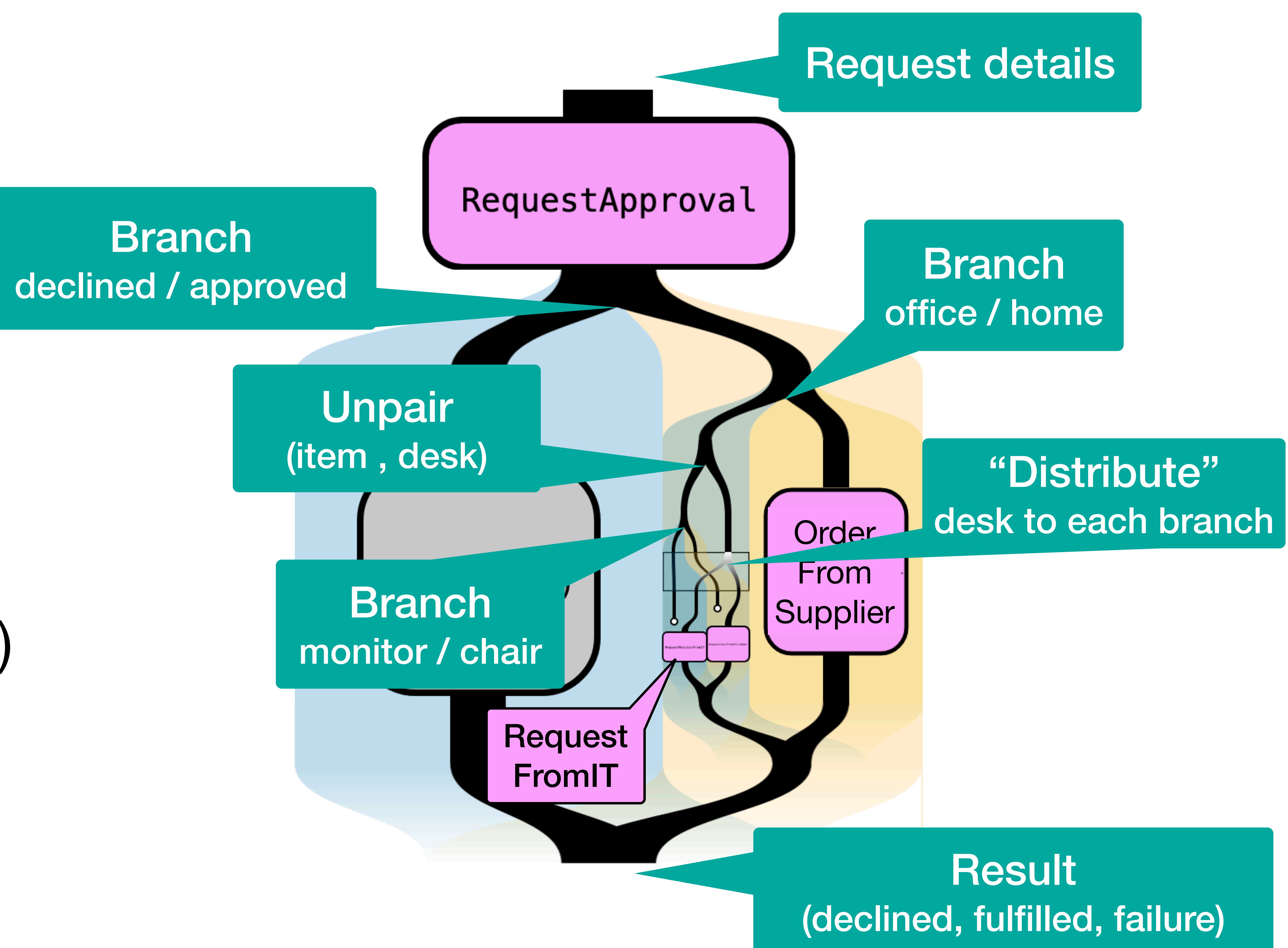


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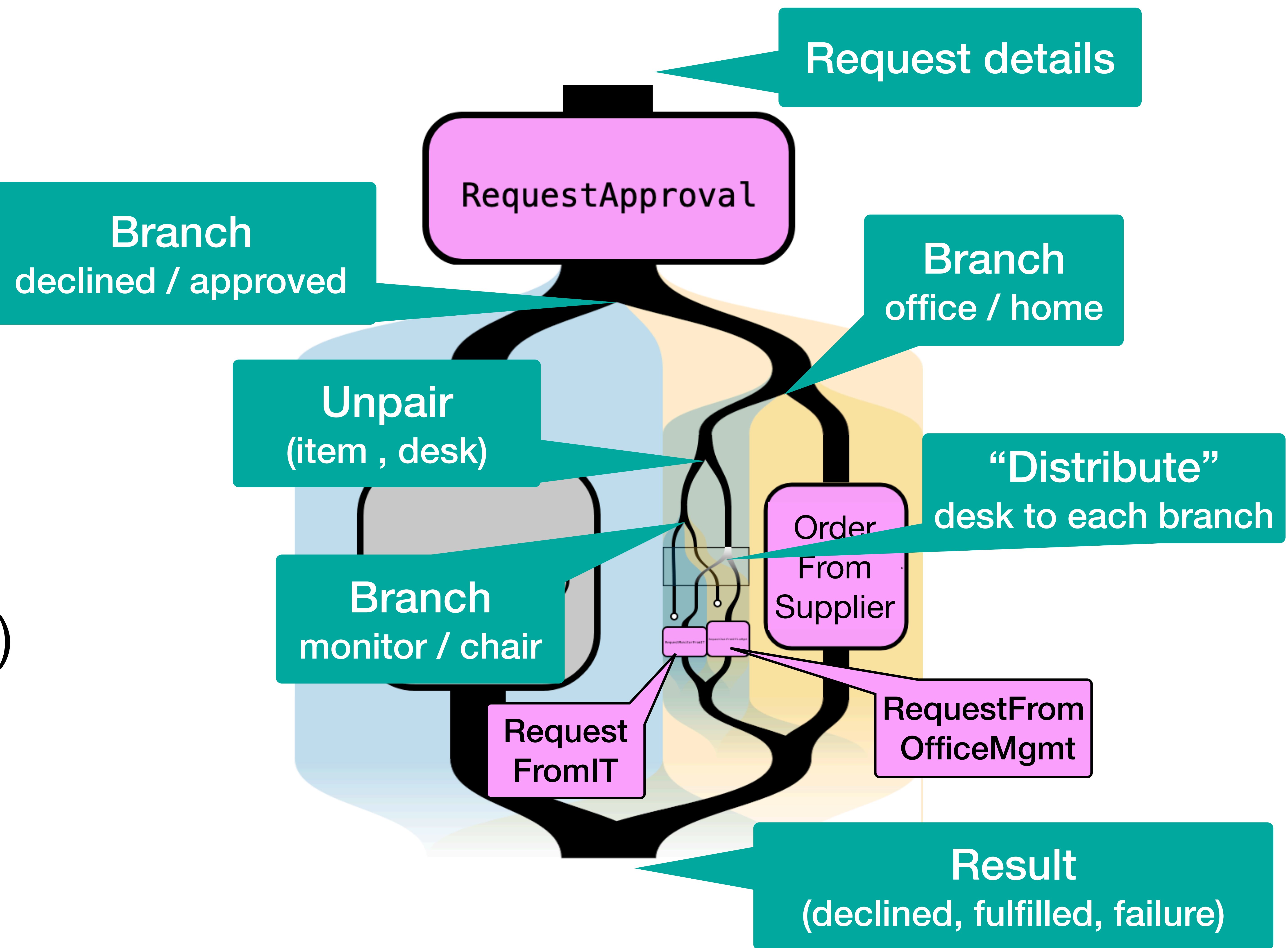


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  - Visualization, Simulation, …

# Gathering Requirements

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  - Branching, Loops, Concurrency
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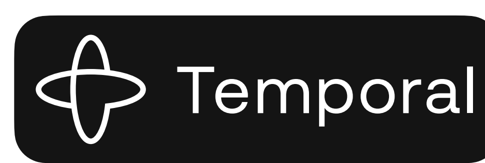
# What Do   Do?

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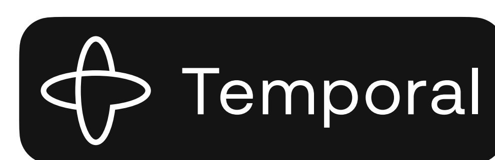
# What Do 

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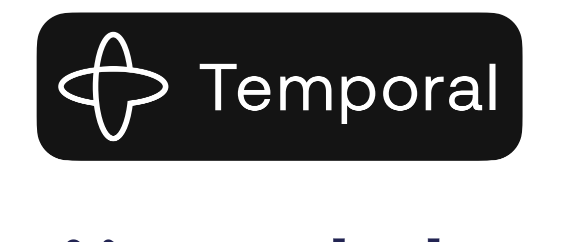
# What Do 

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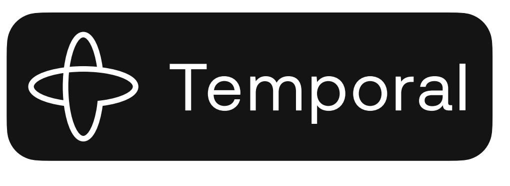
# What Do  restate Do?

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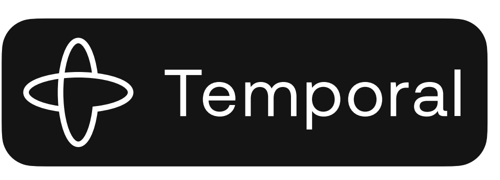
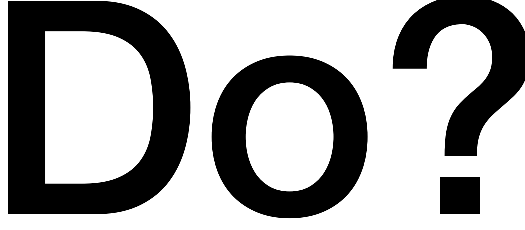
# What Do  Do?





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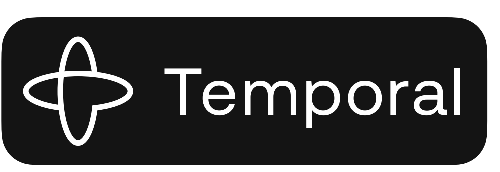
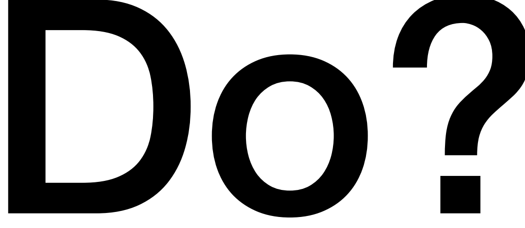
# What Do  Do?





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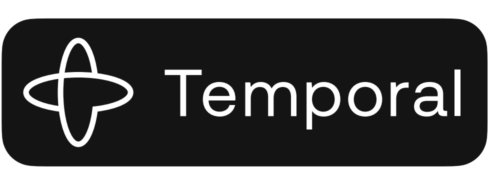
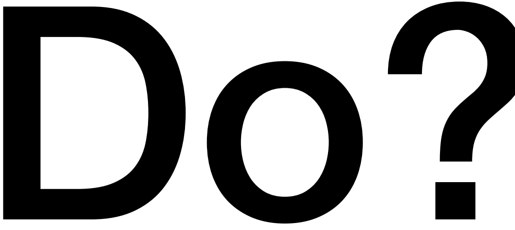
# What Do   Do?







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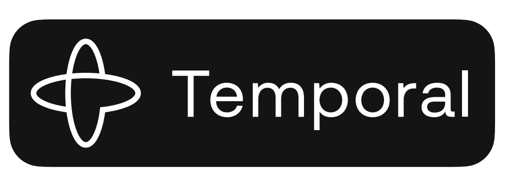
# What Do  Do?



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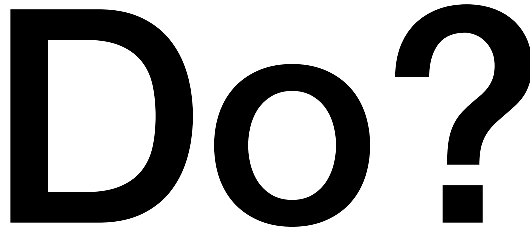

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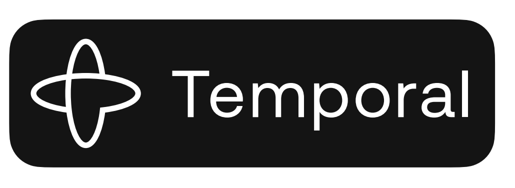

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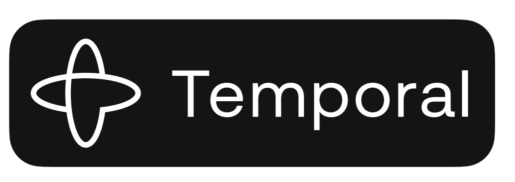
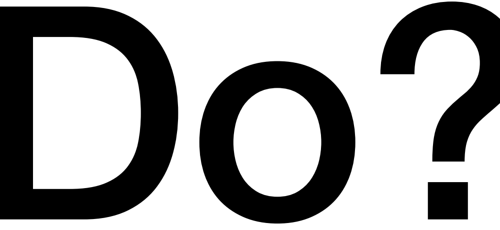
# What Do 

 Do?

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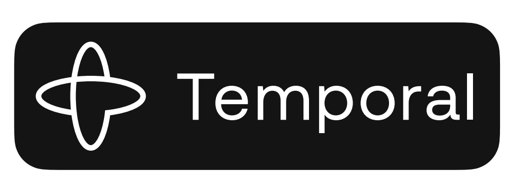
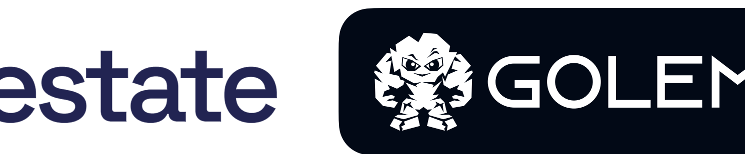
# What Do 



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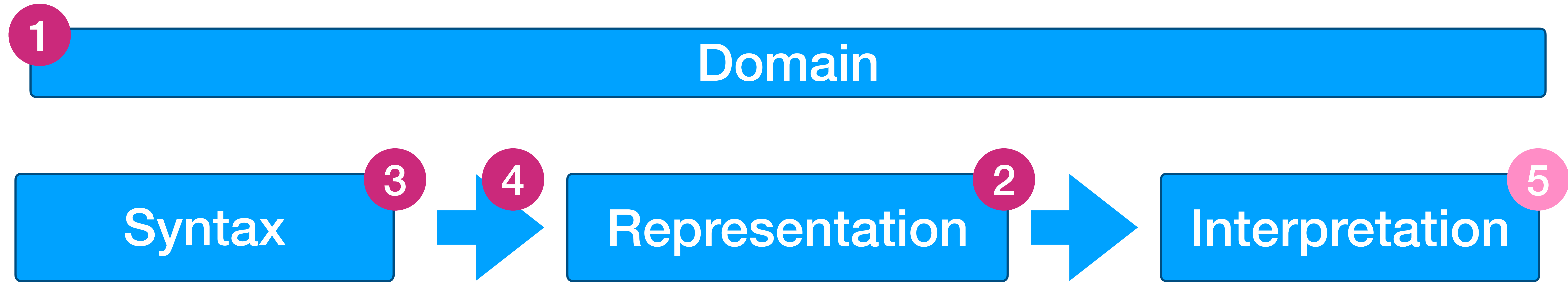
**Off-limits**

**Not in control of representation.**

There's only a single interpretation
of the host language: running it.

# Agenda



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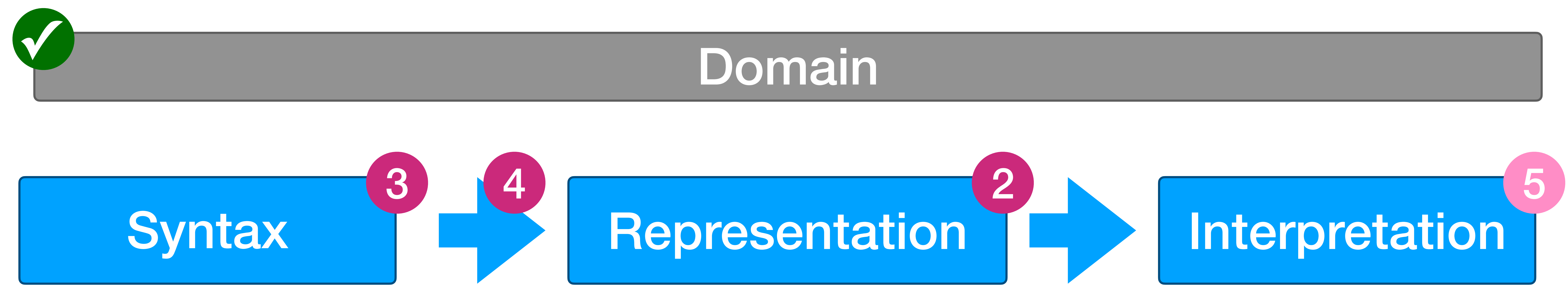

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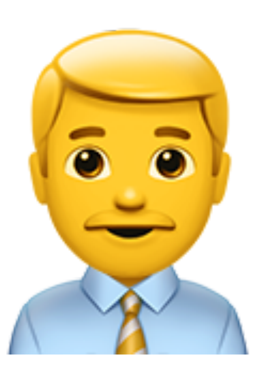

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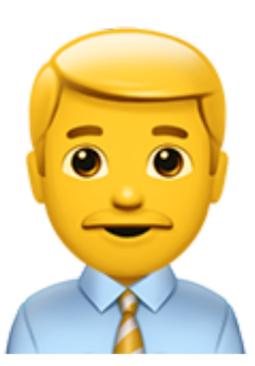

Language Developer

design & implement the Workflow DSL

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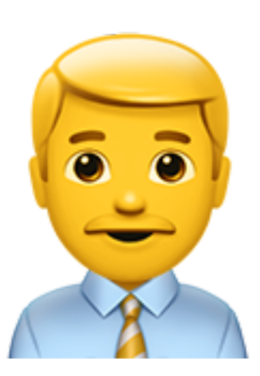

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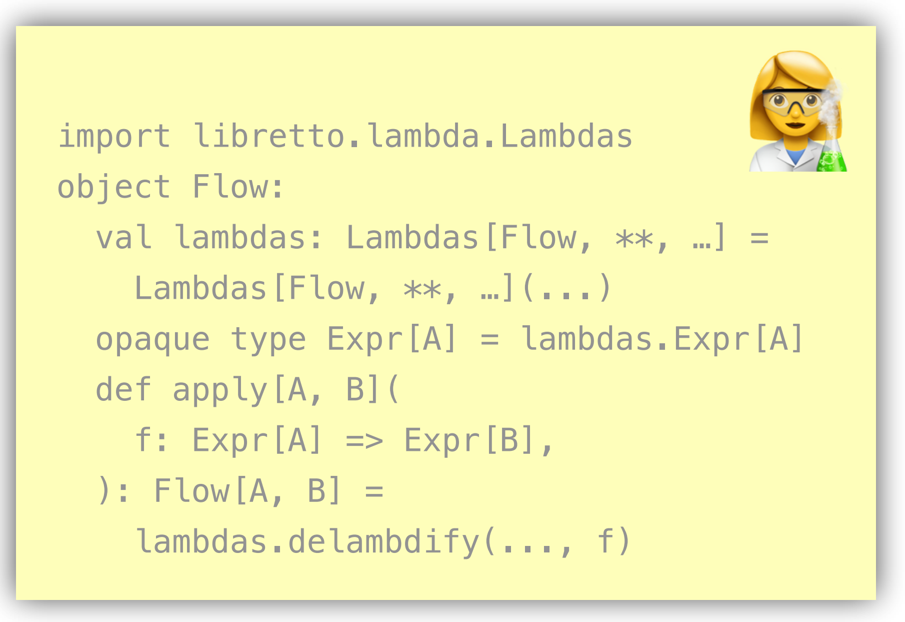

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Business person

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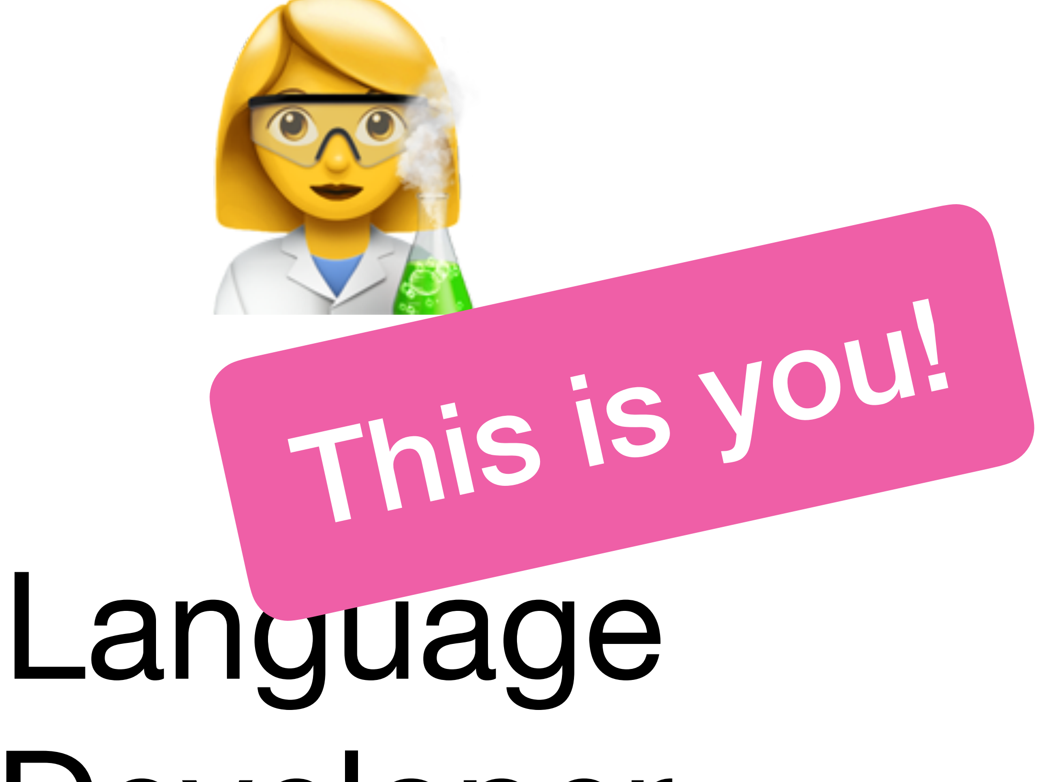


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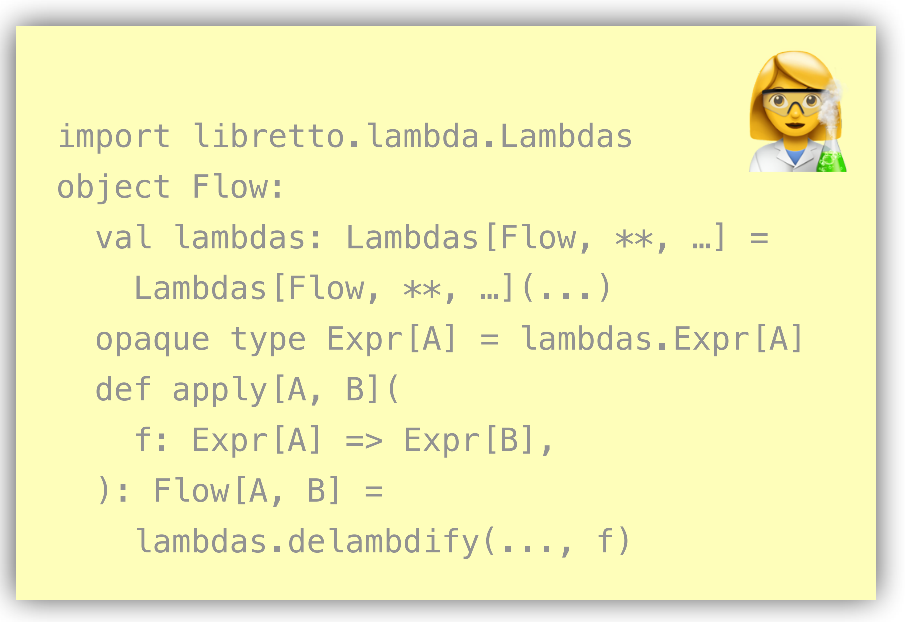

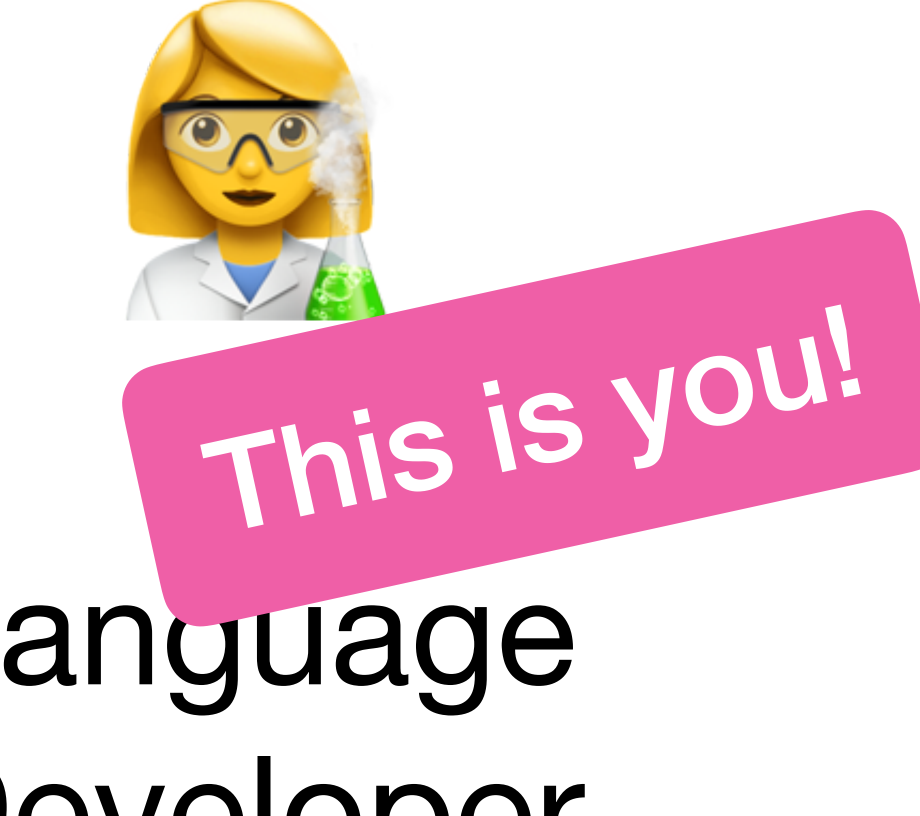


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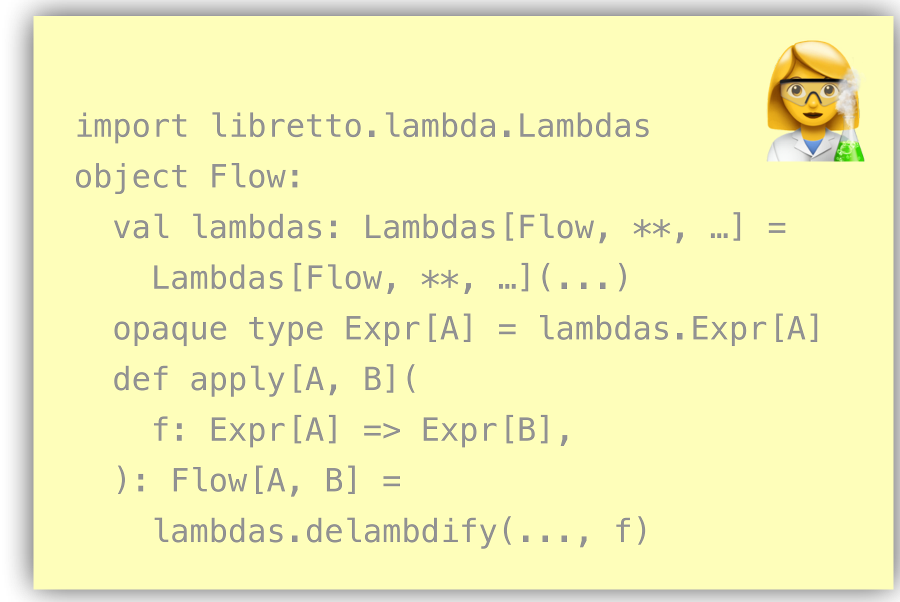


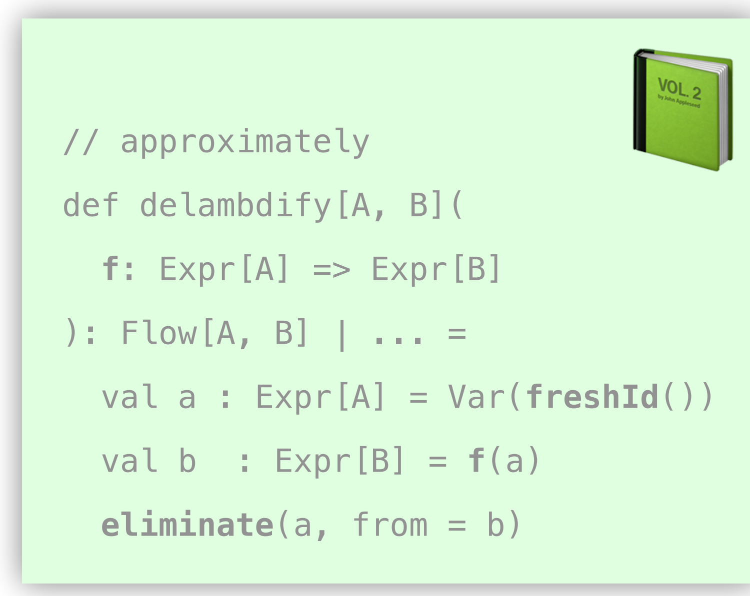

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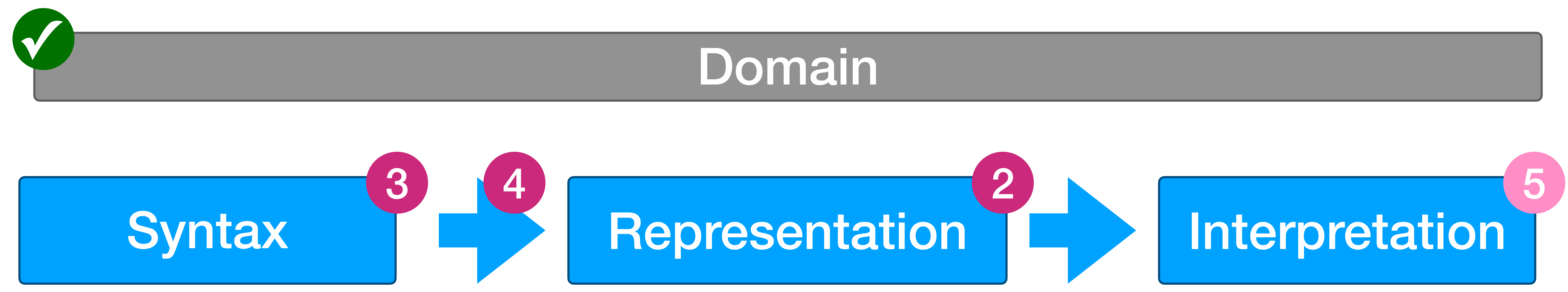

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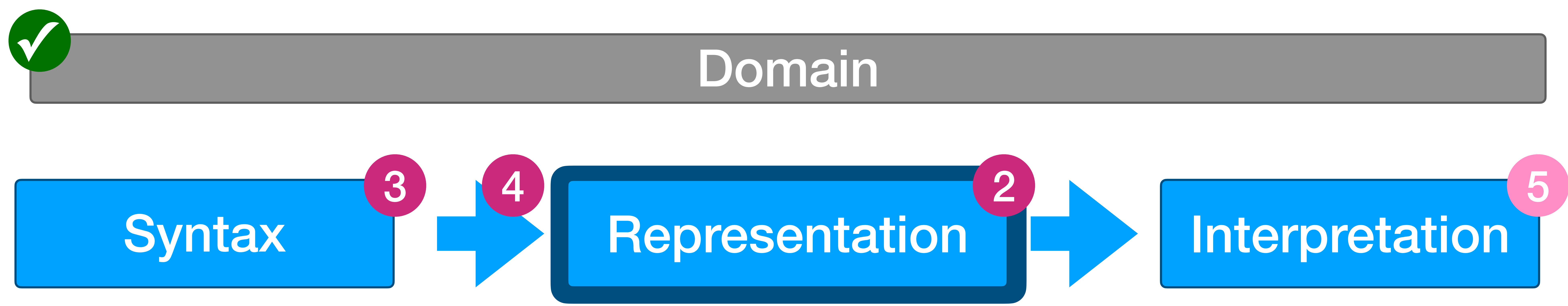

# Representing (eDSL) Programs

Choosing a Suitable Data Structure *("AST")*

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Just use a Scala function

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DEAD END

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EASY WAY | RIGHT WAY

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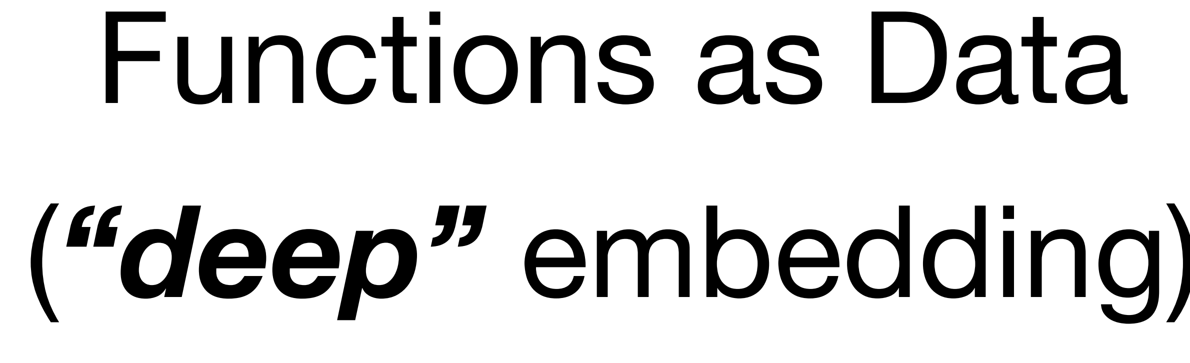
Functions as Data

(***“deep”*** embedding)



deviantart.com/fernandesvincent

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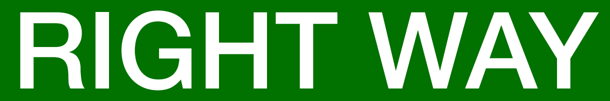


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**no alternative interpretations**

Functions as Data

(***“deep”*** embedding)

- no Scala functions inside

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# Representing (eDSL) Programs

Choosing a Suitable Data Structure *("AST")*

```
enum Expr[A]:
  case IntConstant(i: Int)                       extends Expr[Int]
  case Plus(l: Expr[Int], r: Expr[Int]) extends Expr[Int]
  ...
```

straightforward

until you need functions

## Gain-of-functions crossroads

EASY WAY | RIGHT WAY

Just use a Scala function

(***"shallow"*** embedding)

```
case FlatMap[A, B](a: Expr[A], f: A => Expr[B])
  extends Expr[B]
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- fully introspectable

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Functions as Data

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straightforward

until you need functions

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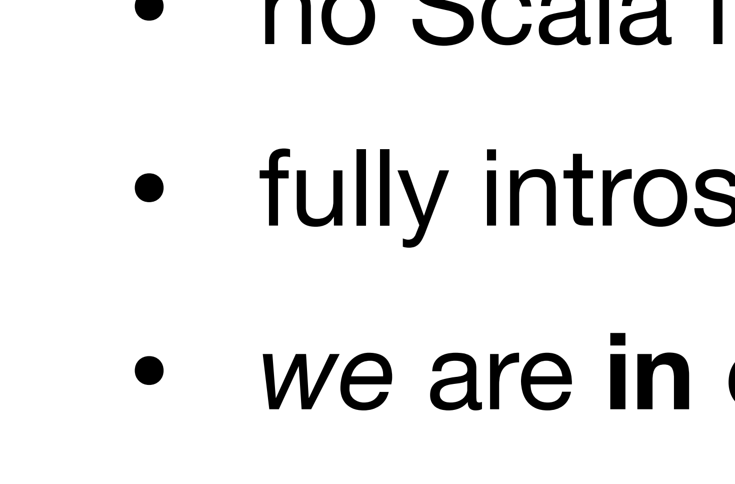


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# Representing Functions

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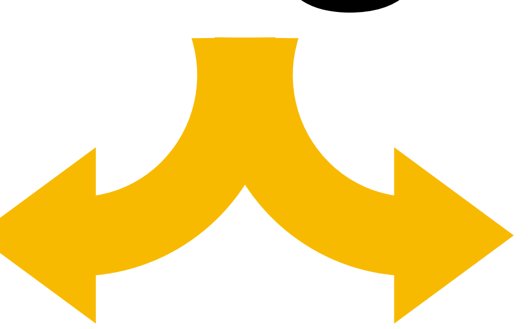

Expression-centric

# Representing Functions

Expression-centric

```
enum Expr[A]:
  case Plus(l: Expr[Int], r: Expr[Int])     extends Expr[Int]
```

# Representing Functions

Expression-centric

```
enum Expr[A]:
  case Plus(l: Expr[Int], r: Expr[Int])     extends Expr[Int]
  case Var[A](name: String)                 extends Expr[A]
```

# Representing Functions

Expression-centric

```
enum Expr[A]:
  case Plus(l: Expr[Int], r: Expr[Int])       extends Expr[Int]
  case Var[A](name: String)                   extends Expr[A]
  case Lam[A,B](a: Var[A], b: Expr[B])        extends Expr[A ⇒ B]
```

# Representing Functions

Expression-centric

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  case Plus(l: Expr[Int], r: Expr[Int])      extends Expr[Int]
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```
x ⇒ f(x) + g(x)
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Expression-centric

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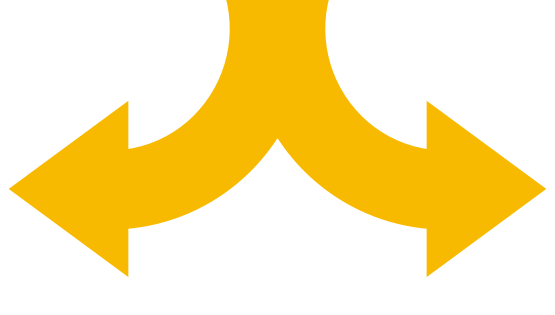
# Representing Functions



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): Expr[Int ⇒ Int]
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# Representing Functions

Expression-centric

```
enum Expr[A]:
  Plus(Expr[Int], Expr[Int]): Expr[Int]
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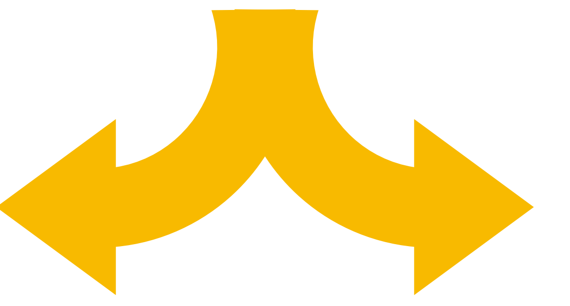
# Representing Functions



Expression-centric

Function-centric
(Point-free)

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  App(Expr[A ⇒ B], Expr[A]) : Expr[B]
```

```
enum Flow[A,B]:
```

```
val f, g: Expr[Int ⇒ Int] = ???
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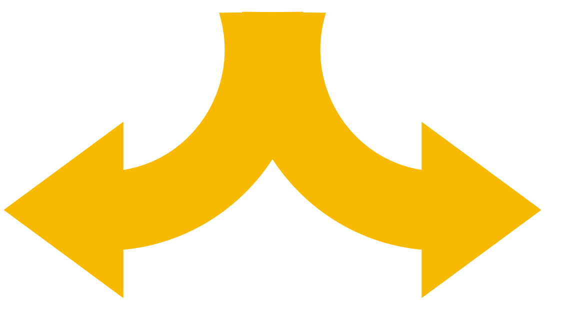
# Representing Functions



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```

```
enum Flow[A,B]:
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```

+

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```

```
enum Flow[A,B]:
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    extends Flow[(Int, Int), Int]
  case Dup[A]()
    extends Flow[A, (A, A)]
```

+

Δ

# Representing Functions

Expression-centric

Function-centric
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  case Dup[A]()
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  case AndThen[A,B,C](
    f: Flow[A,B],
    g: Flow[B,C]
  ) extends Flow[A,C]
```

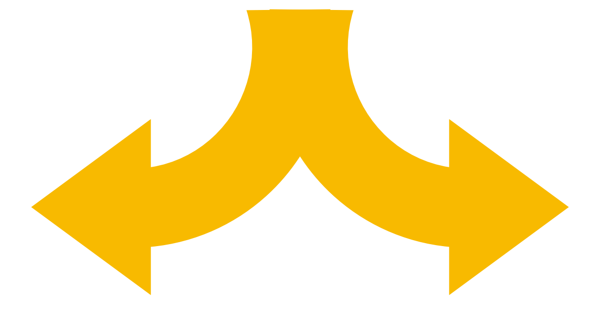
+

Δ

f

g

# Representing Functions



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  ) extends Flow[A,C]
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    f1: Flow[A1, B1],
    f2: Flow[A2, B2]
  ) extends Flow[(A1, A2), (B1, B2)]
```

+

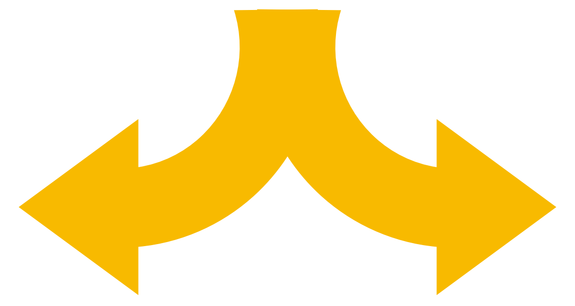
Δ

f

g

$f_1$ $f_2$

# Representing Functions



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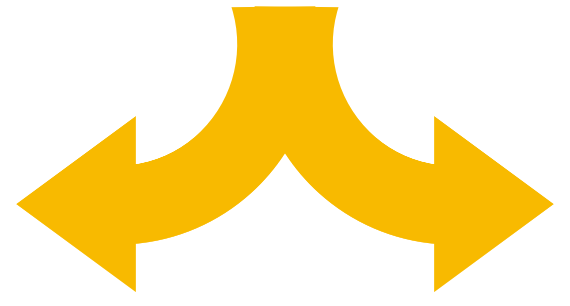

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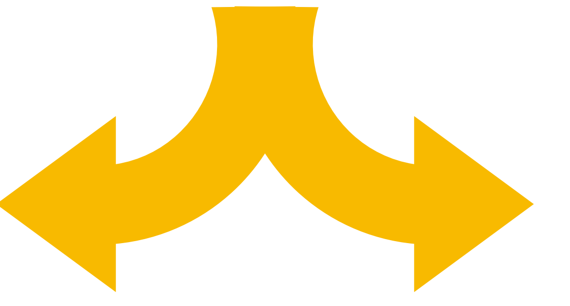

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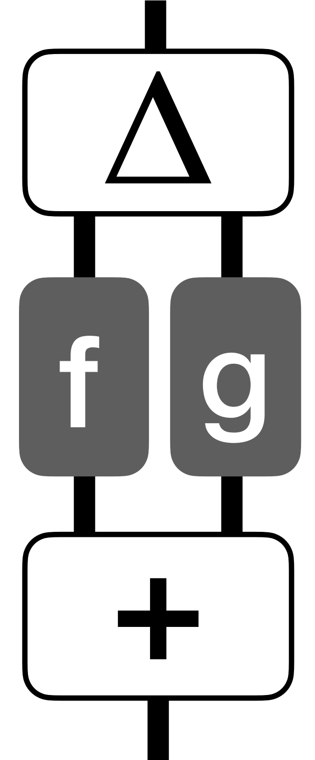
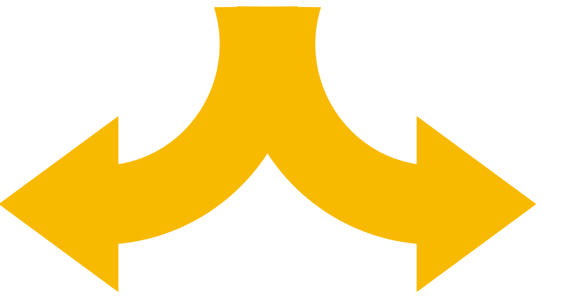


# Representing Functions



Expression-centric

Function-centric
(Point-free)

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  App(Expr[A ⇒ B], Expr[A]) : Expr[B]
```

```
enum Flow[A,B]:
  Plus(): Flow[(Int,Int), Int]
  Dup() : Flow[A, (A,A)]
  AndThen(Flow[A,B], Flow[B,C]): Flow[A,C]
  Par(Flow[A₁,B₁], Flow[A₂,B₂])
   : Flow[(A₁,A₂), (B₁,B₂)]
```

```
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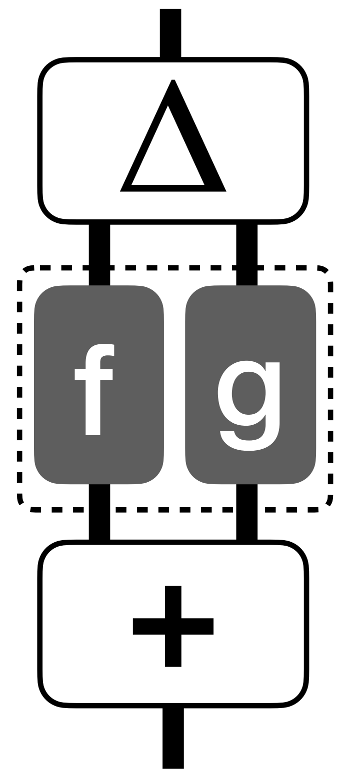
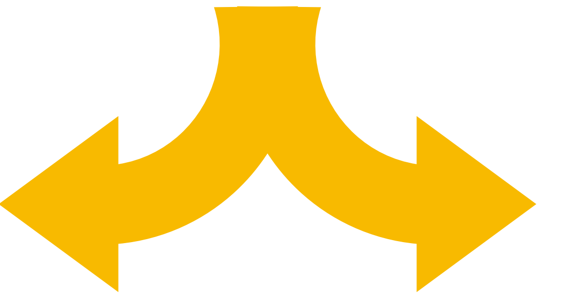


# Representing Functions



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  Par(Flow[A₁,B₁], Flow[A₂,B₂])
   : Flow[(A₁,A₂), (B₁,B₂)]
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```
val f, g: Flow[Int, Int] = ???
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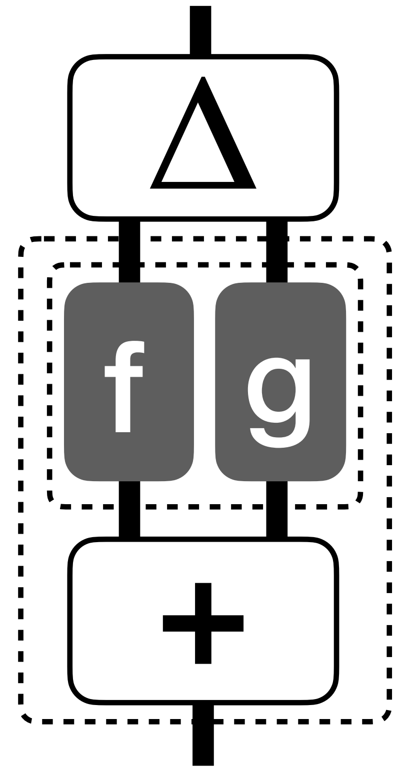
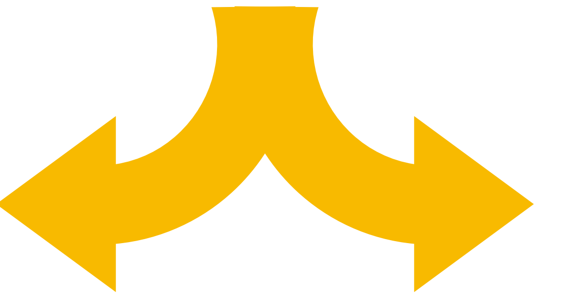


# Representing Functions



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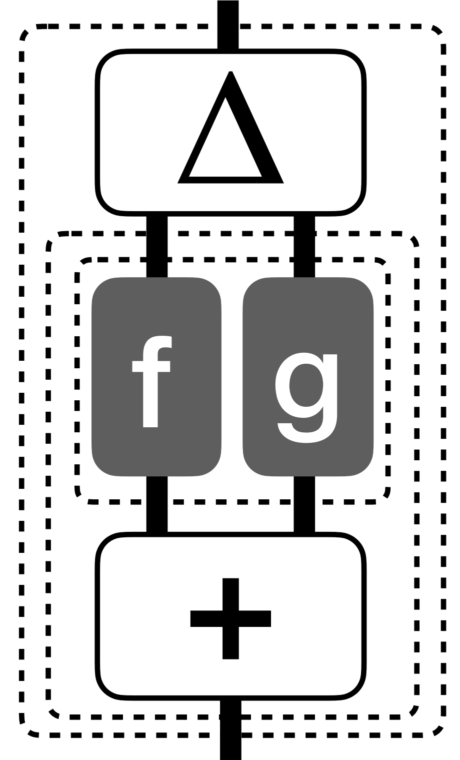

# Expression centric vs. Function centric

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val f, g: Expr[Int ⇒ Int] = ???
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```
val f, g: Flow[Int, Int] = ???
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- close to syntax

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Lam(
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# Expression centric vs. Function centric

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- needs translation

# Expression centric vs. Function centric

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val f, g: Expr[Int ⇒ Int] = ???
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```

```
val f, g: Flow[Int, Int] = ???
```

- close to syntax
- few primitives

```
Lam(
  Var("x"),
  Plus(
    App(f, Var("x")),
    App(g, Var("x"))
  )
): Expr[Int ⇒ Int]
```

```
AndThen(
  Dup(),
  AndThen(
    Par(f, g),
    Plus()
  )
): Flow[Int, Int]
```

- needs translation

# Expression centric vs. Function centric

```
val f, g: Expr[Int ⇒ Int] = ???
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```
x ⇒ f(x) + g(x)
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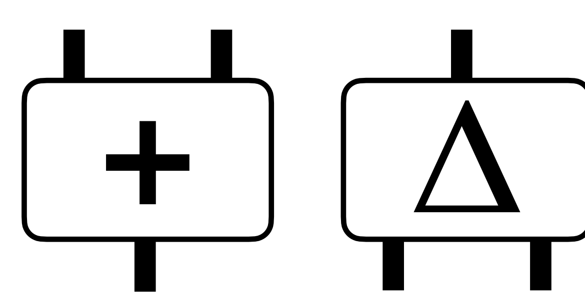

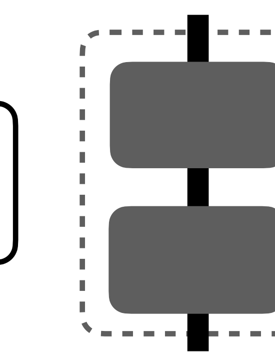
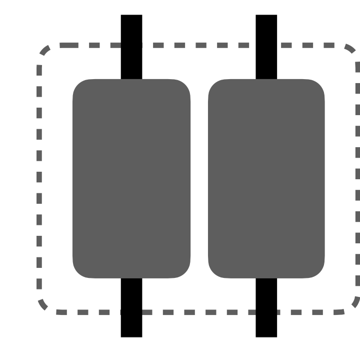

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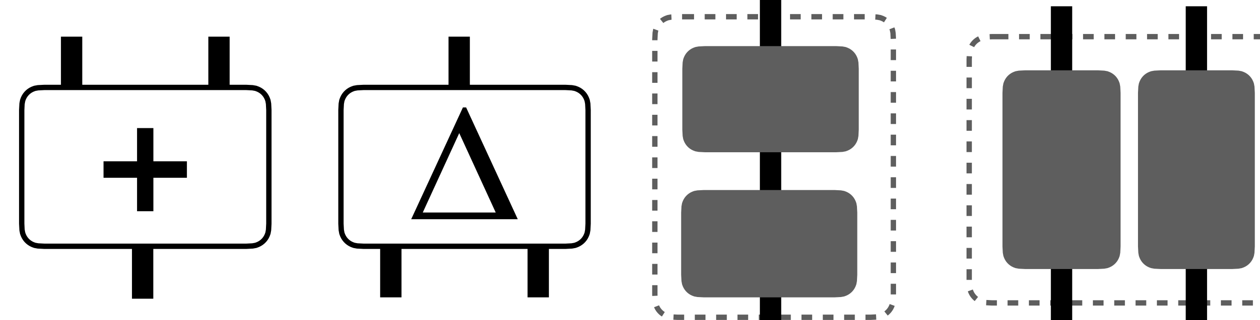


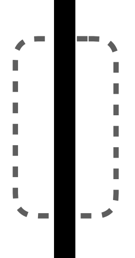

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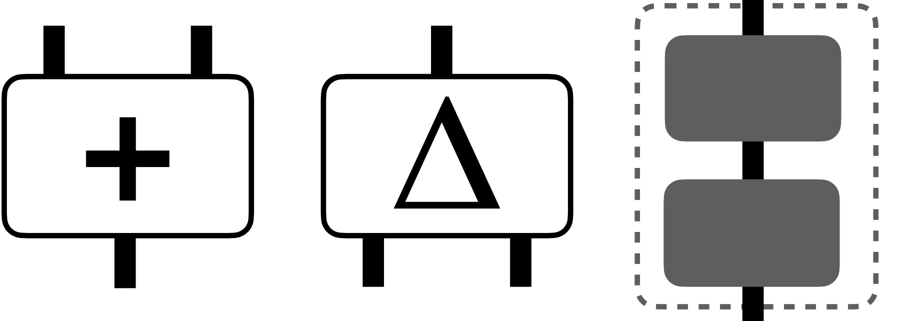


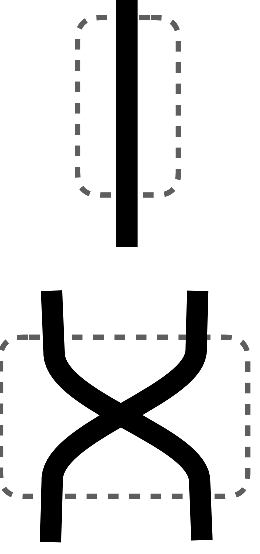

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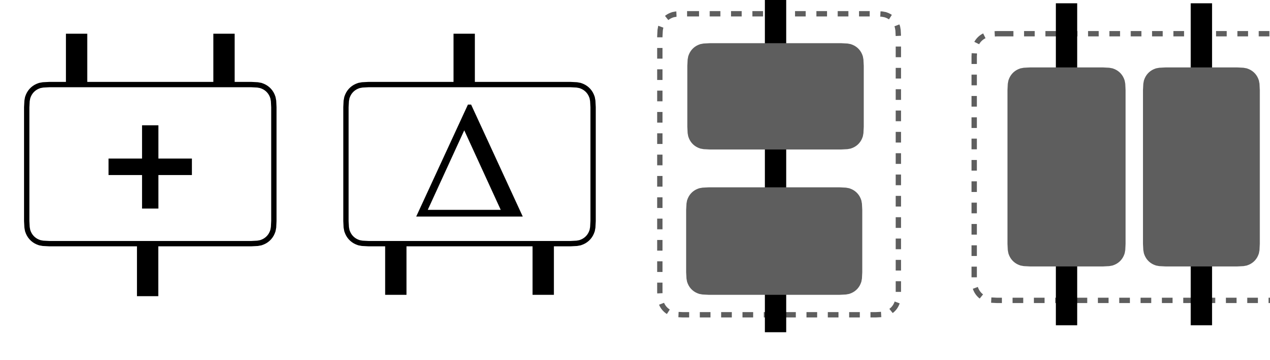


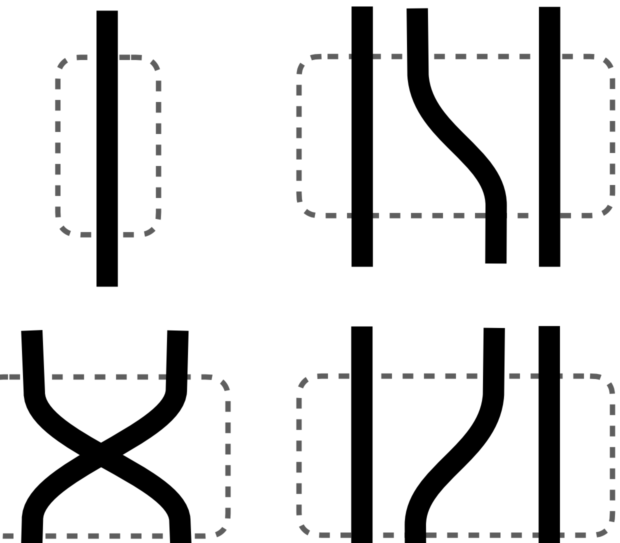

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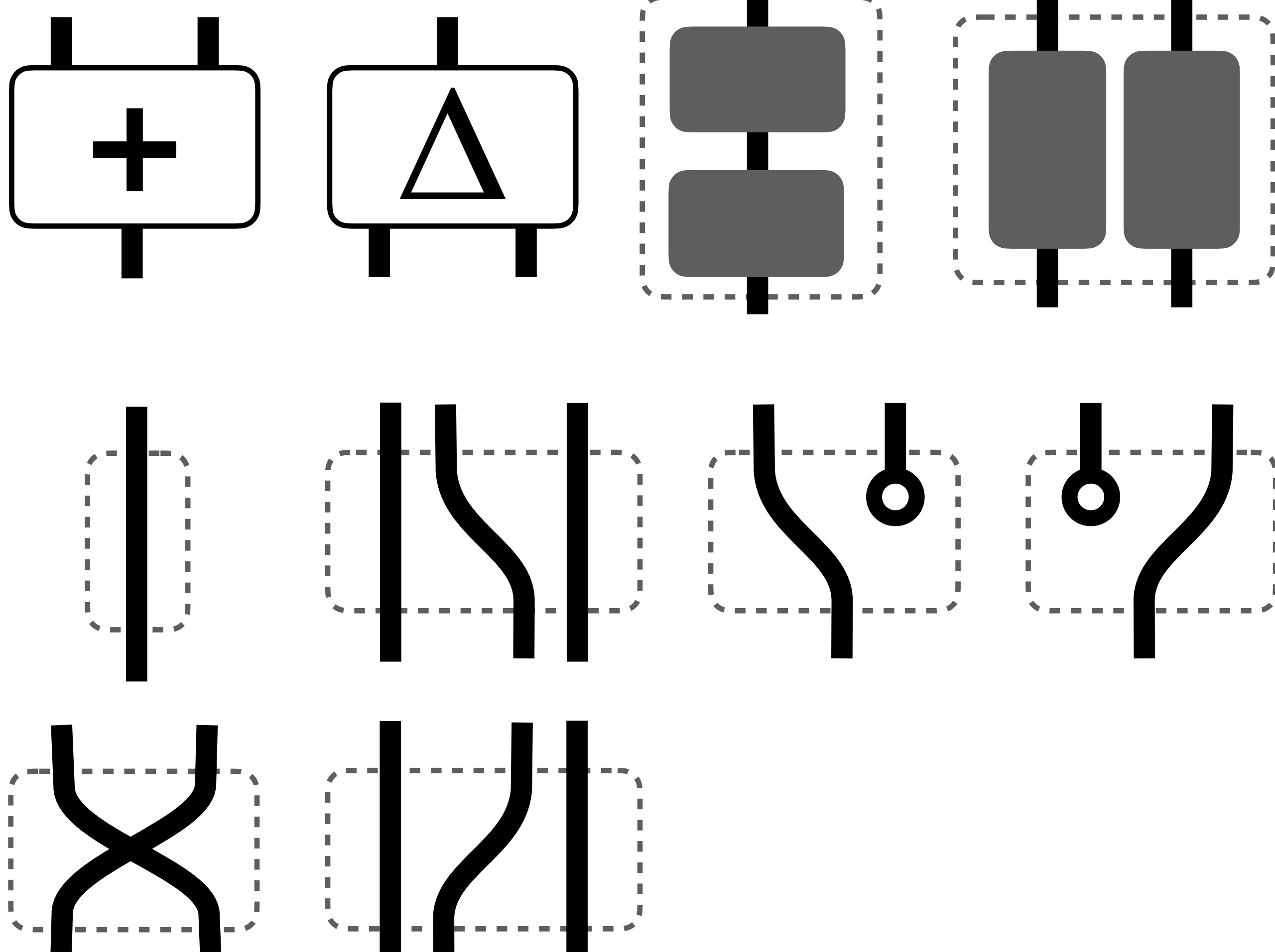

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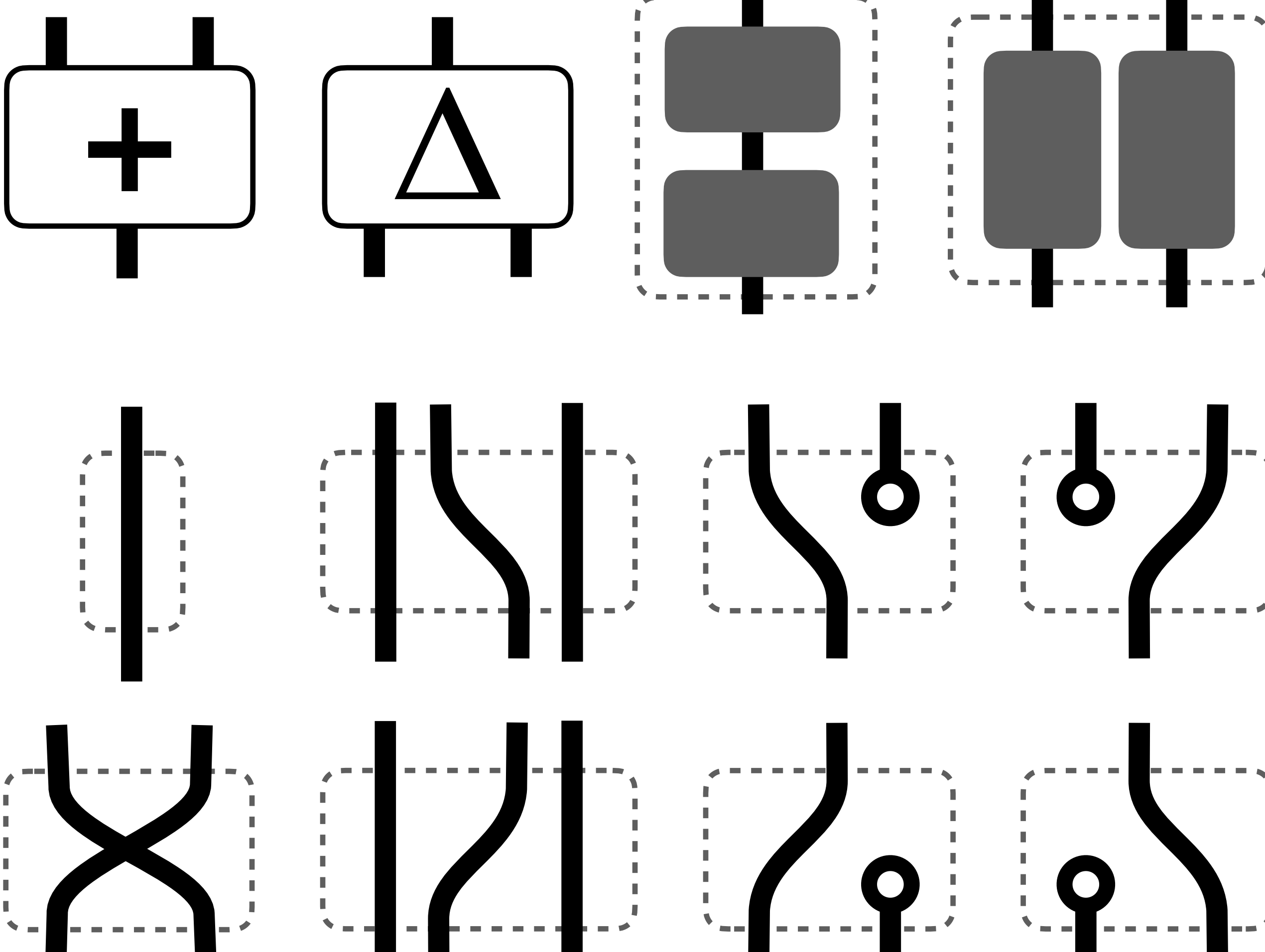

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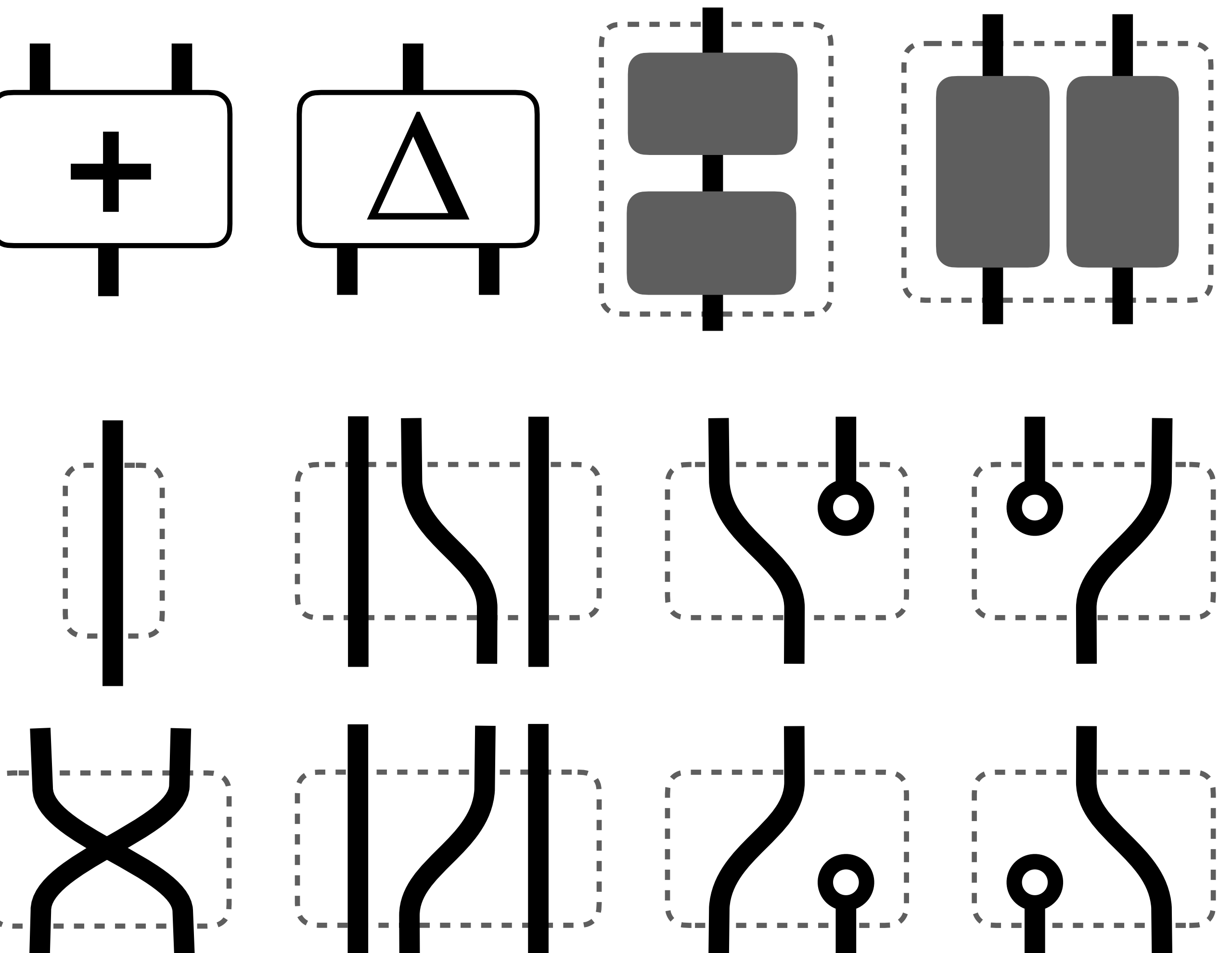

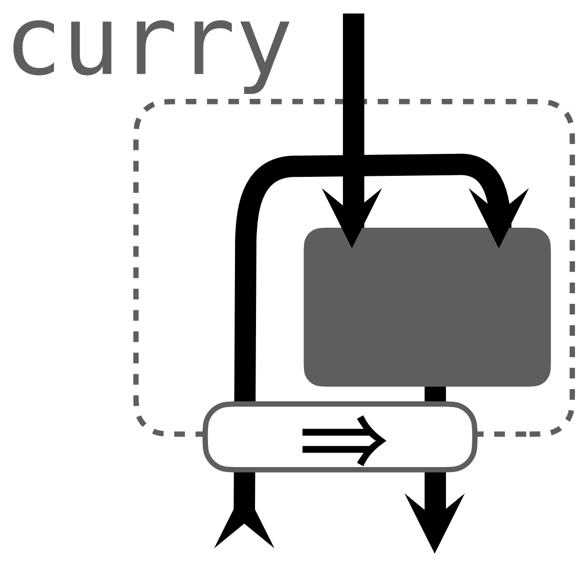

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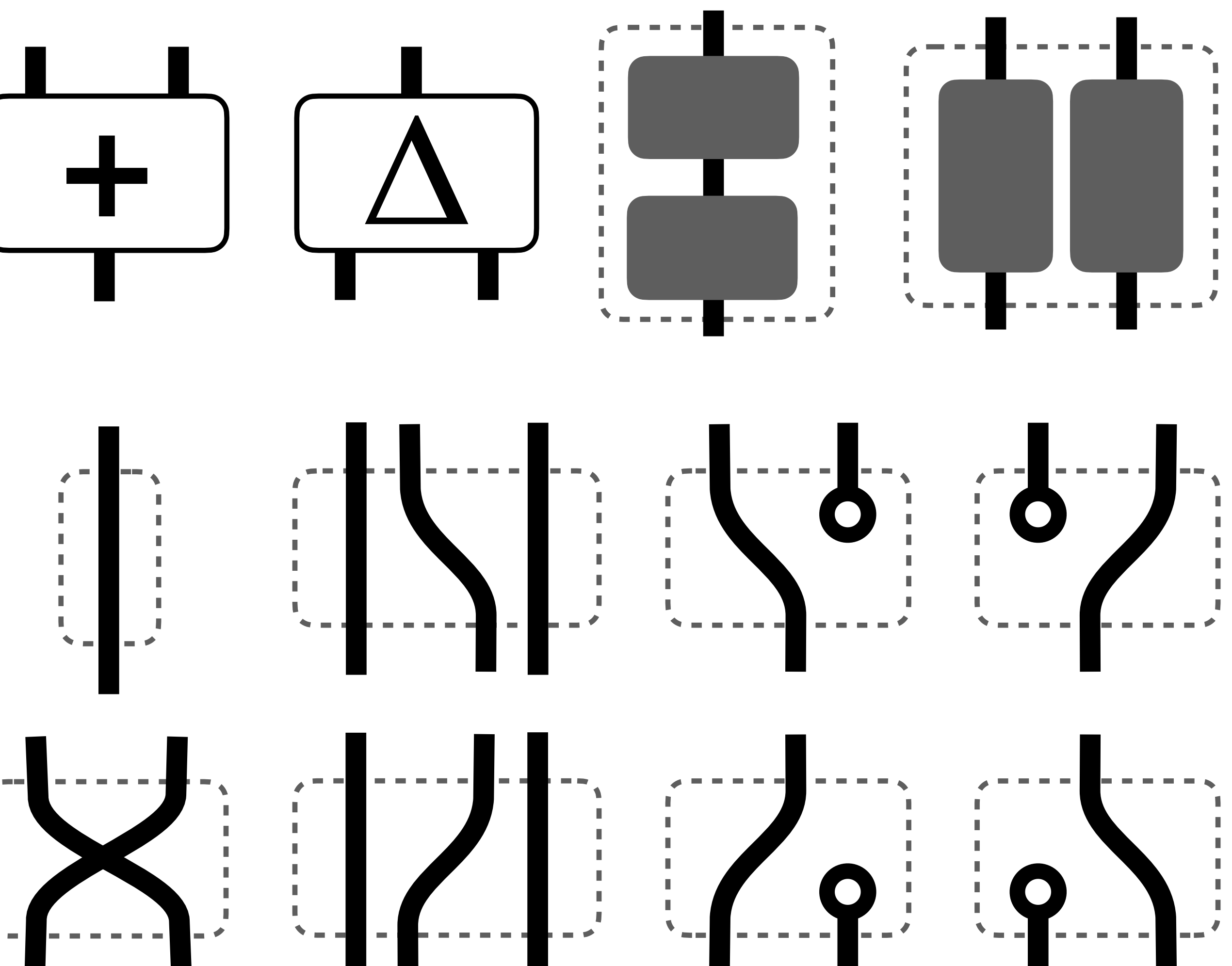


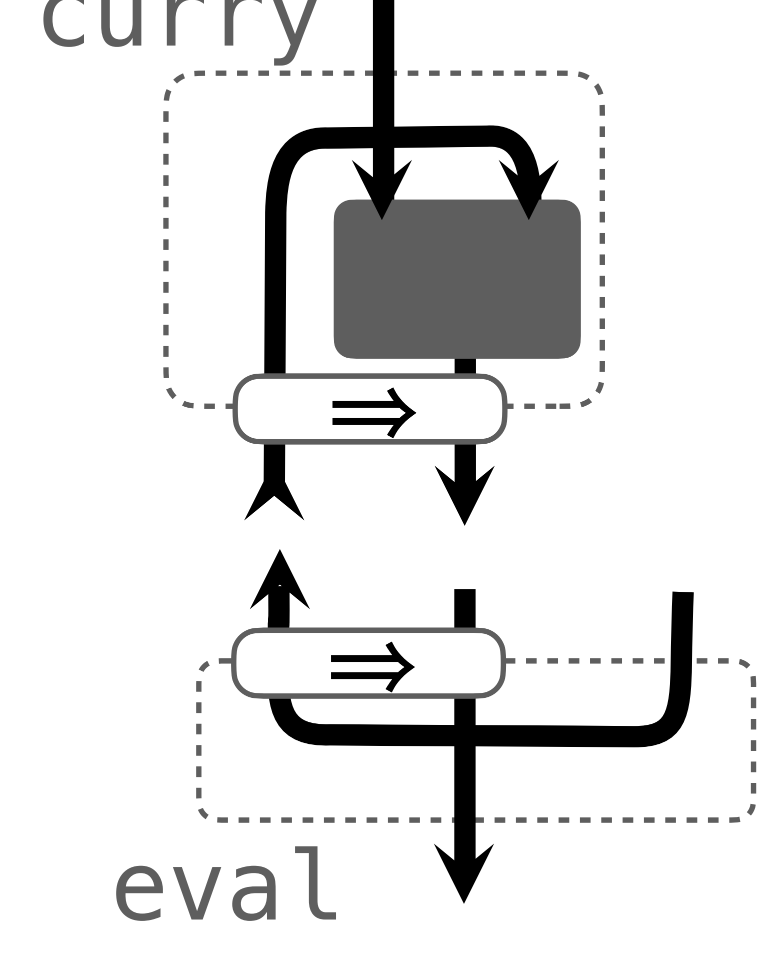

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- needs translation
- many primitives
- verbose
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val f, g: Expr[Int ⇒ Int] = ???
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- close to syntax
- few primitives
- concise
- ~ λ-calculus
- functions as values

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- needs translation
- many primitives
- verbose
- ~ category theory
- values as functions

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- concise
- ~ λ-calculus
- functions as values
  - Is a *world-capturing* closure still a *value?*

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- close to syntax
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  - Is a *world-capturing* closure still a *value?*
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- concise
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Function centric:

- needs translation
- many primitives
- verbose
- ~ category theory
- values as functions
- locality (everything discoverable by "*wire chasing*")

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**Expression centric**

- close to syntax
- few primitives
- concise
- ~ λ-calculus
- functions as values
  - Is a *world-capturing* closure still a *value?*
- non-locality (referencing arbitrarily distant variables)
- all-or-nothing
  - HOFs/closures, non-linearity, Church encodings, …
  - can’t meaningfully take away any of `Var`, `Lam`, `App`

**Function centric**

- needs translation
- many primitives
- verbose
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- values as functions
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**Function centric**

- needs translation
- many primitives
- verbose
- ~ category theory
- values as functions
- locality (everything discoverable by *"wire chasing"*)
- graded expressive power
  - pairs before HOFs; don't have to have HOFs
  - linearity by *taking away* non-linear ops

# Expression centric vs. Function centric

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- verbose
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- values as functions
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- pervasive **illegal state**
  - undefined variables
  - shadowing
  - program transformations *inevitably* deal with illegal fragments

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**Expression centric:**

- 🟢 close to syntax
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- 🟢 concise
- ⚫ ~ λ-calculus
- ⚫ functions as values
- 🔴 non-locality
- 🔴 all-or-nothing
- 🔴 pervasive **illegal state**
  - undefined variables
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  - program transformations *inevitably* deal with illegal fragments

**Function centric:**

- 🔴 needs translation
- 🔴 many primitives
- 🔴 verbose
- ⚫ ~ category theory
- ⚫ values as functions
- 🟢 locality
- 🟢 graded expressive power
- 🟢 illegal state largely unrepresentable
  - no variables ⇒ no *undefined* variables or shadowing
  - no illegal fragments

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- 🔴 many primitives
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  )
): Expr[Int ⇒ Int]
```

- close to syntax
- few primitives
- concise
- ~ λ-calculus
- functions as values
- non-locality
- all-or-nothing
- pervasive **illegal state**
  - undefined variables
  - shadowing
  - program transformations *inevitably* deal with illegal fragments

```
AndThen(
  Dup(),
  AndThen(
    Par(f, g),
    Plus()
  )
): Flow[Int, Int]
```

- needs translation
- many primitives
- verbose
- ~ category theory
- values as functions
- locality
- graded expressive power
- illegal state largely unrepresentable
  - no variables ⇒ no *undefined* variables or shadowing
  - no illegal fragments
- graphical notation

# **Values** as Functions

# Values as Functions

```
case Const[A](value: A) extends Flow[Unit, A]
```

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```
Const(new Thread()) : Flow[Unit, Thread]
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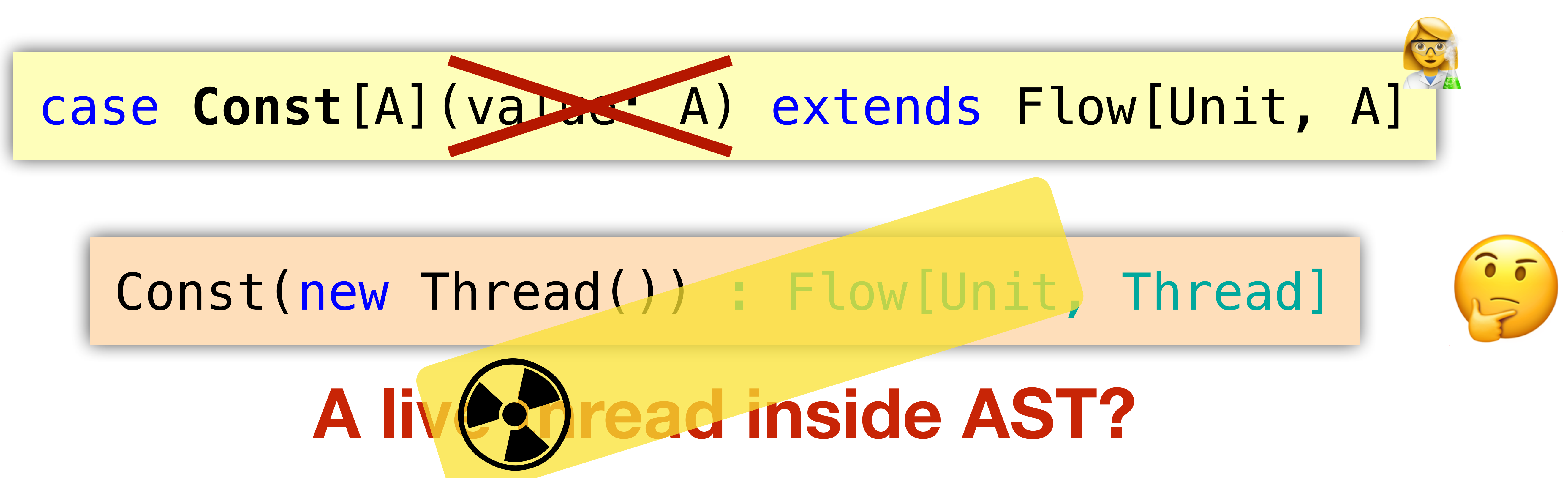

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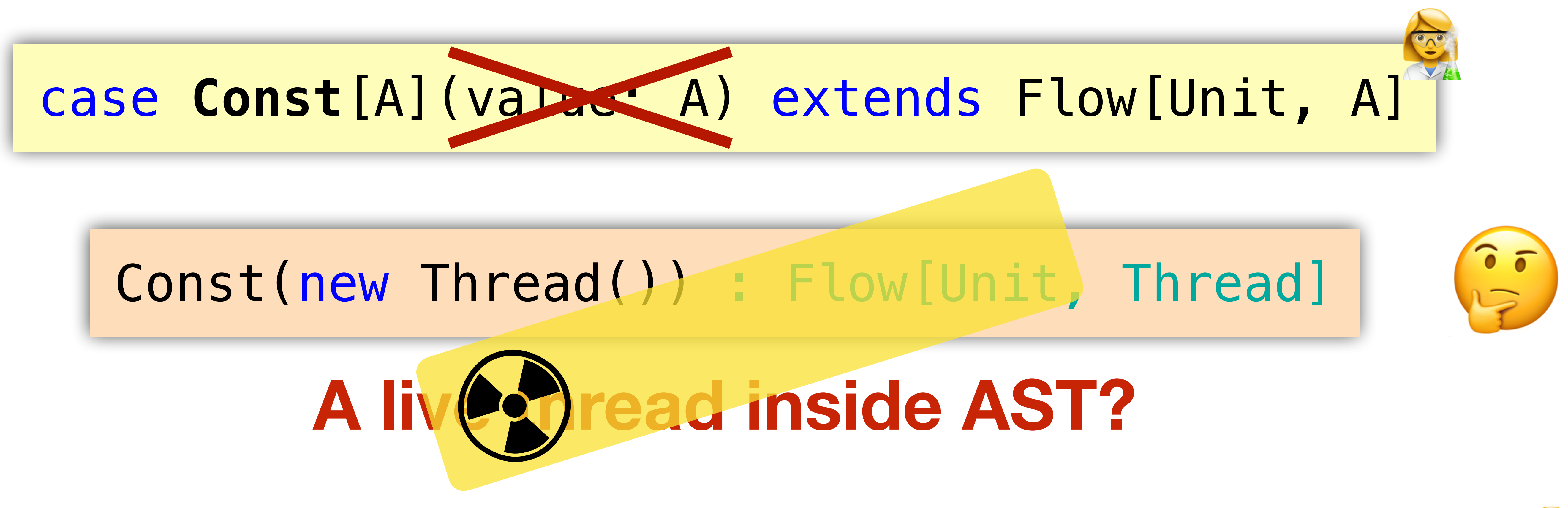
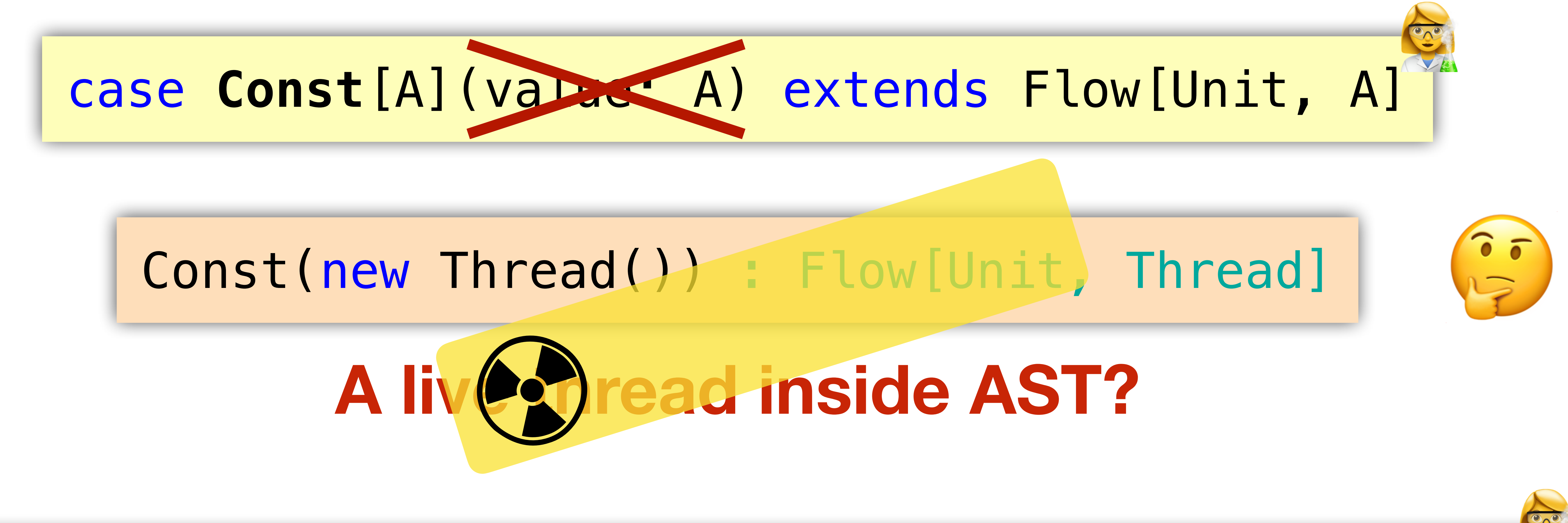



```
case Const[A](value: Value[A]) extends Flow[Unit, A]
```

# Values as Functions

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A GADT that limits what is a domain-level value

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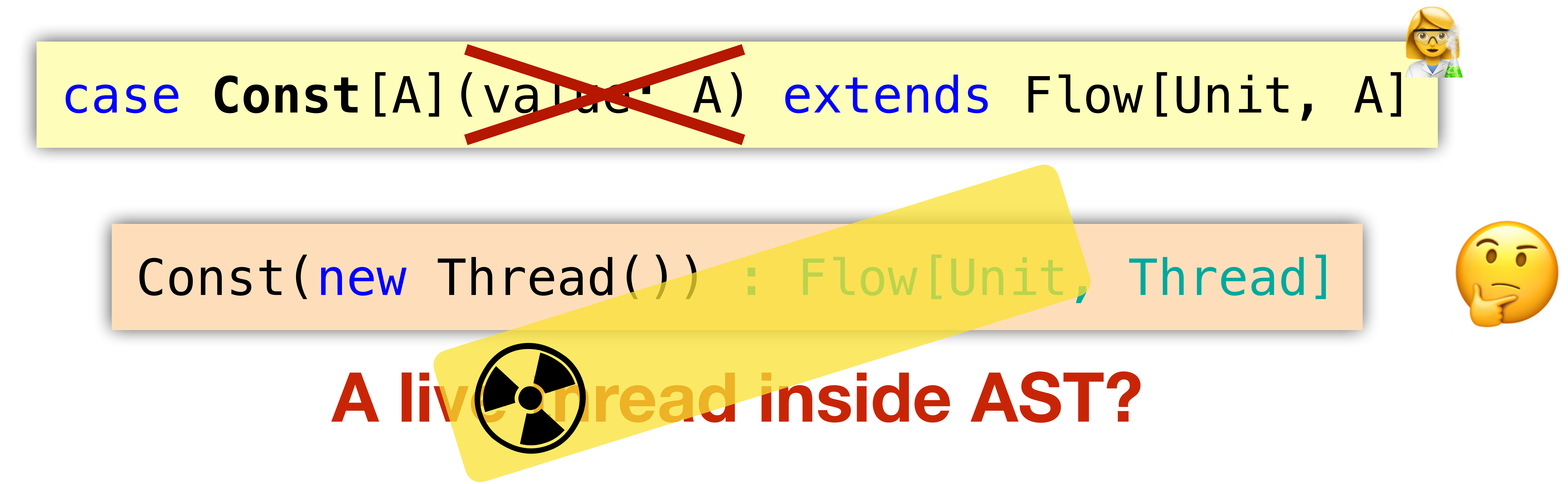


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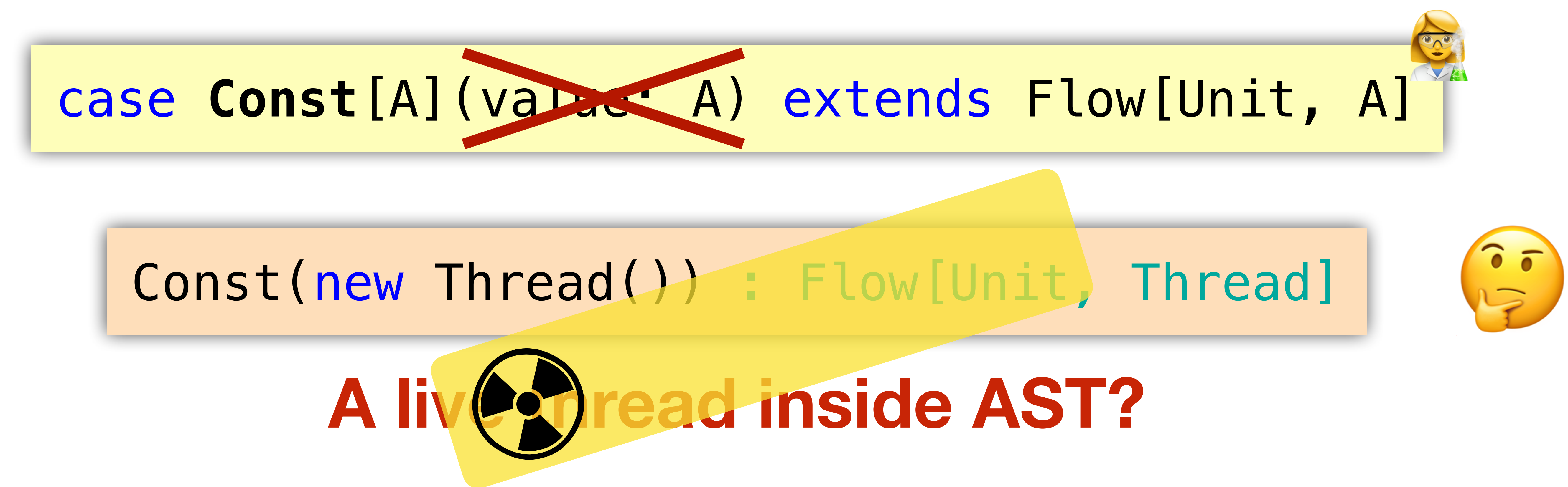
A GADT that limits what is a domain-level value

```
enum Value[A]:
  case Integer(i: Int) extends Value[Int]
  case Pair[A, B](
    a: Value[A],
    b: Value[B]
  ) extends Value[(A, B)]
  ...
```

# Values as Functions

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  ) extends Value[(A, B)]
  ...
```

```
Const(new Thread())
```

```
Found:    Thread
Required: Value[A]
```

## Best Practice:

# Don’t Reuse Scala Types as Domain Types

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Introduce new domain types for common concepts

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| Scala | Domain (Workflows) |
|---|---|
| `(A, B)` | `A ** B` |
| `Either[A, B]` | `A ++ B` |
| `Unit` | `One` |

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sealed trait **[A, B] // no subclasses
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```
enum Flow[A,B]:
  case Dup[A]() extends Flow[A, A ** A]
  case Par[A1, A2, B1, B2](
    f1: Flow[A1, B1],
    f2: Flow[A2, B2]
  ) extends Flow[A1 ** A2, B1 ** B2]
  case Const[A](value: Value[A]) extends Flow[One, A]
  ...
```

# Best Practice:
# Don't Reuse Scala Types as Domain Types

Introduce new domain types for common concepts

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  ...
```

```
enum Value[A]:
  case Pair[A, B](
    a: Value[A],
    b: Value[B]
  ) extends Value[A ** B]
  ...
```

# Domain-level Enums

(a.k.a. sum types, tagged unions, variant types, coproduct types)

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- Looking for domain-level analog of

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enum Request:
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  - ☢ to avoid *contamination* by Scala objects
  - DEAD END would need *Scala* functions to work with

- Aiming for

```
type Request = Enum
  [ "ForOffice"     :: (Equipment ** DeskLocation)
  || "WorkFromHome" :: (Equipment ** DeliveryAddress)
  ]
```

# Domain-level **Enums**

```
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# Domain-level Enums

```
sealed trait **[A, B]
sealed trait Enum[Cases]
sealed trait ||[A, B]
sealed trait ::[Name, Type]
```

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What can we ***do*** with it?

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What do we *need* to ***do*** with it?

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What do we *need* to ***do*** with it?

**Create Requests**
from input data

```
Flow[Equipment ** DeskLocation,    Request]
Flow[Equipment ** DeliveryAddress, Request]
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type Request = Enum
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```

What do we *need* to ***do*** with it?

**Create Requests**
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```
Flow[Equipment ** DeskLocation,    Request]
Flow[Equipment ** DeliveryAddress, Request]
```

**Handle Requests**

```
Flow[Equipment ** DeskLocation,    B]
Flow[Equipment ** DeliveryAddress, B]
```

⇒

```
Flow[Request, B]
```

by providing a handler for each case

# Domain-level **Enums**

What:

**Create Requests**

```
Flow[Equipment ** DeskLocation,    Request]
Flow[Equipment ** DeliveryAddress, Request]
```

```
Flow[Equipment ** DeskLocation,    B]
Flow[Equipment ** DeliveryAddress, B]
```

⇒

**Handle Requests**

```
Flow[Request, B]
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# Domain-level Enums

What:

**Create Requests**

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Flow[Equipment ** DeskLocation,    Request]
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Flow[Equipment ** DeliveryAddress, B]
```

⇒

**Handle Requests**

```
Flow[Request, B]
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**How:** Capture the intent, in a type-safe manner.

# Domain-level Enums

What:

**Create Requests**

```
Flow[Equipment ** DeskLocation,      Request]
Flow[Equipment ** DeliveryAddress, Request]
```

```
Flow[Equipment ** DeskLocation,      B]
Flow[Equipment ** DeliveryAddress, B]
```

⇒

**Handle Requests**

```
Flow[Request, B]
```

**How:** Capture the intent, in a type-safe manner.

```
// create
case class Inject[N, A, Cases](ev: Member[N, A, Cases]) extends Flow[A, Enum[Cases]]
// handle
case class Handle[Cases, B]   (hs: Handlers[Cases, B])  extends Flow[Enum[Cases], B]
```

# Producing **Enums**

```
case class Inject[N, A, Cases](ev: Member[N, A, Cases]) extends Flow[A, Enum[Cases]]
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# Producing Enums

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```
type Cases =
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type Cases =
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```
Inject["ForOffice", Equipment ** DeskLocation, Cases](???)
                                   : Flow[Equipment ** DeskLocation, Enum[Cases]]
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What we wanted

```
Inject["ForOffice", Equipment ** DeskLocation, Cases](???)
                                : Flow[Equipment ** DeskLocation,      Request]
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type Cases =
  ( "ForOffice"    :: (Equipment ** DeskLocation)
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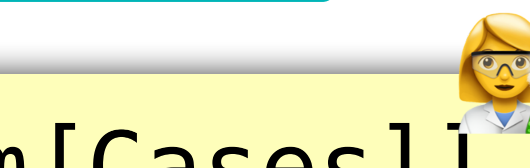
Evidence that N :: A is one of Cases (📗)



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```
Member[“ForOffice", Equipment ** DeskLocation,     Cases]
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Member["ForOffice", Equipment ** DeskLocation,    Cases] ✔
Member["Foo",       Equipment ** DeskLocation,    Cases]
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Evidence that N :: A is one of Cases (📗)

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unrepresentable

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```
Member[“ForOffice", Equipment ** DeskLocation,     Cases] ✔
Member[“Foo",       Equipment ** DeskLocation,     Cases] ✘
Member[“ForOffice", Equipment ** DeliveryAddress, Cases]
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**unrepresentable**

Evidence that **N :: A** is one of **Cases** ()

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```

**unrepresentable**

**unrepresentable**

Evidence that N :: A is one of Cases (📗)

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# Consuming **Enums**

```scala
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
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collection of handlers, one for each case (📗)

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type Cases = “x” :: Tuna  || “y” :: Cod
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collection of handlers, one for each case (📗)

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```
Handle[Cases, B] =
```

```
Enum[ “x” :: Tuna || “y” :: Cod ]
```

```
B
```

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```

Enum[ "x" :: Tuna || "y" :: Cod ]

Tuna

B

Cod

B

B

# Consuming Enums

```
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

collection of handlers, one for each case (📗)

```
type Cases = “x” :: Tuna  ‖  “y” :: Cod
```

```
Handle[Cases, B] =
```

Enum[ “x” :: Tuna ‖ “y” :: Cod ]

Tuna

B

Cod

B

B

**non-exhaustive handlers *unrepresentable***

# Consuming Enum and a Side Dish

(needed to support pattern matching with **capture**)

# Consuming **Enum** and a **Side Dish**

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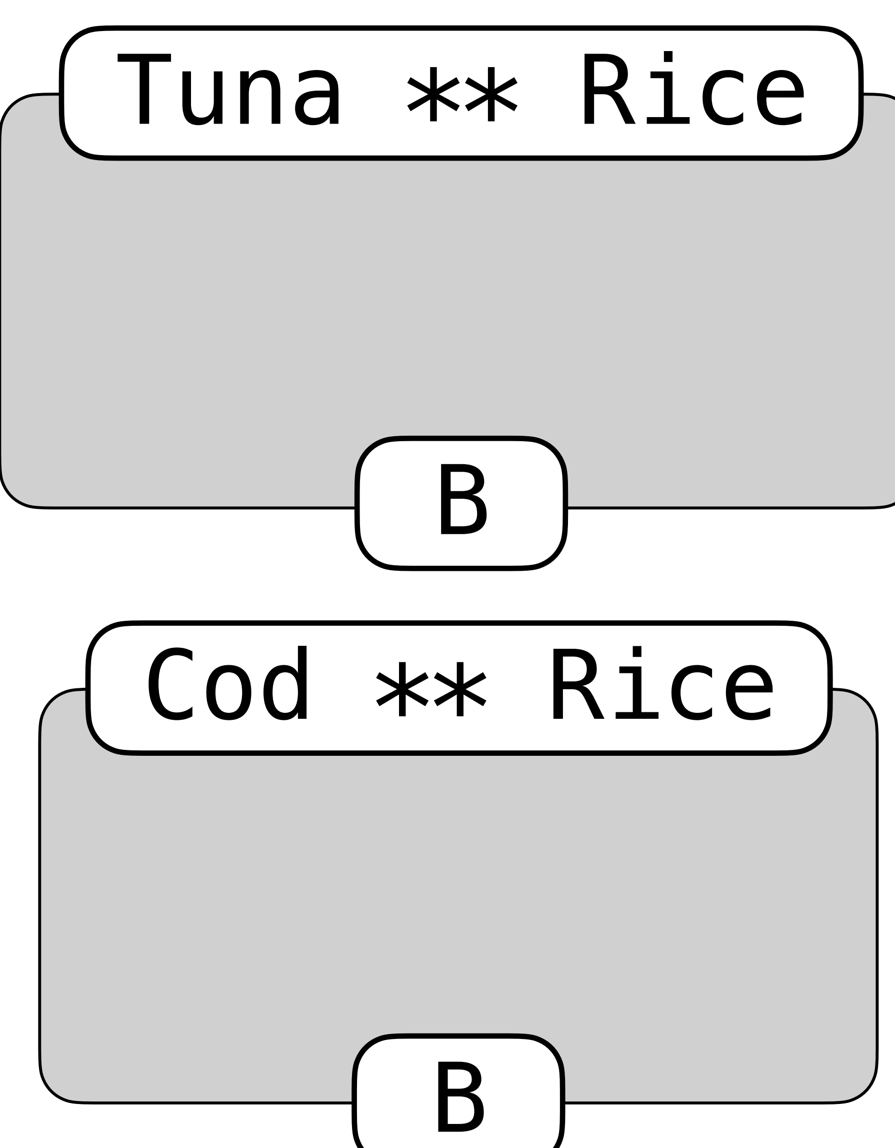

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(needed to support pattern matching with **capture**)

Problem: What if I cannot consume Tuna/Cod without Rice

```
Enum[ "x" :: Tuna  ||  "y" :: Cod ]      **      Rice
```

Tuna ** Rice

B

Cod ** Rice

B

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case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

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```

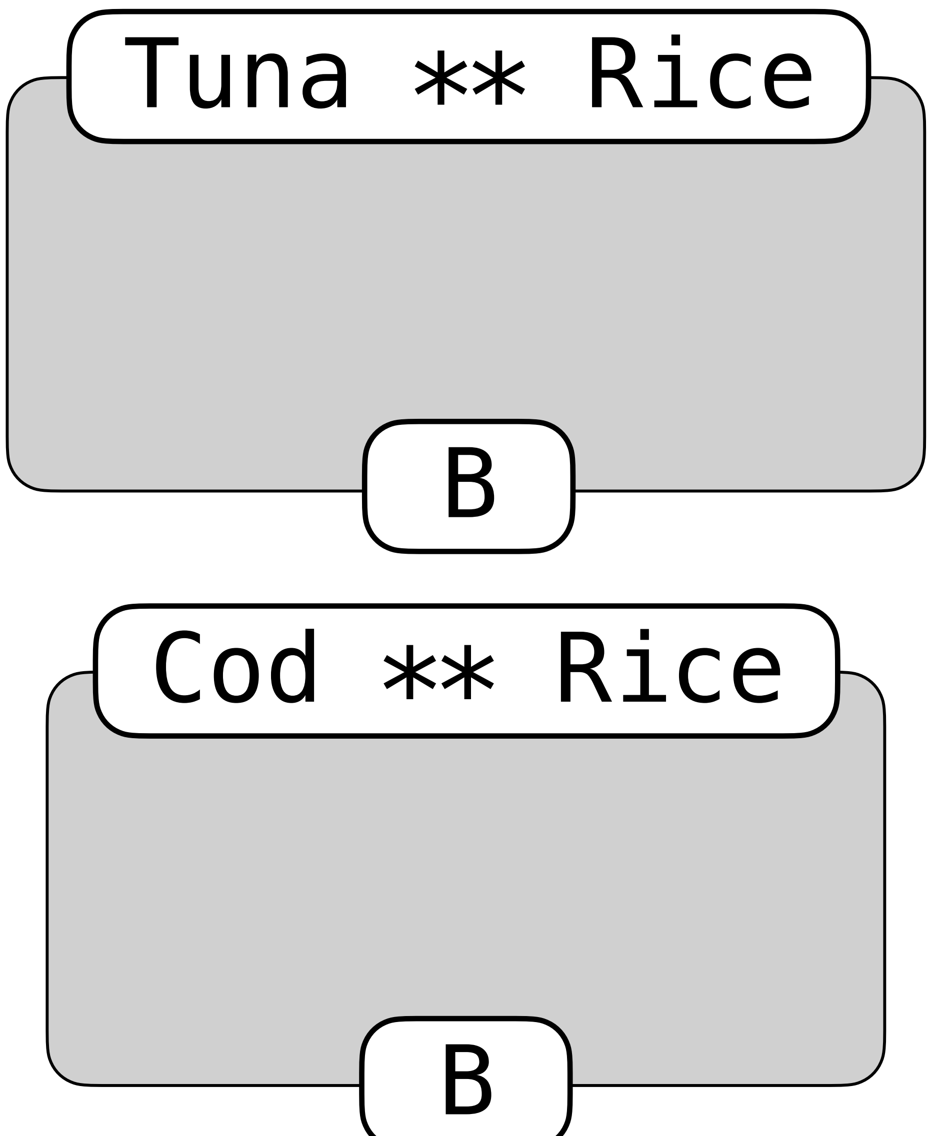

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(needed to support pattern matching with **capture**)

Problem: What if I cannot consume Tuna/Cod without Rice

```
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

Enum[ “x” :: Tuna || “y” :: Cod ] ** **Rice**

Handle[Cases, B] =

Tuna

???

B

Cod

???

B

B

Tuna ** Rice

B

Cod ** Rice

B

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Problem: What if I cannot consume Tuna/Cod without Rice

```
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

```
Enum[ "x" :: Tuna  ||  "y" :: Cod ]        **        Rice

Enum[ "x" :: (Tuna ** Rice)  ||  "y" :: (Cod ** Rice) ]
```

# Consuming **Enum** and a **Side Dish**

(needed to support pattern matching with **capture**)

Problem: What if I cannot consume Tuna/Cod without Rice

```
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

Enum[ “x” :: Tuna ‖ “y” :: Cod ] ** **Rice**

Enum[ “x” :: (Tuna ** **Rice**) ‖ “y” :: (Cod ** **Rice**) ]

Tuna ** Rice

B

Cod ** Rice

B

B

# Consuming **Enum** and a **Side Dish**

(needed to support pattern matching with **capture**)

Problem: What if I cannot consume Tuna/Cod without Rice

```
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

```
DistributeRL[
  Rice,
  Cases,
  Cases1
]
```

=

Enum[ “x” :: Tuna ‖ “y” :: Cod ] ** **Rice**

Enum[ “x” :: (Tuna ** **Rice**) ‖ “y” :: (Cod ** **Rice**) ]

Tuna ** Rice

B

Cod ** Rice

B

B

# Consuming **Enum** and a **Side Dish**

(needed to support pattern matching with **capture**)

Problem: What if I cannot consume Tuna/Cod without Rice

```
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

```
DistributeRL[
  Rice,
  Cases,
  Cases¹
]
          =   Enum[ "x" :: Tuna  ||  "y" :: Cod ]   **   Rice

              Enum[ "x" :: (Tuna ** Rice)  ||  "y" :: (Cod ** Rice) ]
```

# Consuming **Enum** and a **Side Dish**

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Problem: What if I cannot consume Tuna/Cod without Rice

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case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

```
DistributeRL[
  Rice,
  Cases,
  Cases¹
]
```

=

```
Enum[ "x" :: Tuna  ||  "y" :: Cod ]      **      Rice
```

```
Enum[ "x" :: (Tuna ** Rice)  ||  "y" :: (Cod ** Rice) ]
```

- **idea: just capture the intent**

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case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
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]
        =
Enum[ "x" :: Tuna  ||  "y" :: Cod ]        **        Rice

Enum[ "x" :: (Tuna ** Rice)  ||  "y" :: (Cod ** Rice) ]
```

```
case class DistributeRL[R, Cases, Cases¹](
  [ ... evidence that Cases¹ is the result
        of distributing R into Cases ... ]
) extends Flow[Enum[Cases] ** R, Enum[Cases¹]]
```

- **idea: just capture the intent**

# Consuming **Enum** and a **Side Dish**

(needed to support pattern matching with **capture**)

Problem: What if I cannot consume Tuna/Cod without Rice

```
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

```
DistributeRL[
  Rice,
  Cases,
  Cases¹
]
```

=

```
Enum[ “x” :: Tuna  ||  “y” :: Cod ]   **   Rice
```

```
Enum[ “x” :: (Tuna ** Rice)  ||  “y” :: (Cod ** Rice) ]
```

```
case class DistributeRL[R, Cases, Cases¹](
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```

- **idea: just capture the intent**
- completely type-safe

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(needed to support pattern matching with **capture**)

Problem: What if I cannot consume Tuna/Cod without Rice

```
case class Handle[Cases, B](hs: Handlers[Cases, B]) extends Flow[Enum[Cases], B]
```

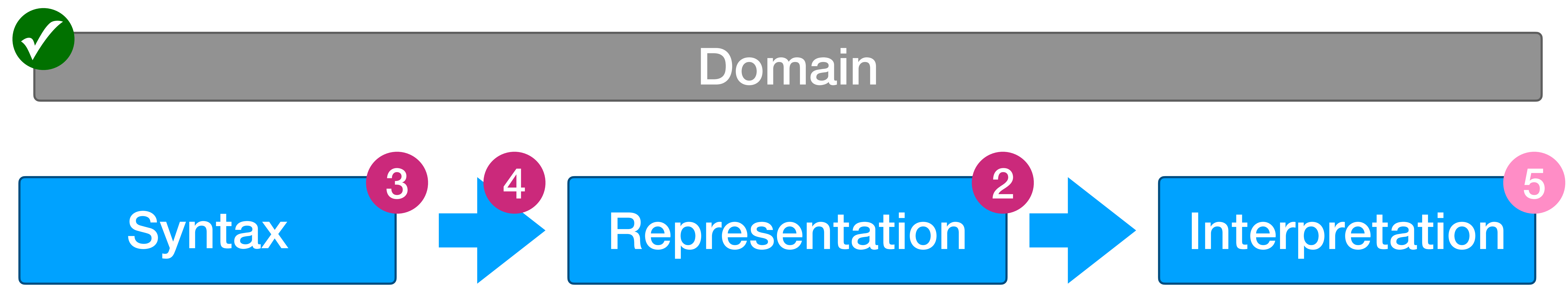
```
DistributeRL[
  Rice,
  Cases,
  Cases¹
]
        =
Enum[ “x” :: Tuna  ||  “y” :: Cod ]      **      Rice

Enum[ “x” :: (Tuna ** Rice)  ||  “y” :: (Cod ** Rice) ]
```

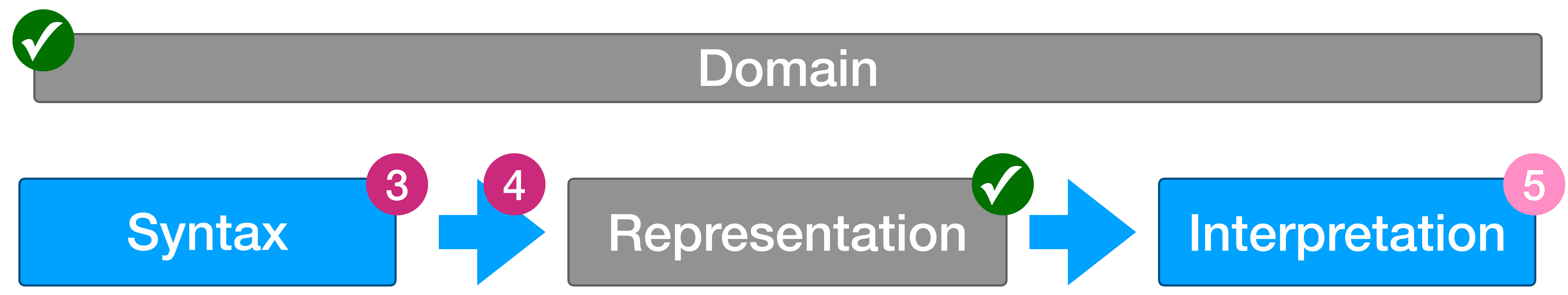
```
case class DistributeRL[R, Cases, Cases¹](
  [ ... evidence that Cases¹ is the result
        of distributing R into Cases ... ]
) extends Flow[Enum[Cases] ** R, Enum[Cases¹]]
```

- **idea: just capture the intent**
- completely type-safe
- works for any number of cases

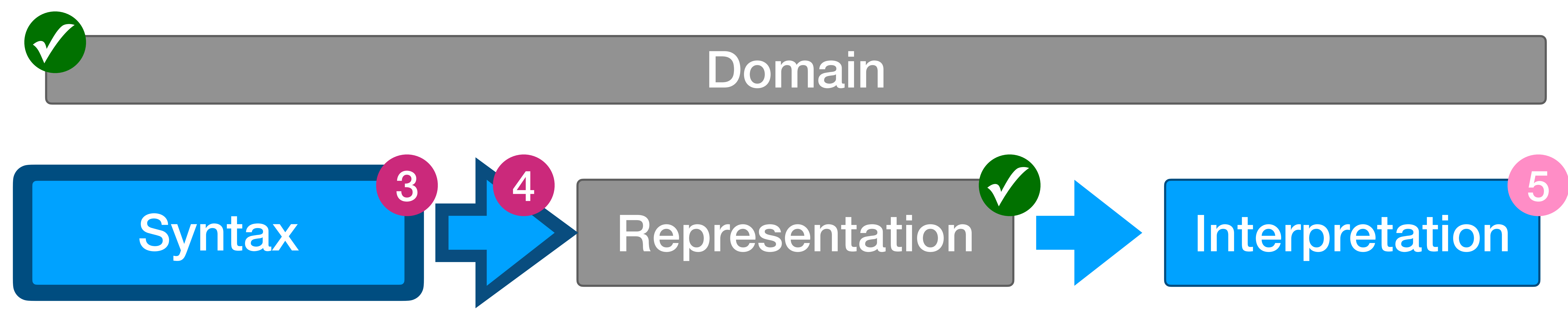
# Agenda



# Agenda



# Agenda



# Why any special Syntax?

Why not construct instances of `Flow[A,B]` directly?

# Why any special Syntax?

Why not construct instances of `Flow[A,B]` directly?

```
AndThen(
  Peel(),
  Either(
    AndThen(
      Extract(),
      AndThen(
        AndThen(
          AndThen(
            Par(Peel(), Id()),
            AndThen(
              AndThen(Swap(), DistributeLR()),
              Either(
                AndThen(Swap(), InjectL()),
                AndThen(Swap(), InjectR())
              )
            )
          ),
          Either(
            AndThen(
              AndThen(
                AndThen(Par(Extract(), Id()), Inject(Single(Monitor))),
                InjectL()
              ),
              Unpeel()
            ),
            Inject(InLast(Chair))
          )
        ),
        AndThen(
          Peel(),
          Either(
            AndThen(
              Extract(),
              AndThen(
                Par(Id(), Ext(RequestMonitorFromIT)),
                Prj2()
              )
            ),
            AndThen(
              Par(
                Id(),
                Ext(RequestChairFromOfficeMgmt)
              ),
              Prj2()
            )
          )
        )
      )
    ),
    Ext(OrderFromSupplier)
  )
)
```

# Why any special Syntax?

Why not construct instances of `Flow[A,B]` directly?

```
AndThen(
  Peel(),
  Either(
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              Either(
                AndThen(Swap(), InjectL()),
                AndThen(Swap(), InjectR())
              )
            )
          ),
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                AndThen(Par(Extract(), Id()), Inject(Single(Monitor))),
                InjectL()
              ),
              Unpeel()
            ),
            Inject(InLast(Chair))
          )
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              AndThen(
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                Prj2()
              )
            ),
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              Par(
                Id(),
                Ext(RequestChairFromOfficeMgmt)
              ),
              Prj2()
            )
          )
        )
      )
    ),
    Ext(OrderFromSupplier)
  )
)
```

Can we get back variables and expressions?

# Desired Syntax

```
Flow { req =>
  req switch {
    case ForOffice(Monitor(_) ** deskLoc) =>
      requestMonitorFromIT(deskLoc)
    case ForOffice(Chair(_) ** deskLoc) =>
      requestChairFromOfficeMgmt(deskLoc)
    case WorkFromHome(item ** address) =>
      orderFromSupplier(item ** address)
  }
}
```

- Lambdas
- Variables
- Pattern-matching
- Expressions

# Desired Syntax

```
Flow { req =>
  req switch {
    case ForOffice(Monitor(_) ** deskLoc) =>
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    case WorkFromHome(item ** address) =>
      orderFromSupplier(item ** address)
  }
}
```

- Lambdas
- Variables
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```
Flow { req =>
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}
```

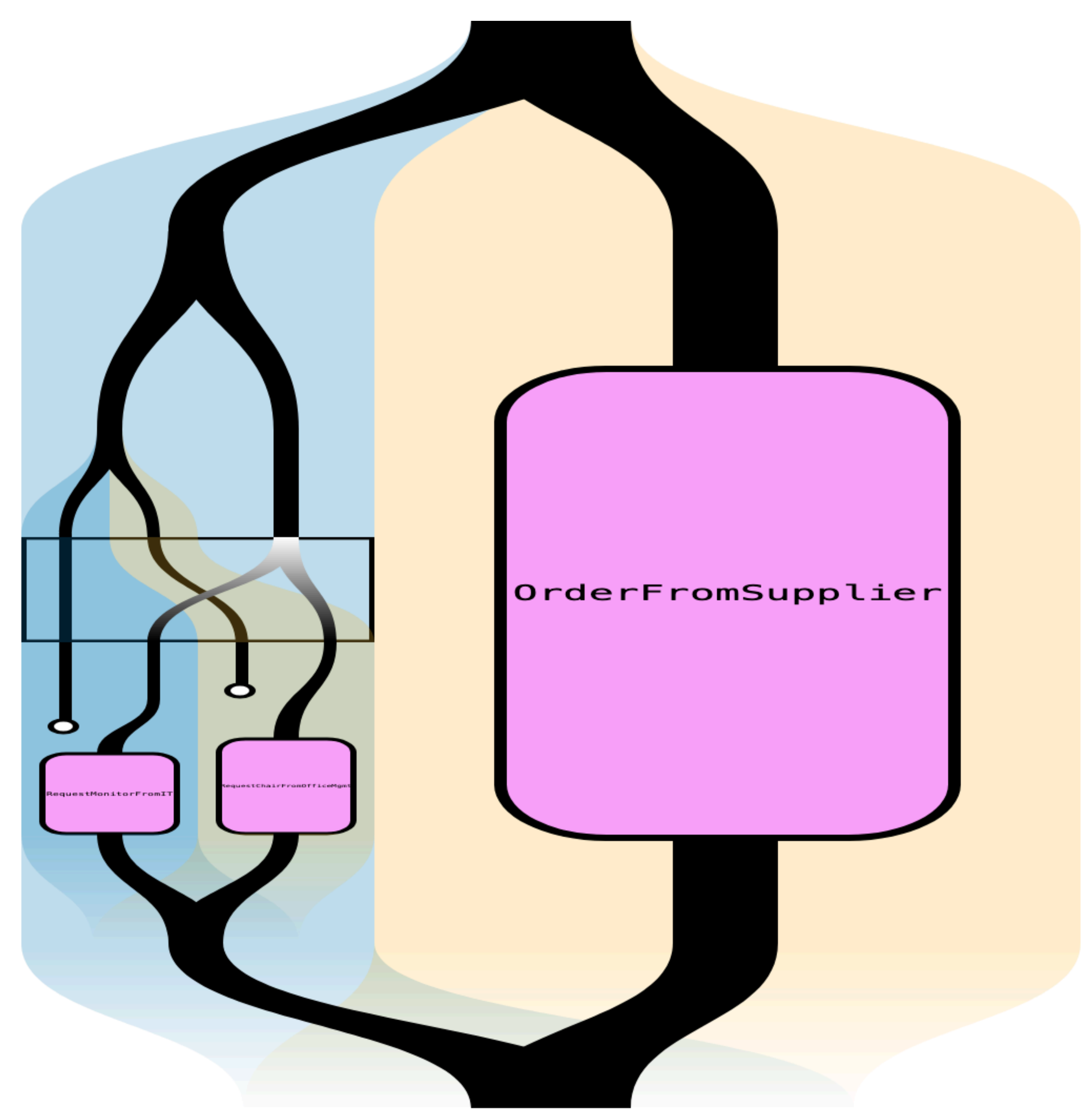

# Let's Break It Down

```
Flow { req =>
  req switch {
    case ForOffice(Monitor(_) ** deskLoc) =>
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```

# Let’s Break It Down

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  }
}
```

1. What does **`Flow`** do?

# Let's Break It Down

```
Flow { req =>
  req switch {
    case ForOffice(Monitor(_) ** deskLoc) =>
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  }
}
```

1. What does **`Flow`** do?
2. What does **`switch`** do?

# Let's Break It Down

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  }
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```

1. What does **`Flow`** do?
2. What does **`switch`** do?
3. What do the **extractors** do? (`ForOffice`, `Monitor`, …)

# Let’s Break It Down

```
Flow { req =>
  req switch {
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```

1. What does **`Flow`** do?
2. What does **`switch`** do?
3. What do the **extractors** do? (`ForOffice`, `Monitor`, …)

# Flow *"Compiles"* Scala Functions

```
Flow { req =>

  ???

}
```

# Flow *“Compiles”* Scala Functions

```
Flow { req =>

  ???

}
```

- Takes a *Scala* function

# Flow *“Compiles”* Scala Functions

```scala
Flow { req =>

  ???

} : Flow[Request, Result]
```

- Takes a *Scala* function
- Returns a `Flow`

# Flow *"Compiles"* Scala Functions

```
Flow { req =>

  ???

} : Flow[Request, Result]
```

- Takes a *Scala* function
- Returns a `Flow`
  - **without** Scala functions

# Flow *"Compiles"* Scala Functions

```
Flow { (req: Expr[Request]) => 🧑‍💻

  ??? : Expr[Result]

} : Flow[Request, Result]
```

- Takes a *Scala* function
  - **on auxiliary expressions**
- Returns a `Flow`
  - **without** Scala functions

# Flow *“Compiles”* Scala Functions

```
Flow { (req: Expr[Request]) =>

  ??? : Expr[Result]

} : Flow[Request, Result]
```

- Takes a *Scala* function
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- Returns a `Flow`
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```
object Flow:

  def apply[A, B](
    f: Expr[A] => Expr[B],
  ): Flow[A, B] =
    ???
```

# Flow *"Compiles"* Scala Functions

```scala
Flow { (req: Expr[Request]) =>

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- Takes a *Scala* function
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- **Uses a library!** (`libretto-lambda`)

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```
object Flow:



  opaque type Expr[A] = lambdas.Expr[A]

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  ): Flow[A, B] =
    ???
```

# Flow *“Compiles”* Scala Functions

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Flow { (req: Expr[Request]) =>

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```

- Takes a *Scala* function
  - **on auxiliary expressions**
- Returns a `Flow`
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- **Uses a library!** (`libretto-lambda`)

```
import libretto.lambda.Lambdas

object Flow:

  val lambdas: Lambdas[Flow, **, …] =
    Lambdas[Flow, **, …](...)

  opaque type Expr[A] = lambdas.Expr[A]

  def apply[A, B](
    f: Expr[A] => Expr[B],
  ): Flow[A, B] =
    ???
```

# Flow *"Compiles"* Scala Functions

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import libretto.lambda.Lambdas

object Flow:
  val lambdas: Lambdas[Flow, **, …] =
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  opaque type Expr[A] = lambdas.Expr[A]

  def apply[A, B](
    f: Expr[A] => Expr[B],
  ): Flow[A, B] =
    lambdas.delambdify(..., f)
    // ... and handle errors ...
```

# Flow *"Compiles"* Scala Functions

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Flow { (req: Expr[Request]) =>

  ??? : Expr[Result]

} : Flow[Request, Result]
```

- Takes a *Scala* function
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- Takes a *Scala* function
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# Peek into `libretto-lambda`

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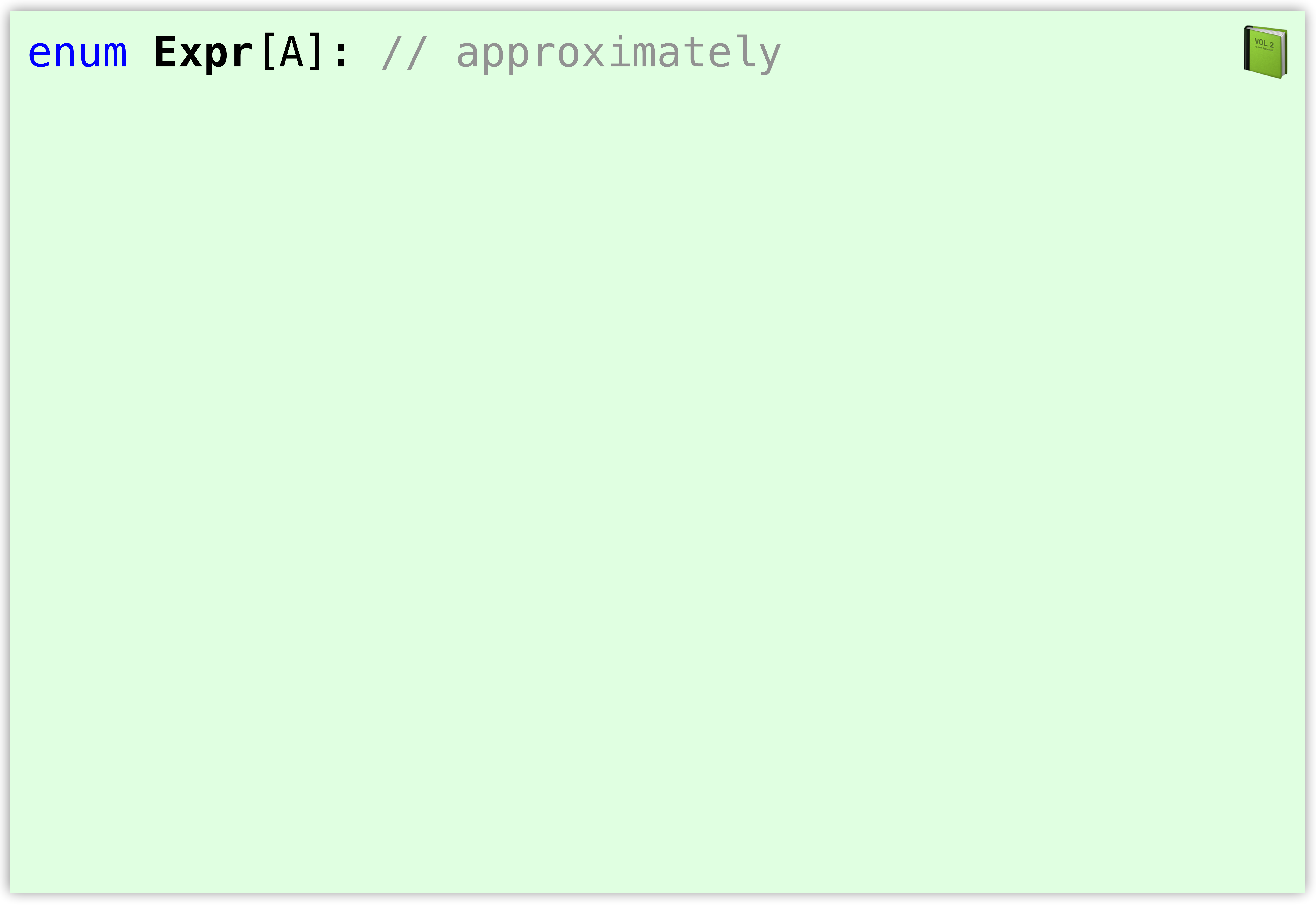

```
enum Expr[A]: // approximately
```

# Peek into `libretto-lambda`

- variables

# Peek into `libretto-lambda`

```
enum Expr[A]: // approximately

  case Var(id: Object)

  case Zip[A, B](
    a: Expr[A],
    b: Expr[B]
  ) extends Expr[A ** B]
```

- variables
- forming pairs

# Peek into `libretto-lambda`

```
enum Expr[A]: // approximately
  case Var(id: Object)
  case Zip[A, B](
    a: Expr[A],
    b: Expr[B]
  ) extends Expr[A ** B]

  case Prj1[A, B](e: Expr[A ** B]) extends Expr[A]
  case Prj2[A, B](e: Expr[A ** B]) extends Expr[B]
```

- variables
- forming pairs
- accessing pairs

# Peek into `libretto-lambda`

```
enum Expr[A]: // approximately
  case Var(id: Object)
  case Zip[A, B](
    a: Expr[A],
    b: Expr[B]
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  case Prj1[A, B](e: Expr[A ** B]) extends Expr[A]
  case Prj2[A, B](e: Expr[A ** B]) extends Expr[B]
  case Map[A, B](
    a: Expr[A],
    f: Flow[A, B]
  ) extends Expr[B]
```

- variables
- forming pairs
- accessing pairs
- applying an *already compiled* `Flow`

# Peek into `libretto-lambda`

```
enum Expr[A]: // approximately
  case Var(id: Object)
  case Zip[A, B](
    a: Expr[A],
    b: Expr[B]
  ) extends Expr[A ** B]
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```

- variables
- forming pairs
- accessing pairs
- applying an *already compiled* `Flow`
- **no** lambda abstraction (immediately delambdified)

# Peek into `libretto-lambda`

```scala
// approximately
def delambdify[A, B](
  f: Expr[A] => Expr[B]
): Flow[A, B] | ... =
```

# Peek into `libretto-lambda`

```scala
// approximately
def delambdify[A, B](
  f: Expr[A] => Expr[B]
): Flow[A, B] | ... =
  val 🍅 : Expr[A] = Var(freshId())
```

# Peek into `libretto-lambda`

```
// approximately                                     📗
def delambdify[A, B](
  f: Expr[A] => Expr[B]
): Flow[A, B] | ... =
  val 🍅 : Expr[A] = Var(freshId())
  val b  : Expr[B] = f(🍅)
```

# Peek into `libretto-lambda`

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// approximately
def delambdify[A, B](
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```

# Peek into `libretto-lambda`

🍅 ∉ ▽🍊🍐 ** 🍅 → p; 🍅 → q; p ** q → r

```scala
// approximately
def delambdify[A, B](
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  val 🍅 : Expr[A] = Var(freshId())
  val b  : Expr[B] = f(🍅)
  eliminate(🍅, from = b)
```

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  val b  : Expr[B] = f(🍅)
  eliminate(🍅, from = b)
```

🍅 ∉ ** p ** r q

# Peek into `libretto-lambda`

∉ ** p q ** r

```
// approximately
def delambdify[A, B](
  f: Expr[A] => Expr[B]
): Flow[A, B] | ... =
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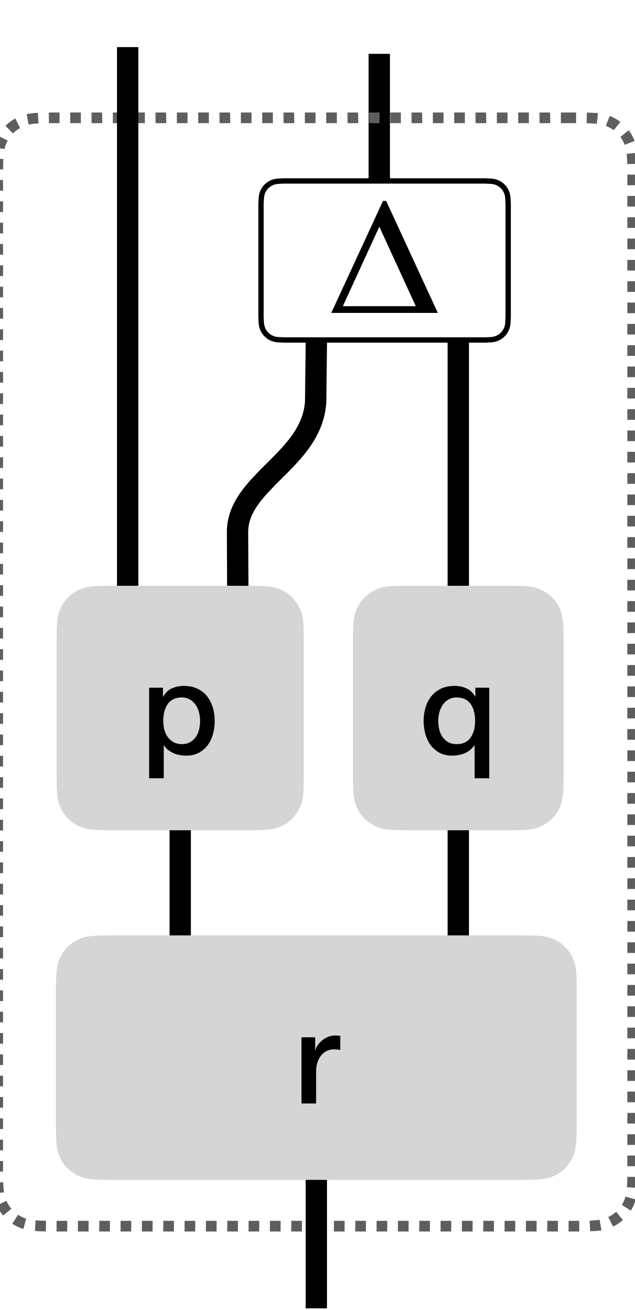

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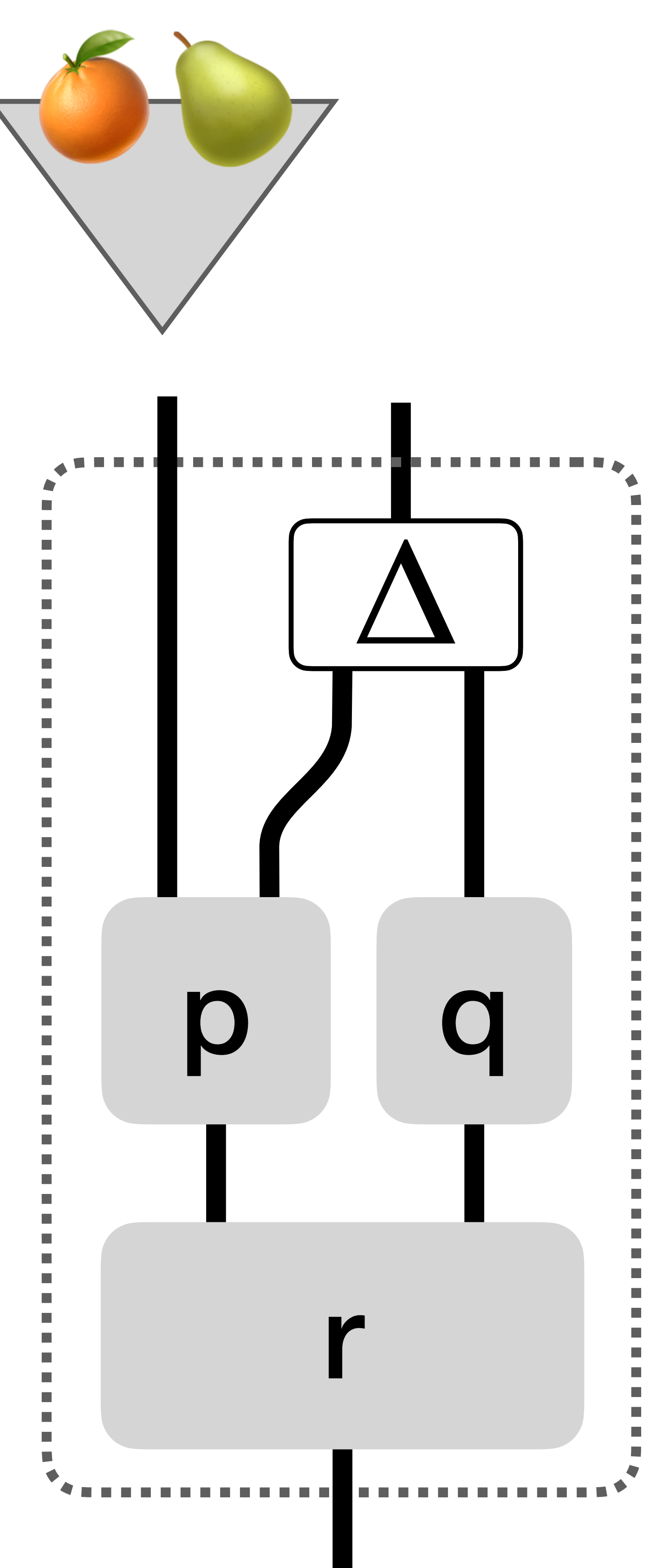

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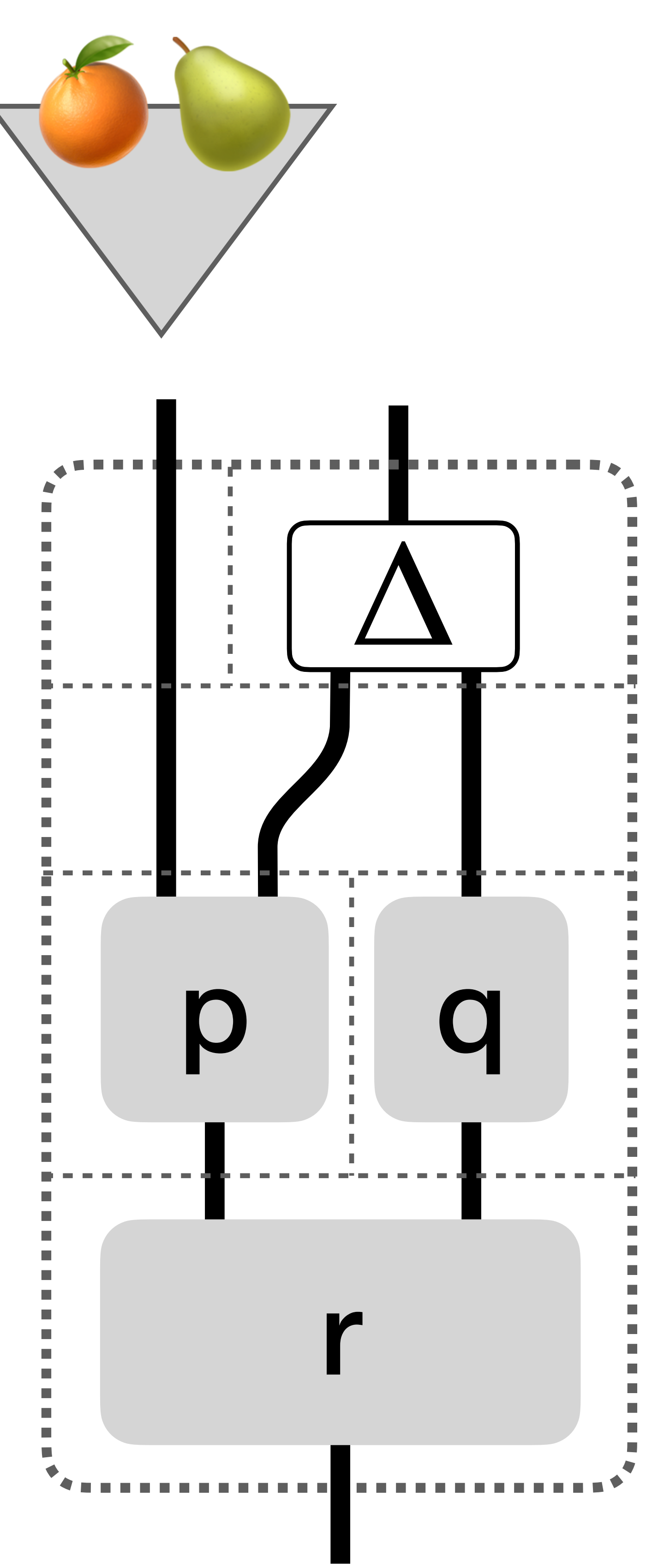

# Breaking It Down

```
Flow { req =>
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1. What does **`Flow`** do?
2. What does **`switch`** do?
3. What do the **extractors** do? (`ForOffice`, `Monitor`, ...)

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# Enum Extractors

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**Knows the partitioning** of a type (`Request`) into disjoint cases.
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```
import libretto.lambda.EnumModule

val Enum = EnumModule[Flow, **, Enum, ||, ::](using ...)
```

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```

```
type Flow¹[A, B] = ...
val lambdas¹: Lambdas[Flow¹, **, …]
type Expr¹[A] = lambdas¹.Expr[A]
```

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(*) not implemented for this demo

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Calls the library 😎

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import libretto.lambda.PatternMatching
val patmat = PatternMatching[Flow, **].forLambdas(lambdas¹)(...)
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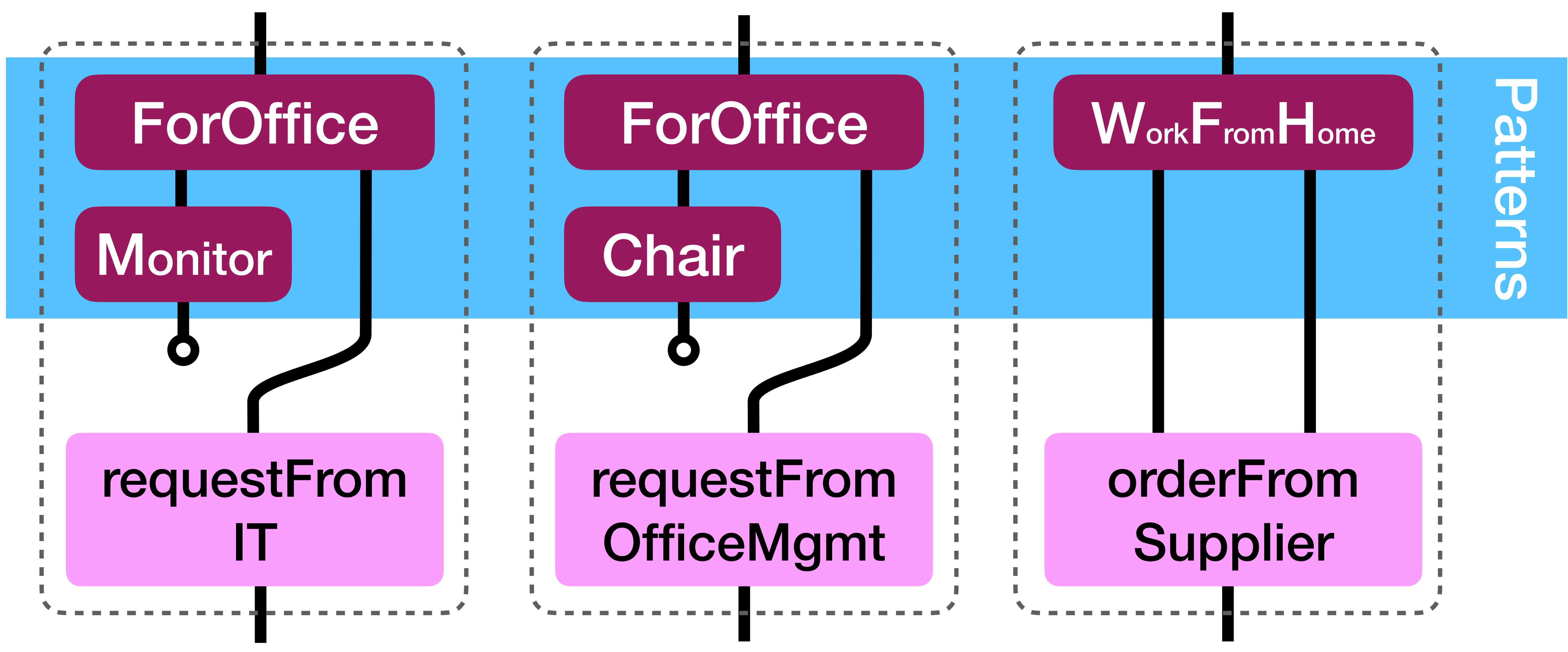
**Idea:** Recombine to

- eliminate (non-total) Extractors
- form (total) Handlers.

Fail if not possible.



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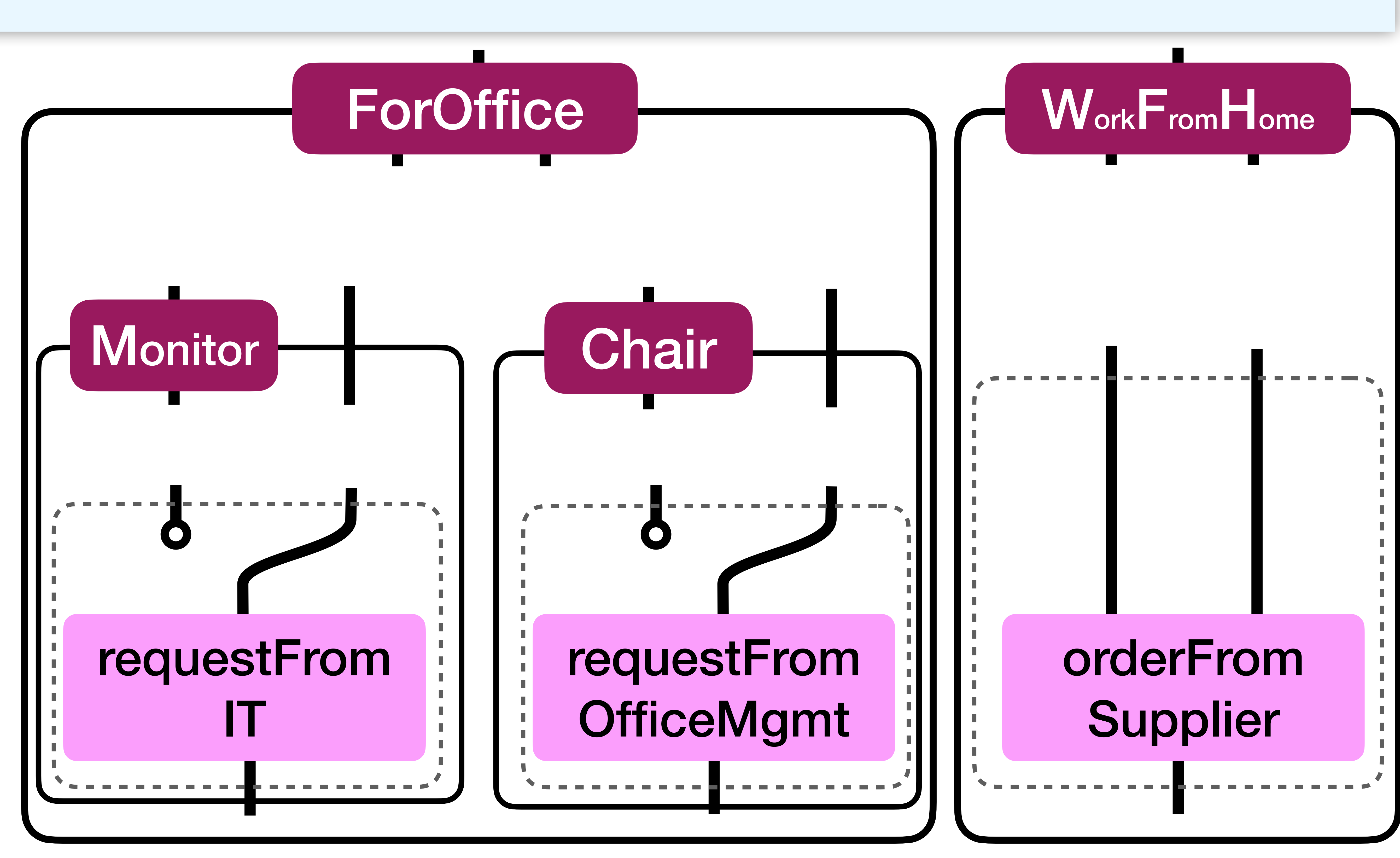

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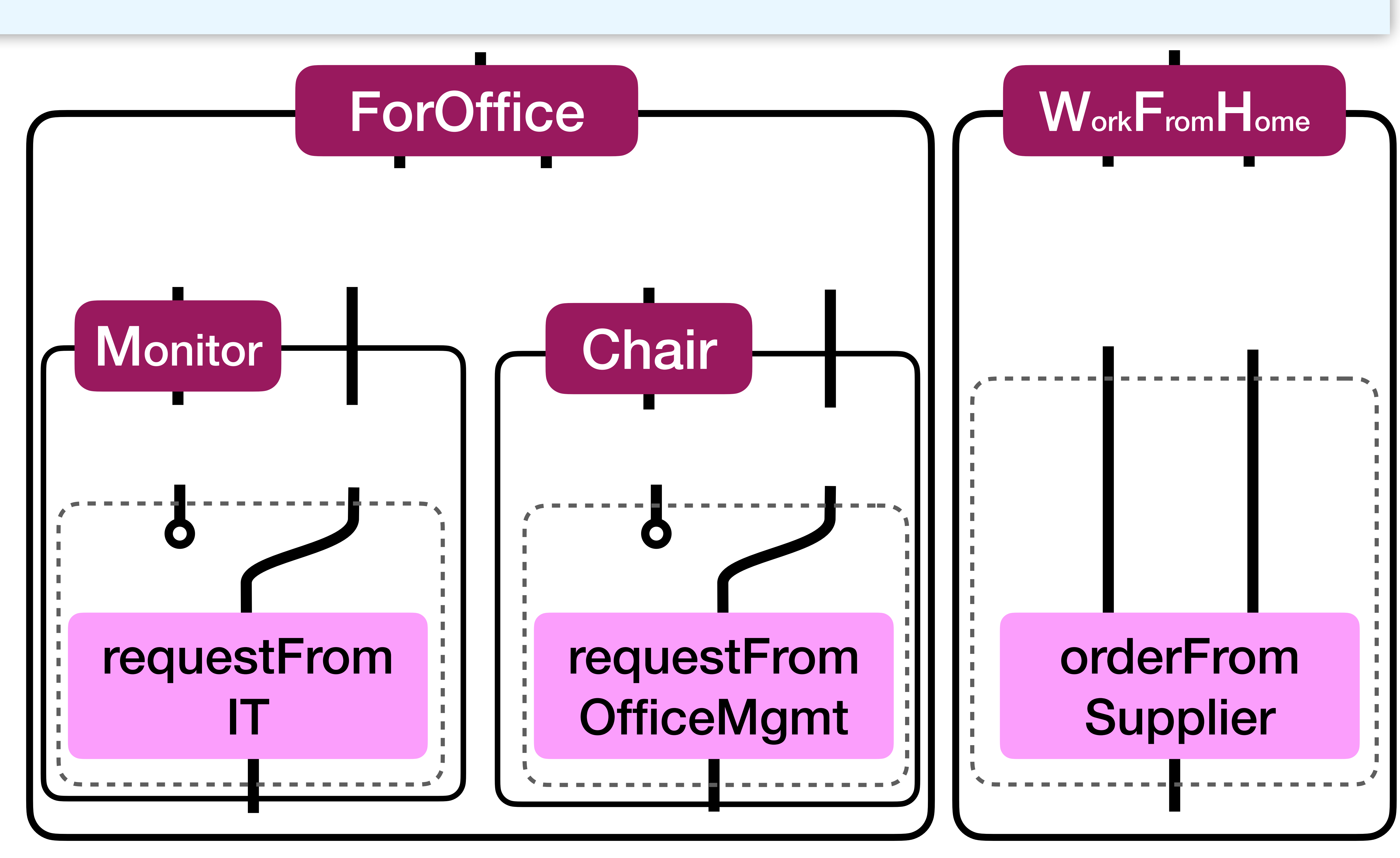

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```

1. Delambdify each case
2. Pick the first Extractor,
   obtain the whole partitioning
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   empty group = non-exhaustivity
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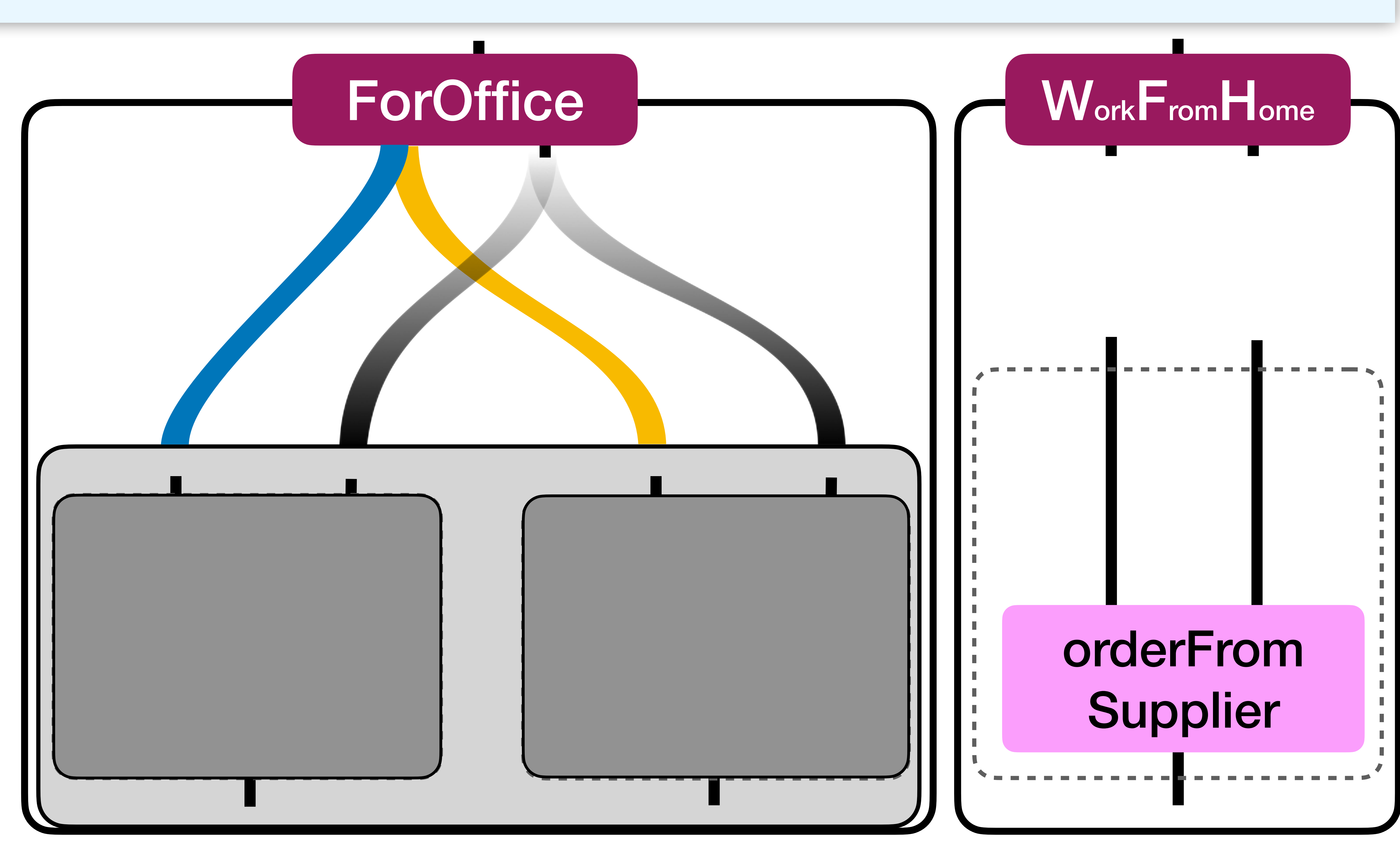

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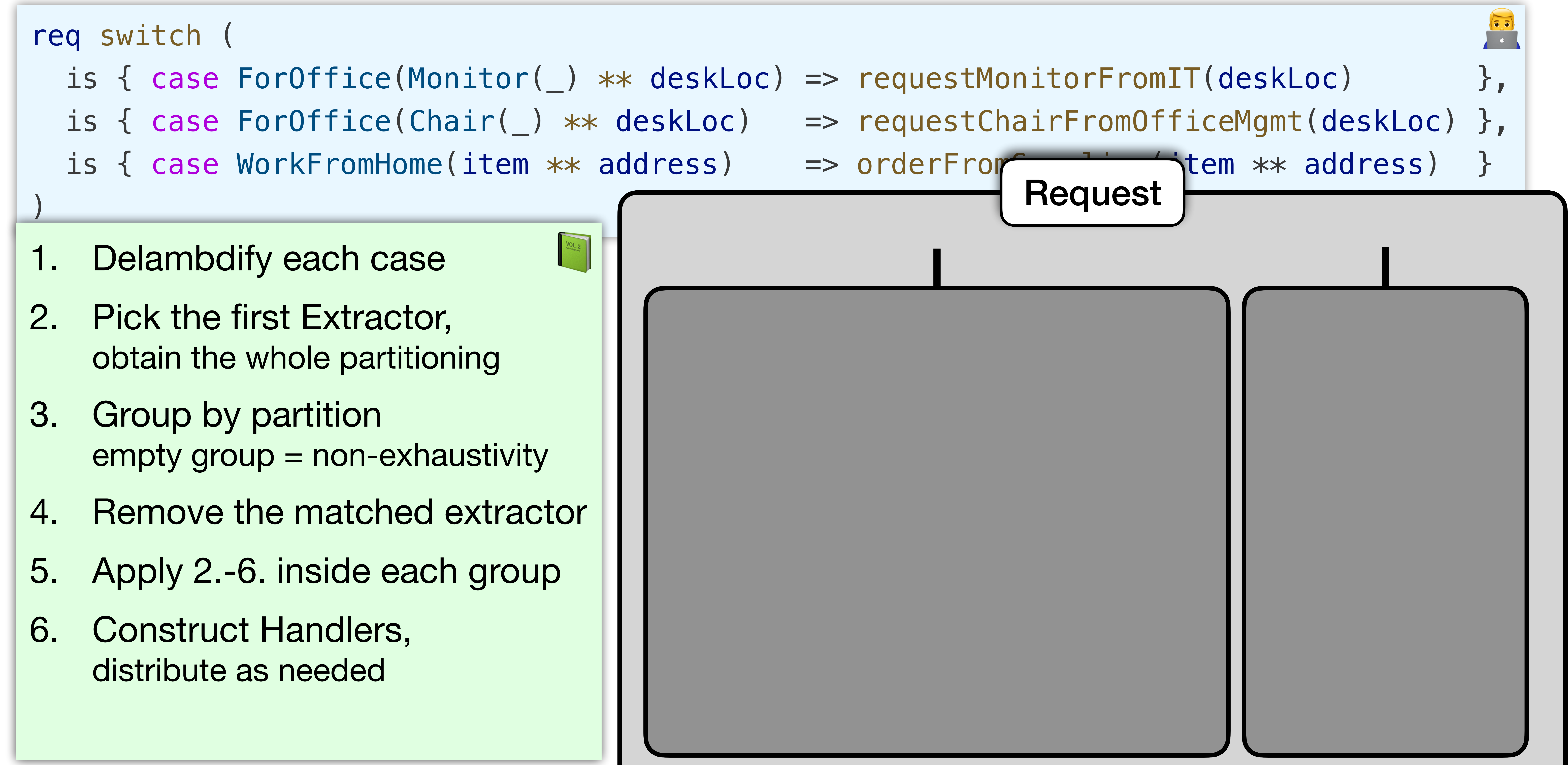

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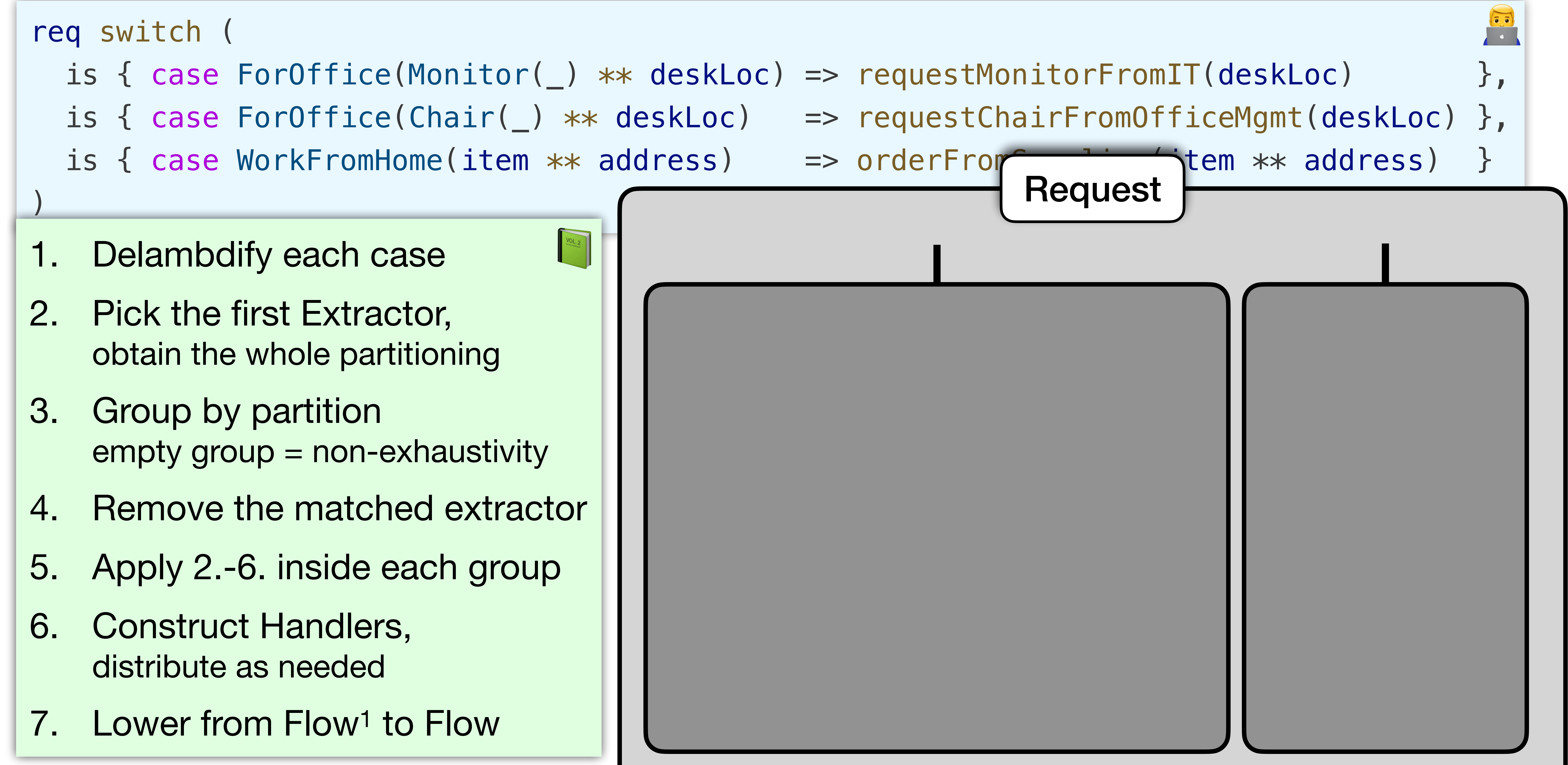

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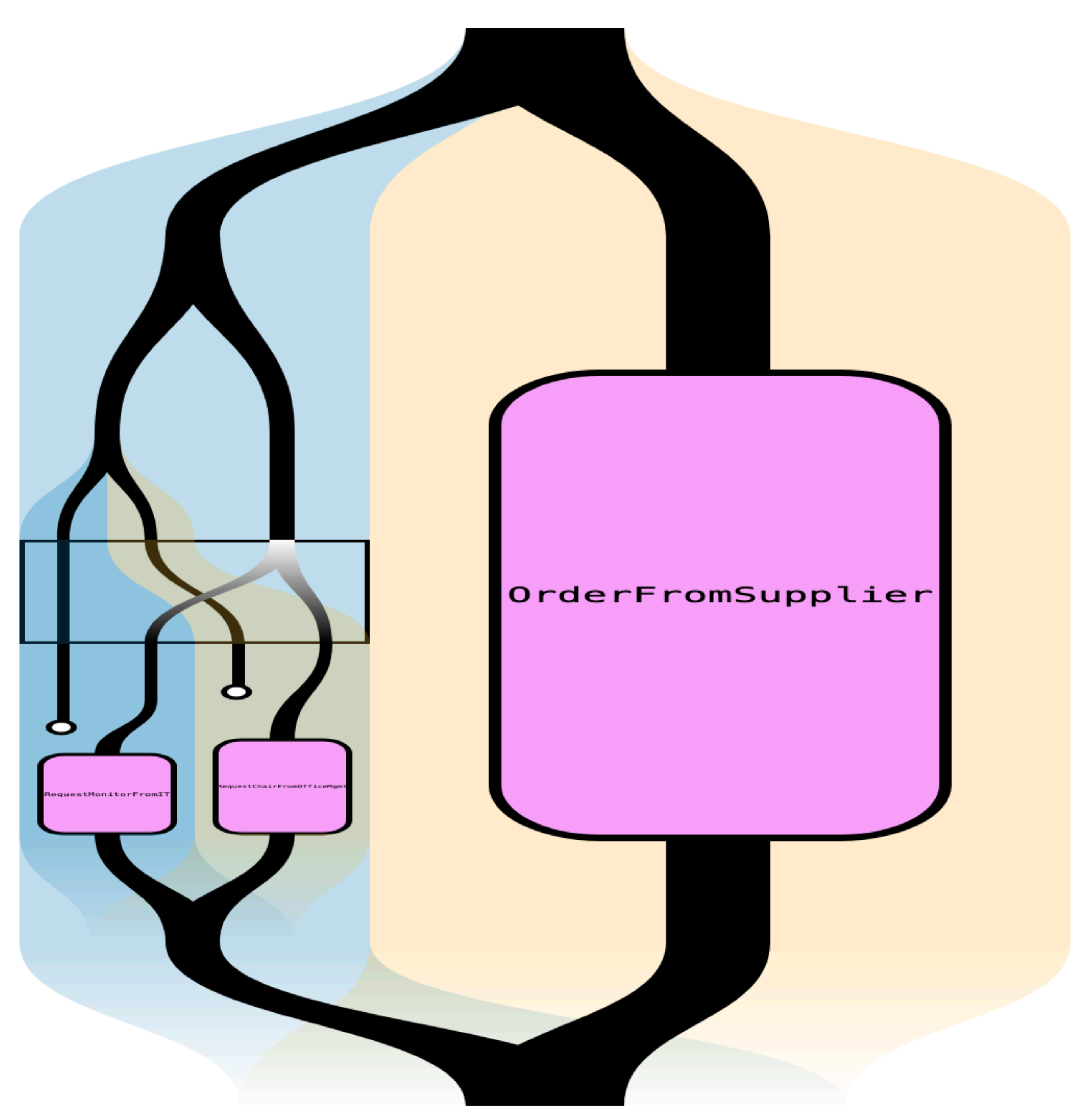
7. Lower from Flow[1] to Flow



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1. What does **`Flow`** do? ✔
2. What does **`switch`** do?
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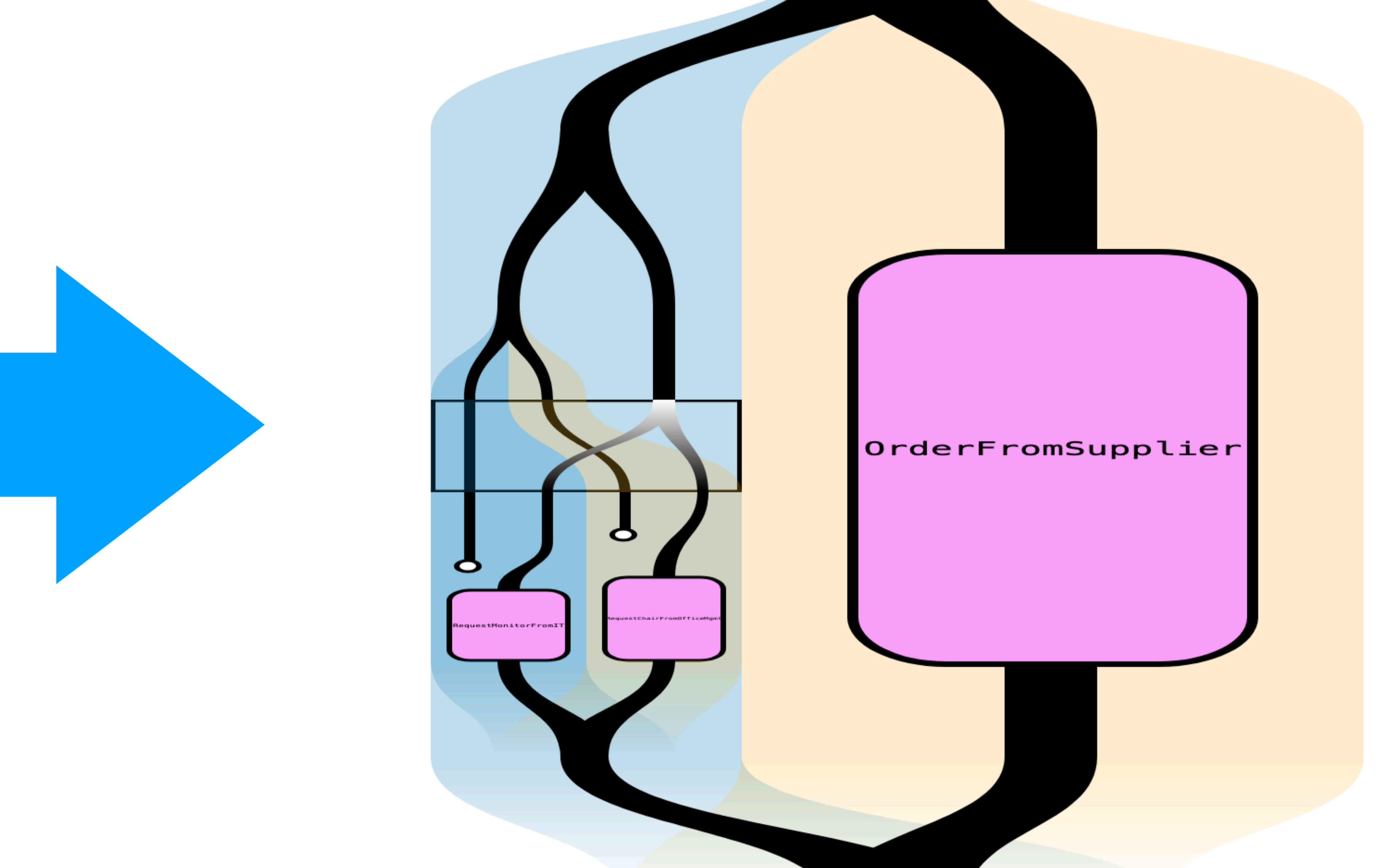

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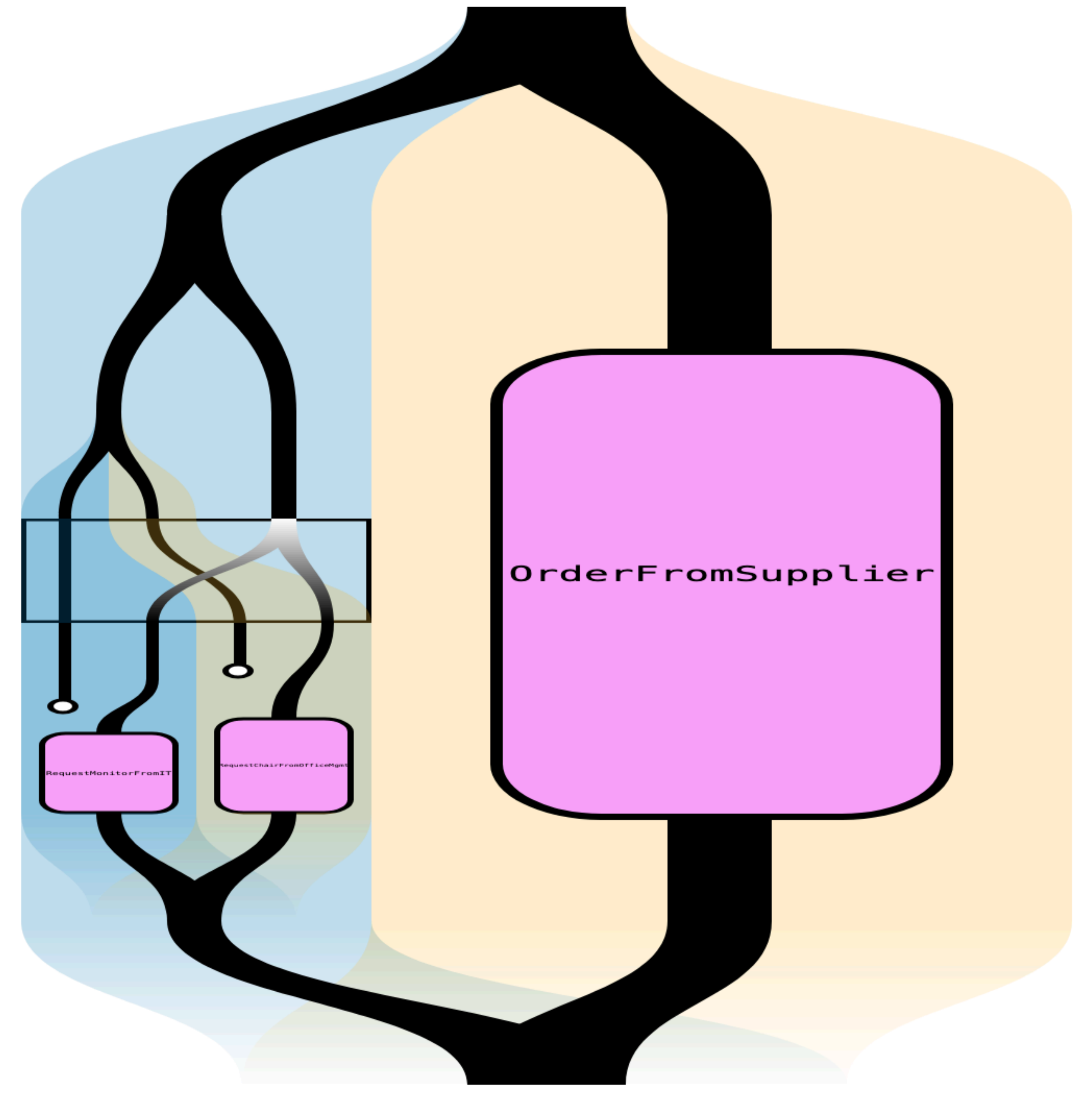

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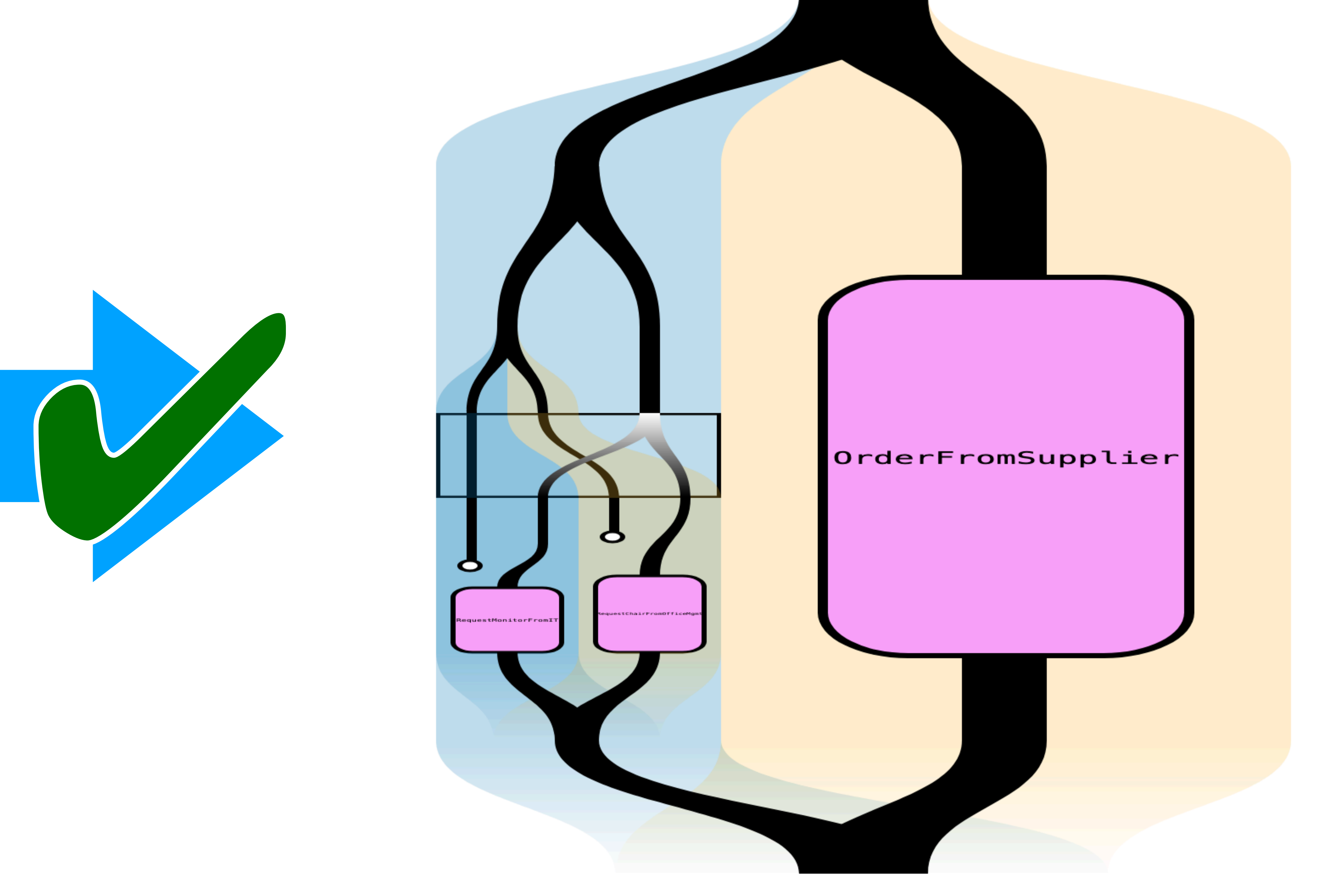


✔ Compiled Scala-like pattern matching

```
Flow { req =>
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    case ForOffice(Monitor(_) ** deskLoc) =>
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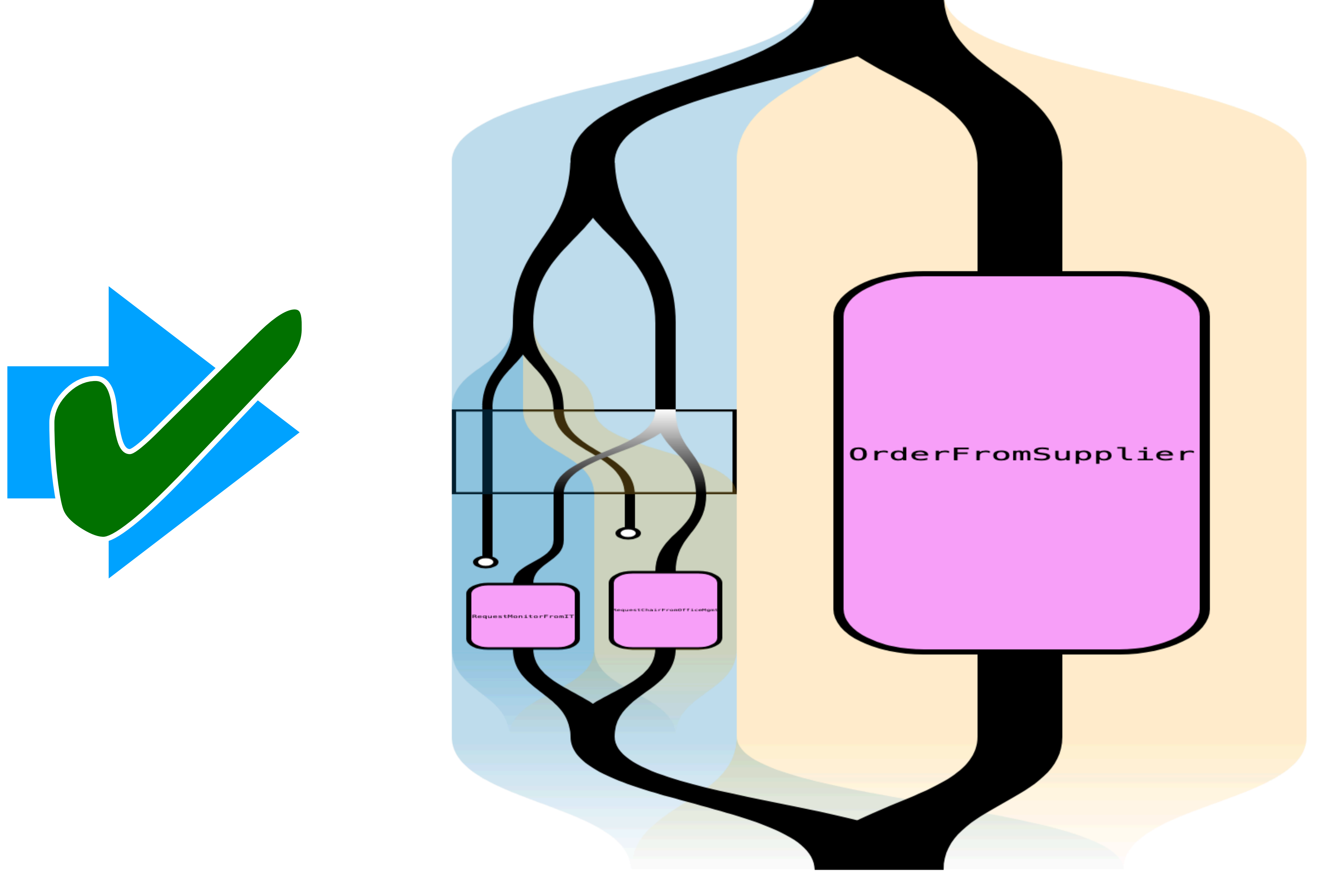


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✔ Representation **exhaustive by construction**

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Flow { req =>
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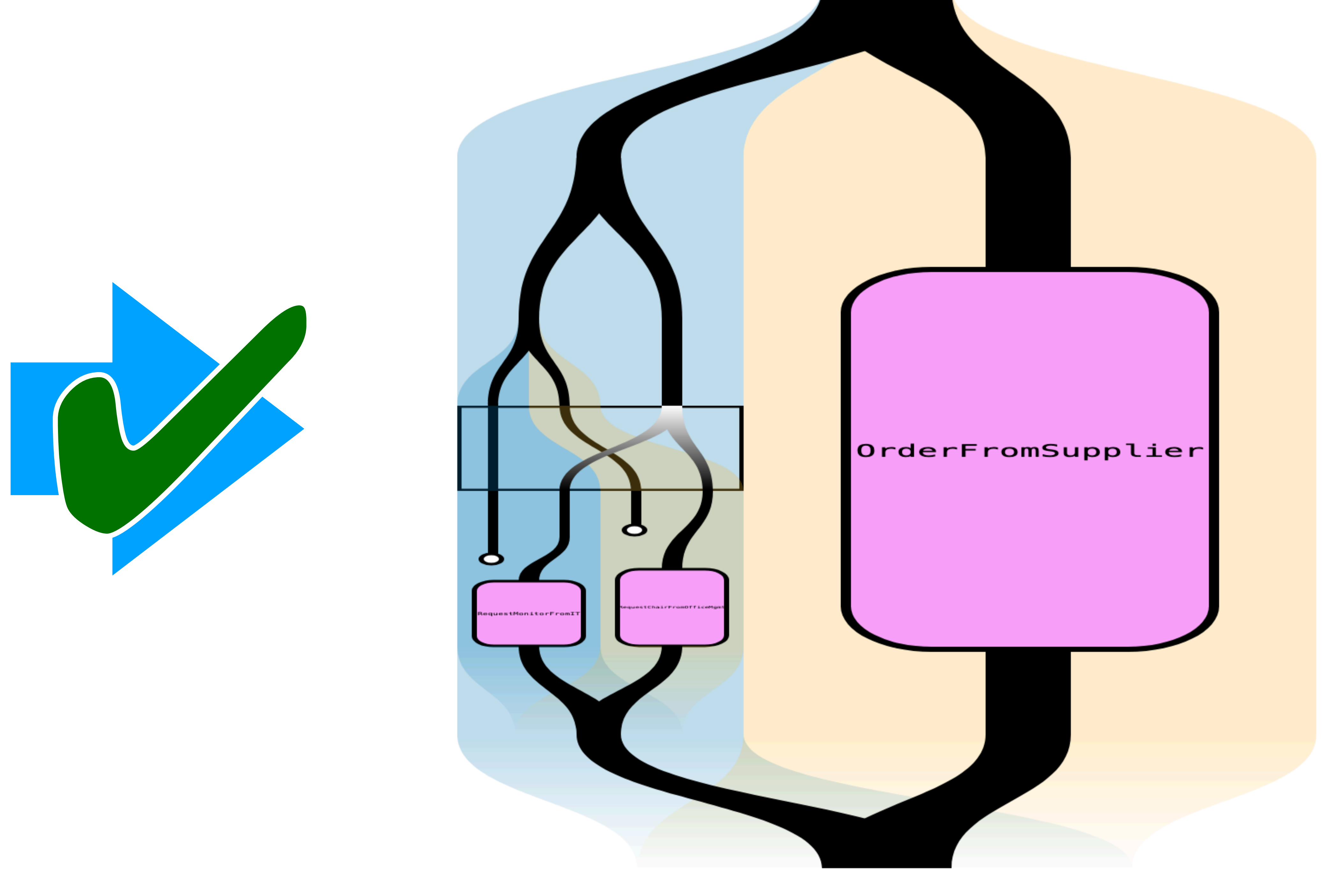
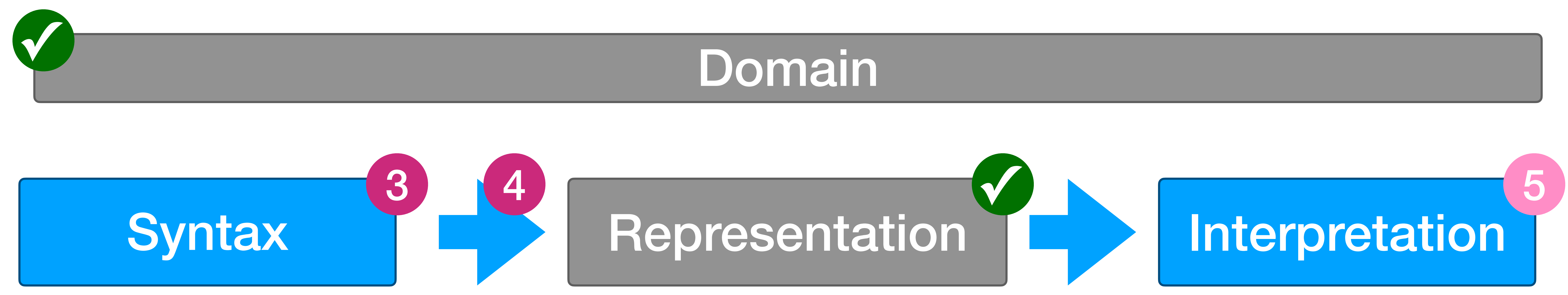
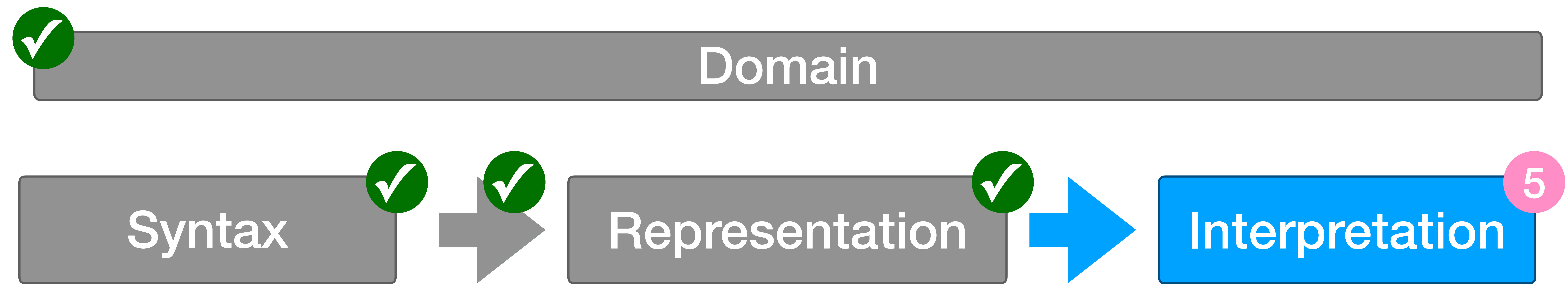



- ✔ Compiled Scala-like pattern matching
- ✔ Representation **exhaustive by construction**
- ✔ Non-exhaustivity reported in **embedded compile-time**

# Agenda



# Agenda



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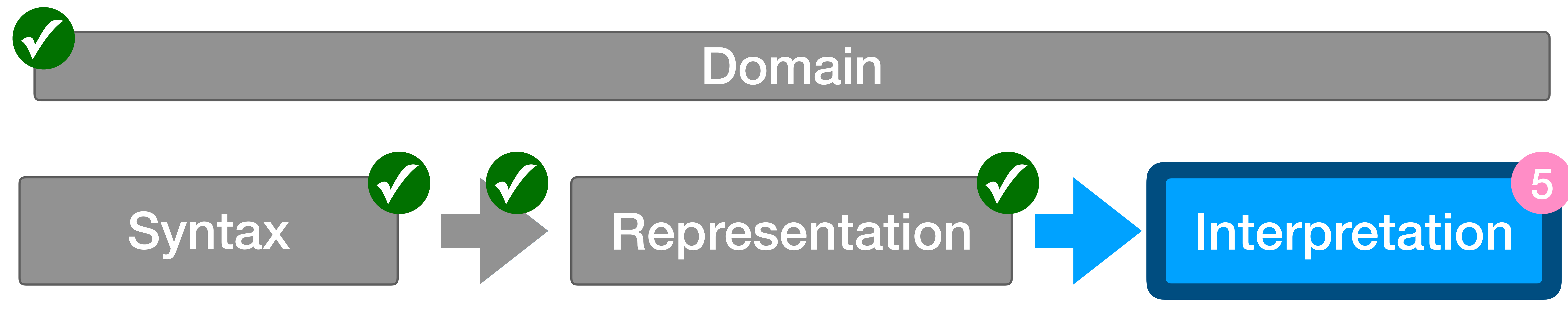

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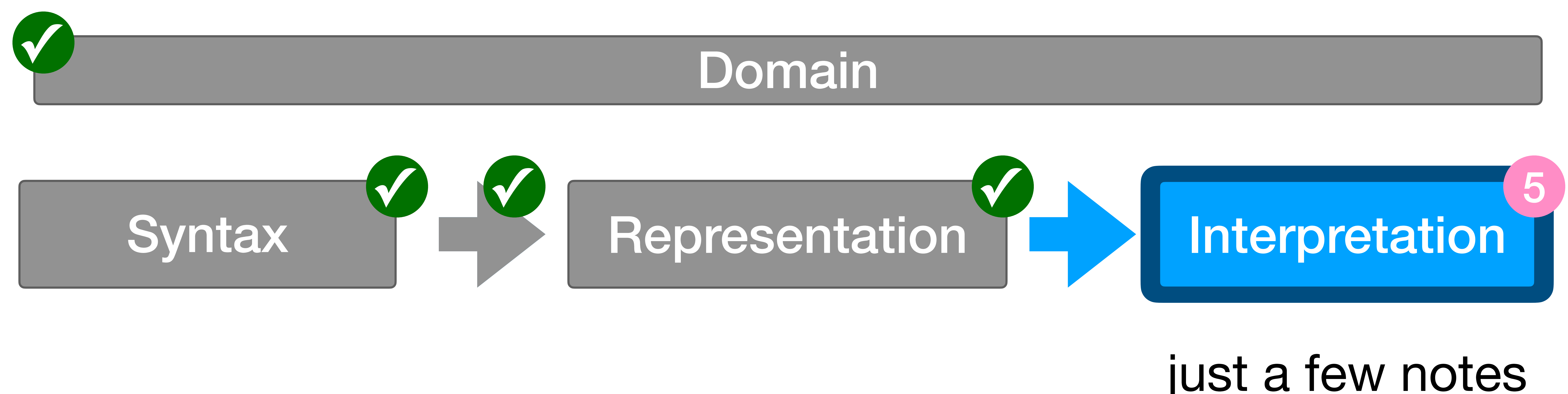


just a few notes

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  - as an alternative to the Scala embedding

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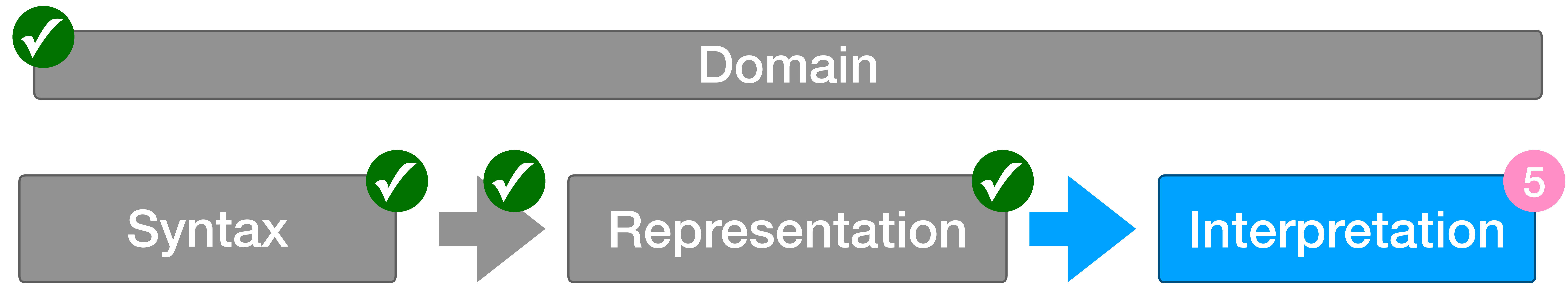

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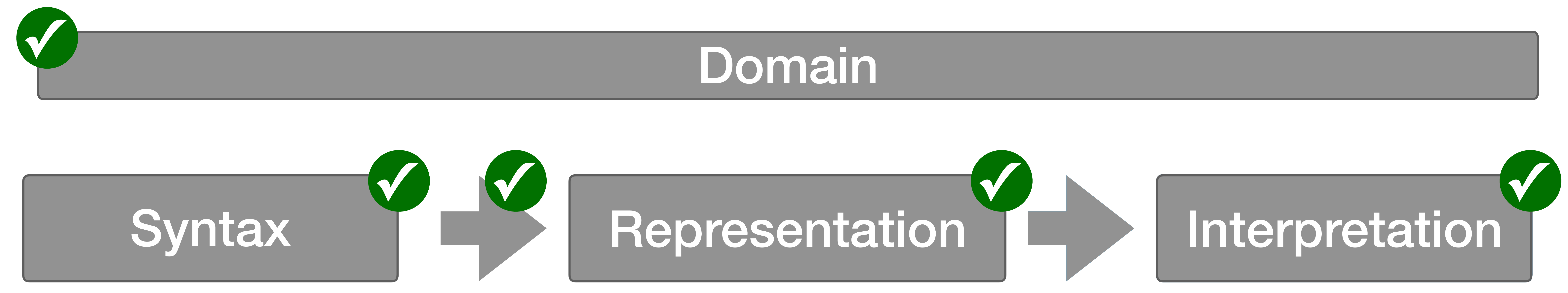

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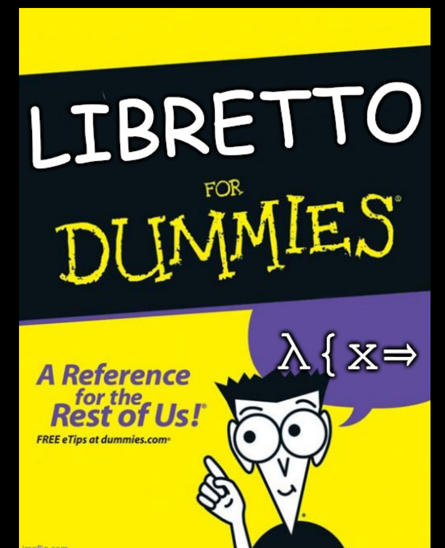

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